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Gas cylinders — Cylinder valves with integrated pressure regulators — Specification and type testing

Bouteilles à gaz — Robinets de bouteilles avec détendeur intégré — Spécifications et essais de type

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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.

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 22435 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, Subcommittee SC 2, *Cylinder fittings*.

Introduction

Cylinder valves with integrated pressure regulators are used to reduce the high cylinder pressure to a lower pressure suitable for use.

These functions cover a wide range of inlet and outlet pressures and flows which require specific design characteristics. It is important that the operating characteristics of these valves be specified and tested in a defined manner.

Such valves are more complicated than conventional cylinder valves yet subject to the same environmental and transportation conditions. These conditions should be borne in mind at the design and development stage.

This International Standard pays particular attention to

— suitability of materials,

— safety (mechanical strength, safe relief of excess pressure and resistance to ignition),

— gas-specificity,

— cleanliness,

— testing,

— identification, and

— information supplied.

Gas cylinders — Cylinder valves with integrated pressure regulators — Specification and type testing

1 Scope

This International Standard applies to cylinder valves with integrated pressure regulators (VIPR) intended to be fitted to gas cylinders that convey compressed, liquefied or dissolved gases.

This International Standard is not intended for medical applications (see ISO 10524-3). Further, additional specific requirements for valves fitted with safety valves and bursting discs (see EN 14513) and for valves fitted with residual pressure valves (see ISO 15996) are not covered by this International Standard.

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 2503:1998, *Gas welding equipment — Pressure regulators for gas cylinders used in welding, cutting and allied processes up to 300 bar*

ISO 3253, *Gas welding equipment — Hose connections for equipment for welding, cutting and allied processes*

ISO 5145, *Cylinder valve outlets for gases and gas mixtures — Selection and dimensioning*

ISO 5171, *Pressure gauges used in welding, cutting and allied processes*

ISO 7289, *Quick-action couplings with shut-off valves for gas welding, cutting and allied processes*

ISO 7291:1999, *Gas welding equipment — Pressure regulators for manifold systems used in welding, cutting and allied processes up to 300 bar*

ISO/TR 7470, *Valve outlets for gas cylinders — List of provisions which are either standardized or in use*

ISO 9090, *Gas tightness of equipment for gas welding and allied processes*

ISO 10156, *Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets*

ISO 10920, *Gas cylinders — 25E taper thread for connection of valves to gas cylinders — Specification*

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 11114-3, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 3: Autogenous ignition test in oxygen atmosphere*

ISO 11117, *Gas cylinders — Valve protection caps and valve guards for industrial and medical gas cylinders — Design, construction and tests*

ISO 13341, *Transportable gas cylinders — Fitting of valves to gas cylinders*

ISO 15001, *Anaesthetic and respiratory equipment — Compatibility with oxygen*

ISO 15996, *Gas cylinders — Residual pressure valves — General requirements and type testing*

EN 13918, *Gas welding equipment — Integrated flowmeter regulators used on cylinders for welding, cutting and allied processes — Classification, specification and tests*

3 Terms and definitions

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

3.1
adjustable pressure regulator
device that has been provided with a means of operator adjustment of the delivery pressure under normal use

3.2
closure pressure
P_4
stabilized outlet pressure, one minute after cessation of the flow, from a pressure regulator by which the flow has been set to a standard discharge

3.3
cylinder valve with integrated pressure regulator
VIPR
device intended to be permanently fitted to a gas cylinder connection and comprising a shut-off valve system and pressure reduction system

3.4
filling port
point on the device through which the cylinder is filled

3.5
flow characteristic
variation of the outlet pressure in relation to the rate of flow from zero to maximum capacity flow of the pressure regulator with the inlet pressure remaining constant

3.6
flow gauge
device that measures pressure and that is calibrated in units of flow

3.7
flowmeter
device that measures and indicates the flow of a specific gas or gas mixture

3.8
hysteresis
lagging of the outlet pressure (effect) when the flow (cause) is varied so that at a constant inlet pressure the values of outlet pressure measured with increasing flow do not coincide with the values of outlet pressure measured with decreasing flow

3.9
maximum discharge flow
Q_{max}
maximum flow which is delivered by the pressure regulator at the rated outlet pressure, p_2, and at the test inlet pressure, p_3

3.10
orifice
restriction of known cross-section that delivers a constant flow of gas when supplied with gas at a constant upstream pressure

3.11
pre-set pressure regulator
pressure regulator that has not been provided with a means of operator adjustment of the delivery pressure under normal use

3.12
pressure characteristic
variation of the outlet pressure with inlet pressure under specific initial flow conditions

3.13
pressure regulator
device for regulation of a generally variable inlet pressure to an outlet pressure as constant as possible

3.14
main shut-off mechanism
shut-off valve between the gas cylinder and the regulating mechanism of the device

3.15
rated outlet pressure
P_2
downstream pressure for the standard discharge, Q_1, specified in the instructions for use

3.16
pressure relief valve
device designed to release excess pressure from the outlet side of the pressure regulator at a pre-set value

3.17
secondary operating mechanism
means of setting the outlet discharge flow between zero and maximum

3.18
standard discharge
Q_1
flowrate, specified in the instructions for use for which the pressure regulator is designed to maintain a rated outlet pressure, p_2, at test inlet pressure, p_3

3.19
test inlet pressure
p_3
inlet pressure at which the standard discharge of the pressure regulator, Q_1, is measured and which is twice the rated outlet pressure, p_2, plus 100 kPa, i.e. p_3 = (2 p_2 + 100 kPa)

3.20
test outlet pressure
p_5
highest or lowest value of the outlet pressure resulting from a variation in the inlet pressure between p_1 and p_3 at previously adjusted conditions p_1, p_2, Q_1

3.21
valve test pressure
p_{vt}
for compressed gases, $p_{vt} = 1{,}2 \times p_w$;

for liquefied gases and dissolved gases under pressure (e.g. acetylene), p_{vt} is at least equal to the minimum test pressure of the cylinder quoted in the relevant transportation regulation for that gas or gas group

3.22
working pressure
p_w
settled pressure, at a uniform temperature of 15 °C, for a full gas cylinder

NOTE 1 For compressed gases, p_w in this International Standard corresponds to p_1 in ISO 2503.

NOTE 2 This definition applies only to compressed gases and not to liquefied gases and dissolved gases (acetylene).

4 Symbols and terminology

The symbols used for the physical characteristics are given in Table 1.

Table 1 — Notations, symbols and designations

Symbol	Designation
p_w	Working pressure
p_{vt}	Valve test pressure
p_1	Inlet pressure
p_2	Rated outlet pressure
p_3	Test inlet pressure, (2 p_2 + 100) kPa
p_4	Closure pressure
p_{4max}	Maximum closure pressure
p_5	Test outlet pressure
Q_1	Standard discharge
Q_{max}	Maximum discharge
Q_{RV}	Discharge of the relief valve
R	Coefficient of pressure increase upon closure, $(p_4 - p_2)/p_2$
i	Irregularity coefficient, $(p_5 - p_2)/p_2$

5 Design requirements

5.1 General

VIPR shall operate satisfactorily over a range of service temperatures, from − 20 °C to + 65 °C. The range may be extended for short periods (e.g. during filling). Where higher or lower service temperatures are required for longer periods, the purchaser shall specify accordingly.

VIPR shall be capable of withstanding the mechanical stresses or chemical attack they may experience during intended service, e.g. during storage, valving into cylinders, filling processes, transportation and end use of the cylinder.

5.2 Description

This International Standard does not prescribe the components that the VIPR shall comprise.

A cylinder valve with integrated pressure regulator typically comprises

— a body,

— an inlet connection to the cylinder,

— a main shut-off mechanism (to isolate the device from the high pressure gas in the cylinder),

— a filling connection (it may be fitted with a non-return valve or an isolating valve),

— the pressure regulating mechanism(s),

— a pressure relief valve on the low pressure side of the regulating mechanism(s) and

— an outlet connection (for the end user).

A VIPR can also be fitted with

— a secondary operating mechanism to set the outlet flow,

NOTE Some devices can have both mechanisms, some others can have only one.

— a pressure relief device to protect the cylinder,

— a siphon tube,

— a screwed plug or cap on the outlet and/or the filling connection,

— an excess flow limiting device,

— a means of preventing the ingress of atmospheric air,

— a residual pressure retaining device (see ISO 15996),

— pressure indicator(s) on the high and/or low pressure sides of devices,

— a flow control device,

— a flow indicator (e.g. flowmeter or flow gauge) and

— filter(s).

5.3 Materials

Metallic and non-metallic materials in contact with the gas shall be chemically and/or physically compatible with the gas (see ISO 11114-1 and ISO 11114-2).

Because of the risk of forming explosive acetylides, VIPR for acetylene may be manufactured from copper-based alloys only if the copper content does not exceed 70 % (by mass). The manufacturer shall not use any procedure resulting in copper enrichment of the surface. For the same reasons, silver content of alloys shall be limited for acetylene VIPR. The acceptable limit varies between 43 % (by mass) and 50 % (by mass), but in no case exceeds 50 % (by mass).

Ignition resistance in oxygen or other highly oxydising gases (see ISO 10156) of non-metallic materials and lubricants shall have been established by an appropriate test procedure (see ISO 11114-3). Where, during the filling of gas mixtures containing oxygen (even if the final mixture is less oxydising than air), there is the possibility that high pressure oxygen comes into contact with such material, the purchaser shall specify accordingly.

Non-metallic sealing material for use with air, oxygen and oxygen-enriched gases shall be capable of withstanding an ageing sensitivity test.

5.4 Pressure indicators

Devices other than pressure gauges may be used to indicate pressure or flow. Pressure indicators shall be of the fail-safe type, i.e. the operator shall not be injured in case of failure.

If pressure gauges are used, they shall comply with the safety features of ISO 5171. This applies also to pressure gauges used to indicate flow.

5.5 Filling connection

The filling connection shall be designed to handle the intended service conditions. It shall comply with ISO 5145, the relevant national standards (see ISO/TR 7470) or be a proprietary connection. If the filling connection is separate to the outlet connection and is not equipped with a non-return valve or isolating valve, it shall be provided with a pressure-tight device, e.g. a valve pressure plug or a cap which can be operated or removed only by the use of a special tool. Where applicable, such a device shall be designed to vent gas before becoming disengaged.

If the filling connection is made through the outlet connection, it shall be designed so that it does not interfere with a gas withdrawal connection made in accordance with the relevant national or International Standard.

The filling connection non-return valve, if fitted, shall comply with the requirements of 5.15 after testing as described in 6.15.

5.6 Cylinder connection

The connection to the cylinder shall be in accordance with international or national standards, (e.g. 25E, see ISO 10920).

If other connectors are used, evidence shall be provided by the manufacturer that an equivalent mechanical strength is achieved.

5.7 Outlet connection

The connection shall be either

a) a proprietary fitting; if a quick connection is used, it shall comply with the endurance tests of ISO 7289 or

b) a welding hose connection (e.g. ISO 3253 for a threaded connection or ISO 7289 for a quick connection or other regional or national standards) or

c) a high pressure cylinder valve outlet connection (e.g. ISO 5145).

If a residual pressure valve is fitted to the outlet connection, it shall be designed so that it does not interfere with a gas withdrawal connection made in accordance with the relevant standard.

5.8 Outlet pressure for acetylene

For acetylene, the closure pressure p_4 shall not exceed 1,5 bar for all inlet pressures when the pressure adjusting device is fully charged.

5.9 Flow control valve (flow controller)

If a flow control valve is fitted, the flow control knob and the valve spindle shall be captive such that they cannot be dismantled without the use of a tool.

Compliance shall be tested by attempting to remove the knob and spindle without the use of a tool.

5.10 Pressure adjusting device

The pressure adjusting device, if fitted, shall be captive and shall be removable only by the use of a tool. The VIPR shall be designed so that the pressure regulator valve cannot be held in the open position as a consequence of the pressure regulator spring being compressed to its solid length and thereby allowing gas to pass from the high pressure to the low pressure side. For VIPR designed to allow filling of the cylinder through the outlet connection, a special tool may be used to hold the pressure regulator valve open for filling only.

Compliance shall be tested by visual inspection.

5.11 Filtration

The pressure regulator valve seat shall be protected from particulates contamination (e.g. by the use of a filter). A dust filter, having an effective cross-section compatible with the discharge, shall be mounted within the pressure regulator upstream of the pressure regulator valve. The filter shall retain particles greater than or equal to 0,1 mm.

5.12 Main shut-off valve

The main shut-off mechanism shall meet the requirements given in 5.15 after 2 000 opening and closing cycles. The test is described in 6.14.1.

If the main shut-off valve is the pressure regulator valve itself, an endurance test shall be performed according to 6.14.2. The requirements stated in 5.15 shall be respected after 100 000 cycles.

5.13 Flow and pressure performance for regulators without flow metering devices

5.13.1 Flow performance and characteristics

The standard discharge, Q_1, and the rated outlet pressure, p_2, shall be in accordance with the values stated by the manufacturer.

The test method for the standard discharge, Q_1, and rated outlet pressure, p_2, is given in 6.6.2.

The test method for the flow characteristic is given in 6.6.3.

5.13.2 Coefficient of pressure increase upon closure R

The coefficient R shall be less than 0,3 when determined in accordance with 6.6.4.

5.13.3 Irregularity coefficient i

The coefficient i shall be within the limits $\pm$ 0,3 when determined in accordance with 6.6.5.

5.14 Pressure relief valve

A pressure relief valve shall be provided as a component part of the pressure regulator. In the case of acetylene, such a valve is optional and its performance will be specified by the manufacturer. The overpressure protection device shall be

a) pre-set to a fixed value or to a fixed differential value above the reduced pressure and

b) adjustable only with the use of a special tool.

A pressure relief valve (if fitted) shall lift automatically to relieve excess pressure and shall reset at a pressure $\geqslant p_2$ or the set pressure.

For the whole inlet pressure range, the relief valve shall remain gas tight according to 5.15 when the flow is stopped with the adjusting pressure device totally screwed in. The test shall be performed at least at p_w, p_3 and at the inlet pressure corresponding to p_5 if p_5 is greater than p_2.

The minimum discharge of the relief valve Q_{RV} shall be equal to or greater than the standard discharge Q_1 at a pressure $p_{RV} = 2\ p_2$. The test for the relief valve is described in 6.7.

NOTE The relief valve and other protection devices should be fitted in such a way that gas will be discharged safely.

5.15 Leakage

5.15.1 The total external leakage (to the atmosphere) shall not exceed 6 cm^3/h.

5.15.2 The total internal leakage (through the pressure regulator valve or the main shut-off device) shall not exceed 6 cm^3/h.

The test for leakage is described in 6.12.

5.16 Mechanical strength

5.16.1 The inlet side of the VIPR (valve to the cylinder connection) shall be capable of withstanding, for 2 min without permanent deformation or rupture, $2{,}25 \times p_w$ for compressed gases and $1{,}5 \times p_{vt}$ for liquefied gases. For acetylene VIPR, this pressure test shall be carried out at 450 bar.

The outlet side of the VIPR shall be capable of withstanding four times its rated outlet pressure, p_2, or 60 bar for compressed gas and liquefied gas and 30 bar for acetylene (whichever is the greatest) without rupturing or showing any sign of deformation.

The test for mechanical strength is described in 6.5.

5.16.2 If the VIPR is intended to be fitted on cylinders with a protection cap or guard, it shall pass the drop test in accordance with ISO 11117. After the drop test, the cylinder shall be pressurized to one bar minimum, the shut-off valve shall be closed with the closure torque specified by the manufacturer or by using a lever, and the VIPR shall comply with 5.15. After the drop test, the filling port non-return valve, if fitted, shall comply with 5.15.1.

NOTE Distortion of the VIPR due to the drop is not a failure of the test.

5.16.3 If it is not intended for the VIPR to be fitted on cylinders with a protection cap or another form of guard, an impact test shall be carried out (see Annex A).

5.17 Resistance to ignition

5.17.1 Oxygen

VIPR for oxygen and other gases with oxidising potential greater than air (see ISO 10156) shall not ignite or show internal scorching damage when submitted to an oxygen pressure surge test.

Where during the filling with gas mixtures containing oxygen (even if the final mixture is less oxydising than air) there is the possibility that high pressure oxygen comes into contact with such material, the purchaser shall specify accordingly.

The test for ignition is described in 6.16.

5.17.2 Acetylene

VIPR for acetylene shall pass the acetylene decomposition test described in Annex A of ISO 7291:1999, with the tube connected to the filling port and with any non-return valve open.

5.18 Requirement for VIPR with flow metering devices

Flow metering device requirements are given in EN 13918. The accuracy class shall be specified by the manufacturer.

5.19 Constructional requirements

5.19.1 Cleaning

VIPR shall be supplied clean to meet the requirements of the intended service. Lubricants are allowed in accordance with 5.19.2. Cleanliness levels for oxygen service are specified in ISO 15001.

5.19.2 Lubricants

If lubricants are used that are liable to come in contact with the gas, they shall be compatible with the intended gas service and the materials of construction in the specified pressure and temperature range.

5.19.3 Integrity of valve assembly

VIPR shall be constructed and assembled in such a way that it is not possible inadvertently to dismantle the VIPR or its component parts in normal use.

The test for loosening torques is given in 6.13. Torques are given in the documentation requested from the manufacturer (see 6.2).

5.20 Valve operating device

It shall be designed to permit the closure of the valve after exposure to a flame. The test method for flame resistance is given in 6.18.

6 Test methods

6.1 General

6.1.1 Conditions

Before VIPR are introduced into service, they shall be submitted for prototype testing. Prototype testing is valid for a given family of valves having the same basic design.

Variations to connections do not require further prototype testing.

Changes to the internal components for reasons of gas/material compatibility (for example O-ring, packing, diaphragm, spindle, lubricant) constitute a type variant within the given family.

Type variants require repetition of the relevant parts of the type test.

Changes of the basic design dimensions of components or changes of the valve body material constitute a new family and require the full type test.

No VIPR or its components used in the test programme shall enter normal service.

6.1.2 Ambient conditions

Except where otherwise stated, carry out tests at ambient temperature.

6.1.3 Test gas

Carry out tests with clean, oil-free dry air or nitrogen.

In all cases, carry out tests with dry gas with a maximum moisture content corresponding to a dew point of − 40 °C at atmospheric pressure.

When a VIPR is tested with a gas other than that for which it is intended, convert the flows as shown in Table 2.

Table 2 — Conversion coefficients

Test gas [a]	Coefficient for										
	Air	O_2	N_2	Ar	H_2	CO_2	N_2O	He	Xe	C_2H_2	C_3H_8
Air	1	0,950	1,02	0,851	3,81	0,81	0,81	2,695	0,47	1,05	0,800
N	0,983	0,930	1	0,837	3,75	0,79	0,79	2,65	0,46	1,03	0,784

[a] Flow of intended gas = Flow of test gas × conversion coefficient.

6.1.4 Reference conditions

Flows shall be corrected to 23 °C and 101,3 kPa.

6.2 Documentation

The manufacturer shall make available to the test body the following documents:

— a set of drawings consisting of the general arrangement, parts list, material specifications and detail drawings including assembly torques and detail of thread sealing/locking components; any type variant within the given family shall be clearly identified;

— description of VIPR and method of operation;

— information on the field of application of the VIPR (gases and gas mixtures, pressures, use with or without valve protection device, etc.); it shall be clearly indicated which gases and gas mixtures can be used with each type variant;

— certificates of material compatibility as required.

6.3 Number of test samples

A minimum of eight samples valves (ten for a VIPR with flowmeter) are required:

— one sample for the mechanical strength test;

— one sample for the safety test;

— two samples for the flowmeter mechanical strength;

— one sample for the performance, functional and operating characteristics and the relief valve;

— two more samples for the relief valve, the loosening torques and for flame resistance;

— three samples for the leakage and endurance tests.

In addition, the following are required:

— three samples for the ignition test (in the case of valves for oxygen cylinders);

— three samples for the acetylene decomposition (in the case of valves for acetylene cylinders);

— three samples for the impact test if needed.

6.4 Test sequence

Tests shall be carried out in accordance with the schedule given in Table 3.

Table 3 — Sequence of tests

Test sequence	Test	Subclause No.	Condition of test valve	Test temperature °C	Valve sample number	Valve samples
1	Mechanical strength test (high pressure chamber)	6.5	As received	20 ± 5	1	1
2	Mechanical strength test (low pressure chamber)	6.5	As received from sequence 1	20 ± 5	1	1
3	Pressure retention of the low pressure side of the pressure regulator	6.8	As received	20 ± 5	2	1
4	Flowmeter mechanical strength	6.9	As received	20 ± 5	9 to 10	2
5	Flow and pressure performance	6.6	As received	20 ± 5	3	1
6	Accuracy of VIPR with flowmeter	6.10	As received	20 ± 5	3	1
7	Accuracy of VIPR with flowmeter and with fixed orifices	6.11	As received	20 ± 5	3	1
8	Pressure relief valve	6.7	One sample as received from sequence 5	20 ± 5	3 to 5	3
9	Leakage	6.12	As received	20 ± 5	6 to 8	3
10	Leakage	6.12	From test sequence 9, aged at 65 °C for 5 days	20 ± 5	6 to 8	3
11	Endurance of the main shut-off mechanism	6.14	As received from sequence 10	20 ± 5	6 to 8	3
12	Endurance of the non-return valve	6.15	As received from sequence 11	20 ± 5	6 to 8	3
13	Leakage	6.12	As received from sequence 12	20 ± 5	6 to 8	3
14	Leakage	6.12	As received from sequence 13	65 ± 5	6 to 8	3
15	Leakage	6.12	As received from sequence 14	− 20 ± 5	6 to 8	3
16	Operating and loosening torques	6.13	As received from sequence 8	20 ± 5	4	1
17	Flame resistance	6.18	As received (if applicable)	800 to 1 000	5	1
18	Ignition	6.16	As received (if applicable)	20 ± 5	—	3
19	Acetylene decomposition	6.17	As received (if applicable)	20 ± 5	—	3
20	Impact test	—	As received	20 ± 5	—	3

6.5 Test method for mechanical strength

6.5.1 All tests shall be performed on one sample.

6.5.2 For an adjustable pressure VIPR, ensure that the pressure adjusting device is in the position where the pressure regulator valve is closed.

For a pre-set VIPR, plug the outlet.

6.5.3 Hydraulically pressurize the high pressure side of the VIPR as indicated in 5.16.1, for 2 min.

For this test, replace the high pressure gauge, if fitted, by a plug.

6.5.4 Pressurize the low pressure chamber of the VIPR as indicated in 5.16.1, for 2 min.

For this test, replace the diaphragm, relief valve and low-pressure gauge, if fitted, by plugs.

6.6 Test methods for flow and pressure performance for regulators without flow metering devices

6.6.1 Number of samples

All tests shall be performed on one sample.

6.6.2 Test method for standard discharge, Q_1, and rated outlet pressure, p_2

An example of the test bench required for this test is shown in Figure 1. The bench should be constructed in such a way that the inlet and outlet pressures can be regulated separately. The equipment can be operated by remote control.

The gas supply for the working pressure, p_w, and the test inlet pressure, p_3, should have sufficient capacity for the tests.

All the pipelines of the pressure installation together with the valve controlling the flow should have a flow capacity greater than that of the VIPR being tested. The VIPR can be supplied from a buffer cylinder.

Carry out the test at the standard discharge, Q_1, and the outlet pressure, p_2, stated by the manufacturer.

With the flow control valve closed, apply an inlet pressure, p_3. Set the outlet pressure to p_2. Gradually open the flow control valve until the standard discharge, Q_1, is attained. If the outlet pressure has decreased, readjust it to the value of p_2 on an adjustable VIPR. This is not possible with a pre-set VIPR.

6.6.3 Test method for flow characteristic

6.6.3.1 General

A flow characteristic curve shows the change of outlet pressure caused by variation of the flow from zero to full flow at a constant inlet pressure. Different curves are obtained at different starting pressures and different inlet pressures. (See Figures 3 and 4.)

6.6.3.2 Adjustable VIPR

Record a flow characteristic under the following initial conditions:

a) starting with a test inlet pressure, p_3, outlet pressure, p_2, and standard discharge, Q_1, close the flow control valve and record the closure pressure, p_4, after 60 s;

b) starting with the inlet pressure, p_w, outlet pressure, p_2, and standard discharge, Q_1, close the flow control valve and record the closure pressure, p_4, after 60 s;

c) starting with a test inlet pressure, p_3, outlet pressure, p, and maximum discharge, Q_{max}, close the flow control valve and record the maximum closure pressure, p_{4max}, after 60 s.

In each case, at the end of the initial conditions given above, gradually open the flow control valve in steps and record the outlet pressure and flow at each step until the outlet control valve is fully opened.

Plot the values of flow and pressure as shown in Figure 3.

NOTE Values of flow and pressure measured with increasing outlet pressure (which results from a decreasing flow) can produce a curve at higher pressures due to hysteresis.

The result of the test shall be registered in the test report.

6.6.3.3 Pre-set VIPR

Record a flow characteristic using the procedure described in 6.6.3.2 under the following conditions:

a) starting at the closure pressure, p_4, resulting from the test inlet pressure, p_3, and the standard discharge, Q_1;

b) starting at the closure pressure, p, resulting from the rated inlet pressure, p_w, and the standard discharge, Q_1.

NOTE 1 The closure pressure obtained will depend on the pressure characteristic of the pressure regulators (rising or falling).

Plot the values of flow and pressure as shown in Figure 4.

NOTE 2 Figure 4 shows a typical flow characteristic for a pre-set VIPR with a rising pressure characteristic in which an increasing inlet pressure tends to hold the pressure regulator valve closed.

6.6.4 Test method for coefficient of pressure increase upon closure R

This does not apply to VIPRs with a flow metering device.

Use the test equipment shown in Figure 1. Adjust the test VIPR to the standard initial conditions, inlet pressure, p_3, outlet pressure, p_2, and standard discharge, Q_1. Stop the discharge by closing the flow control valve. The indicator on the low pressure gauge will move to a higher value and stabilize. Note the closure pressure, p_4, after 60 s and from it determine the value of R using the expression:

$$R = \frac{p_4 - p_2}{p_2}$$

6.6.5 Test method for irregularity coefficient *i*

This does not apply to VIPRs with flow metering devices.

Use the test equipment shown in Figure 2. For the determination of the irregularity coefficient, i, and correct mechanical functioning, plot a curve (see Figures 5 and 6). The curve indicates the variation of outlet pressure as a function of the inlet pressure.

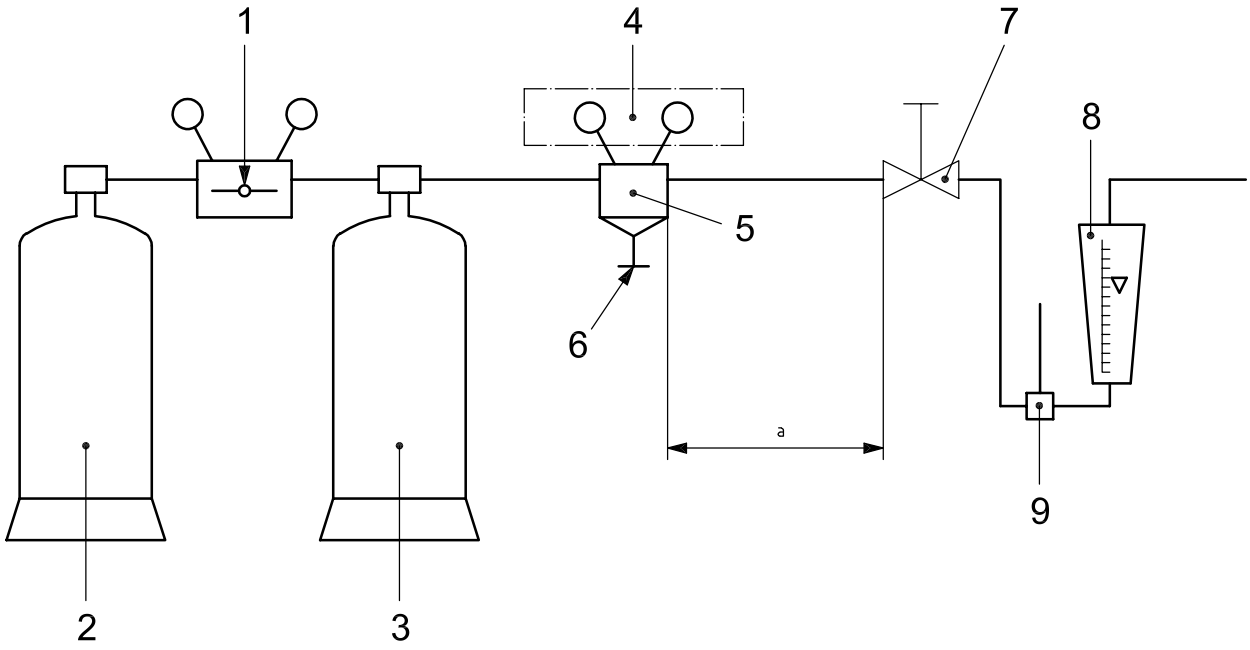
Equip the test VIPR with two calibrated gauges or recording equipment. Control the discharge of the test VIPR by the flow control valve and measure it by a flowmeter. With the inlet pressure, p_w, operate the pressure adjusting device (if fitted) on the test pressure regulator and the flow control valve to obtain the standard discharge, Q_1, at the outlet pressure, p_2, taking into account the corrections given in Table 2. For pre-set VIPR, the test is started at the inlet pressure, p_w, with the flow control valve of the test equipment adjusted so that the VIPR delivers its standard discharge, Q_1.

Record the value of the inlet and outlet pressures whilst the inlet pressure is varied through the range p_w to p_3. Ensure that sufficient gas is available in the gas supply to complete the test in one session.

During this test there should be a smooth regular curve, either rising to a maximum (see Figure 5) or falling (see Figure 6).

The pressure, p_5, for the irregularity coefficient, i, is the highest or lowest value of the outlet pressure during the test in which the inlet pressure varies from p_w to p_3. Determine the value of coefficient i using the expression:

$$i = \frac{p_5 - p_2}{p_2}$$

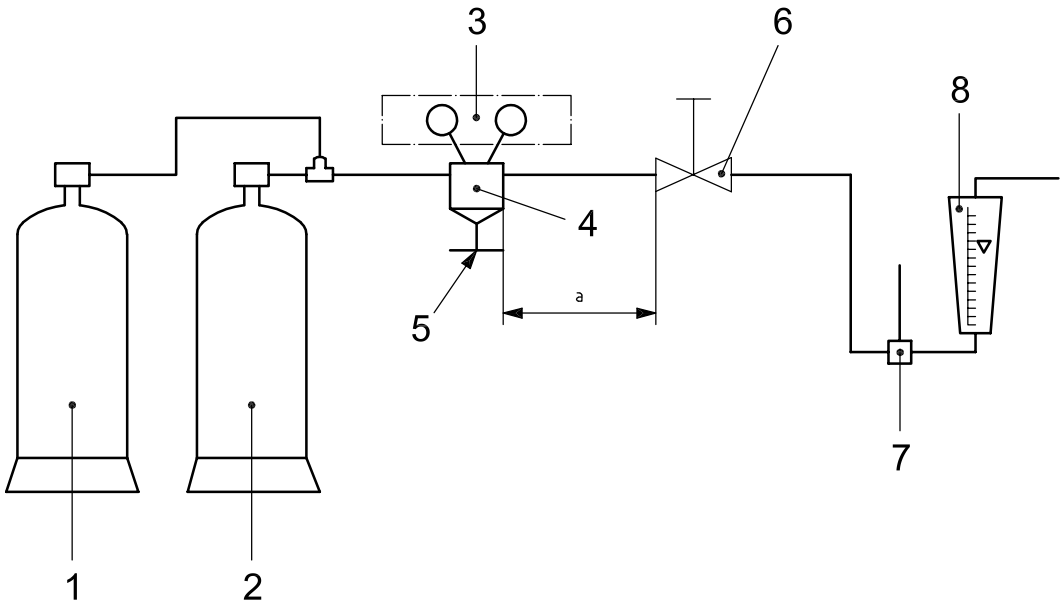


Key

1 auxiliary pressure regulator
2 gas supply
3 buffer cylinder
4 calibrated gauges
5 test sample
6 pressure adjusting device
7 test bench flow control valve
8 flowmeter
9 thermometer

[a] 1 m maximum.

Figure 1 — Example set-up for the measurement of the maximum discharge, Q_{max}

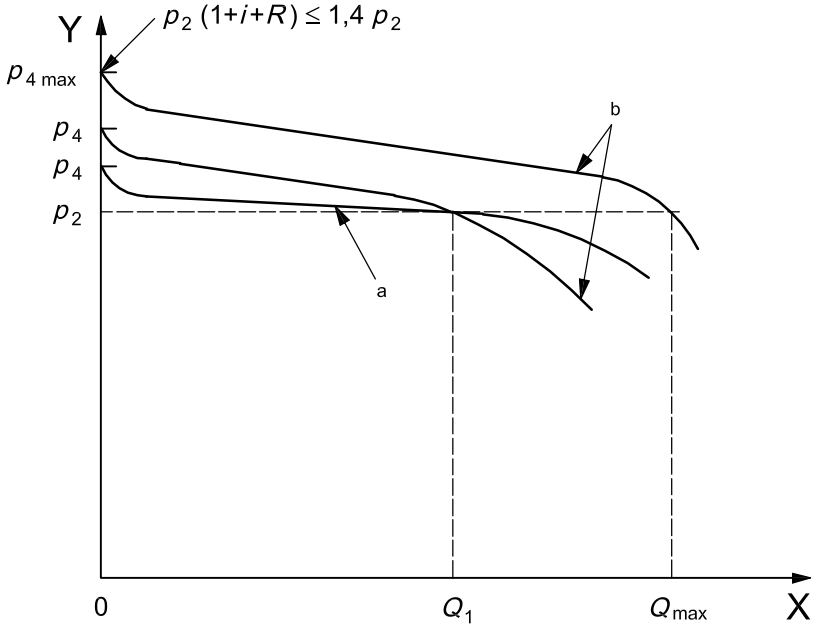


Key

1 auxiliary gas cylinder
2 primary gas cylinder
3 calibrated gauges
4 test sample
5 pressure adjusting device
6 test bench flow control valve
7 thermometer
8 flowmeter

[a] 1 m maximum.

Figure 2 — Example set-up for the determination of the pressure characteristics



Key

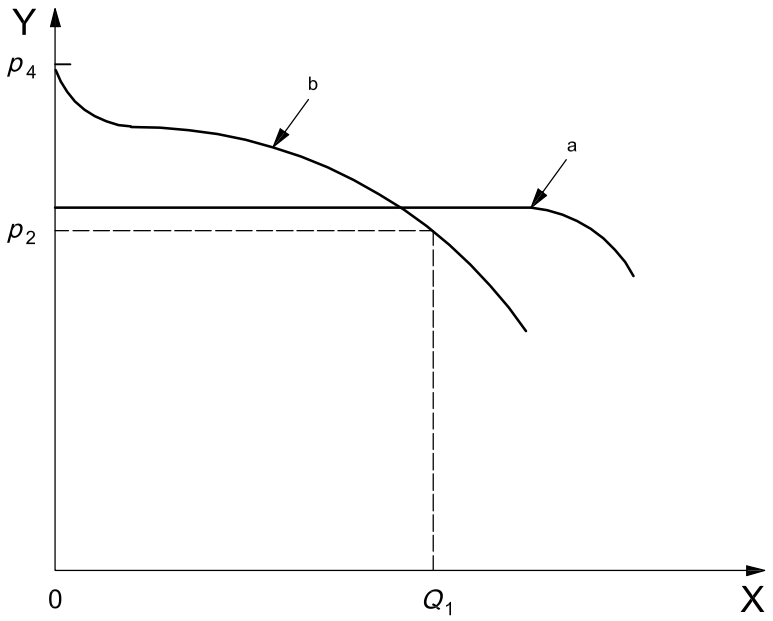
X flow

Y outlet pressure

a Inlet pressure, p_w.

b Inlet pressure, p_3.

Figure 3 — Typical flow characteristic for an adjustable pressure regulator



Key

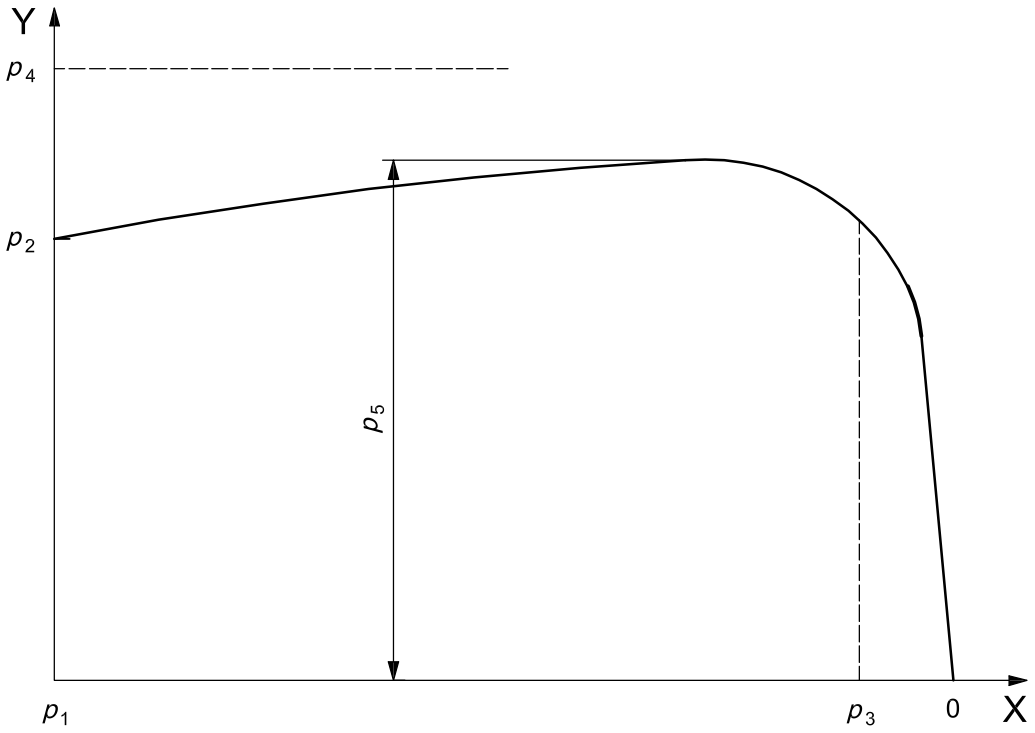
X flow

Y outlet pressure

a Inlet pressure, p_w.

b Inlet pressure, p_3.

Figure 4 — Typical flow characteristic for a pre-set pressure regulator

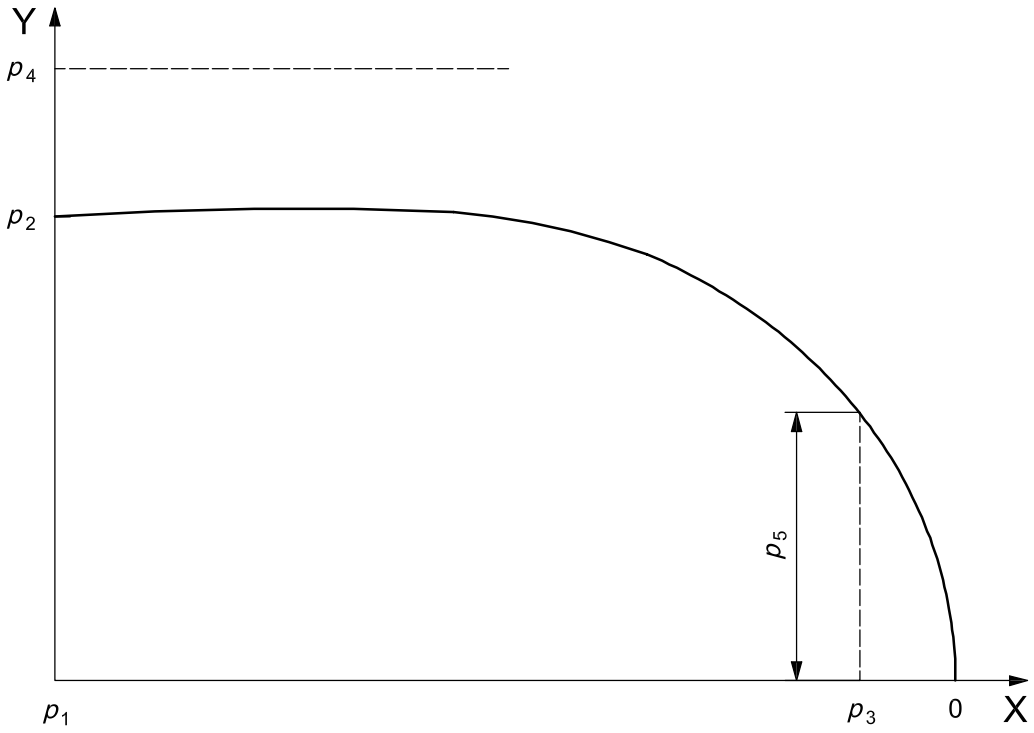


Key

X flow

Y outlet pressure

Figure 5 — Typical rising pressure characteristic



Key

X flow

Y outlet pressure

Figure 6 — Typical falling pressure characteristic

6.7 Test method for relief valve

The test shall be performed on one sample.

An increasing pressure is applied through the outlet connection up to the pressure given in 5.14. At this pressure, the relief valve shall be leak tight. The pressure shall then be increased up to the opening pressure of the relief valve, which shall be noted. The pressure shall be increased up to the pressure $p_{RV} = 2 \times p_2$. At this pressure, the discharge, Q_{RV}, of the relief valve shall be measured (see 5.14). The pressure shall be decreased and the closing pressure of the relief valve shall be noted (see 5.14).

6.8 Pressure retention of the low-pressure side of the pressure regulator

The regulating valve within the VIPR shall be held permanently open. Pressure gauges, if any, shall be replaced by blind plugs and the outlet blanked off.

A pneumatic pressure of p_{vt} shall be applied to the VIPR inlet through a remote valve which is opened quickly, the VIPR main shut-off valve being in the fully open position.

If no rupture of the VIPR occurs, the test is satisfactory. If rupture occurs, no piece shall be ejected. Venting of gas through pressure relief devices, if fitted, is allowed.

WARNING — Adequate protection for personnel is required during this test.

6.9 Test method for flowmeter mechanical strength

The test shall be performed on one sample.

Apply an increasing pressure to the flowmeter up to the value $4 \times p_2$. After 2 min, check that the flowmeter has not ruptured. If a safety relief valve is fitted to the flowmeter and it limits the pressure to below $4 \times p_2$, the flowmeter is considered to comply with 5.18.

6.10 Test method for accuracy of VIPR with flowmeter

The test shall be performed on one sample (see EN 13918).

Test the accuracy of flow using the equipment shown in Figure 1. Repeat this test after exposure of the flowmeter to an inlet pressure of p_3.

6.11 Test method for accuracy of VIPR with flowmeter and with fixed orifices

The test shall be performed on one sample (see EN 13918). Test the accuracy of flow using the equipment shown in Figure 1.

6.12 Test methods for leakage

6.12.1 Number of samples

The test shall be performed on three samples.

6.12.2 Internal leakage across the main shut-off device

6.12.2.1 Conditions

The main shut-off device shall be closed as specified by the manufacturer (e.g. hand wheel torque of 7 N·m).

6.12.2.2 Adjustable VIPR

Measure the internal leakage at the inlet pressure, p_{vt}, with the adjustable pressure regulator open and the outlet open.

Repeat the test at 10 bar inlet pressure. Finally, repeat the test at 0,1 bar for toxic and flammable gases and at 0,5 bar for all other gases.

6.12.2.3 Pre-set VIPR

Measure the internal leakage at the rated inlet pressure, p_w.

Repeat the test at 10 bar inlet pressure. Finally repeat the test at 0,1 bar for toxic and flammable gases and at 0,5 bar for all other gases.

6.12.3 Internal leakage across the regulating valve seat

6.12.3.1 Conditions

With the main shut-off device open, carry out the following leakage test.

6.12.3.2 Adjustable VIPR

Gas tightness to the atmosphere shall be tested in accordance with ISO 9090.

Gas tightness of the regulator valve assembly:

a) The gas tightness of the regulator valve seat is tested at the maximum inlet pressure, p_w, for 5 min. The regulator valve shall be closed (pressure adjusting screw completely unscrewed) and the outlet open. An escape of gas of 0,2 mbar l/min (12 cm^3/h) is allowed.

b) The gas tightness of the regulator valve is also tested with the outlet closed and the pressure in the low pressure chamber adjusted to the value of p_2 with the pressure adjusting screw. The value of p_2 shall be constant during the test period of 5 min.

Both tests shall be repeated with the critical test pressure, p_3.

6.12.3.3 Pre-set VIPR

Gas tightness to the atmosphere shall be tested in accordance with ISO 9090.

The gas tightness of the regulator valve seat is tested at the maximum inlet pressure, p_{w1}, with the outlet connection closed. The value of the outlet pressure shall be constant during the test period of 5 min.

The test shall be repeated with the inlet pressure, p_3.

6.12.4 External leakage

Measure the external leakage of the VIPR at the inlet pressure, p_{vt}, with the adjustable pressure regulating mechanism in the fully open position with the outlet closed and the main shut-off device in the open position.

Repeat the test at 10 bar inlet pressure. Finally repeat the test at 0,1 bar for toxic and flammable gases and at 0,5 bar for all other gases.

6.13 Test method for operating and loosening torques

The test shall be performed on one sample.

Measure the torques using an appropriate torque spanner and check that they conform with the manufacturer's specification given in the documentation (see 6.2).

6.14 Test method for endurance of the main shut-off mechanism

6.14.1 Independent shut-off valve upstream of the regulator valve

The test shall be performed on three samples pre-aged at 65 °C for 5 days. This test consists of repeated fully opening and closing of the shut-off valve. Pressurize the VIPR through the inlet connection to p_{vt}. Close the valve either by using a closing torque of twice the minimum closing torque specified by the manufacturer or one of 7 N·m, whichever is less, or using the procedure/system proposed by the manufacturer. After at least 6 s, release the pressure downstream of the valve seat to atmospheric. After at least 6 s, open the valve, without applying significant torque when it is in the fully open position, and repressurize it. Repeat this cycle to a total of 2 000 cycles (see Annex B for detailed procedure).

Ensure that, during the test, friction does not cause a significant increase in temperature.

After completion of the test, the samples shall be subjected to the tightness tests in accordance with 6.12. The tightness test shall be performed at ambient temperature, − 20 °C and + 65 °C.

When the endurance test and the subsequent leakage tests have been completed, sealing elements such as diaphragms, bellows, O-rings, shall be subjected to a visual check for unacceptable wear and/or damage.

6.14.2 Pressure regulator valve acting as main shut-off valve

6.14.2.1 Shut-off function obtained by unscrewing the pressure-regulating mechanism

The test shall be performed on three samples pre-aged at 65 °C for 5 days. For this test the VIPR shall be installed so that the inlet is connected to a source of test gas at p_{vt}. The pressure adjusting mechanism shall be set in order to reach the nominal pressure, p_2, and flow, Q_1. After performing the setting, the VIPR shall then be subjected to the required cyclic testing (see 5.12). Each cycle consists of:

— pressurization of the inlet connection at the test pressure, p_{vt}, with the outlet connection closed;

— opening of the outlet connection after 3,5 s;

— closing of the supply line to the inlet connection after 5 s in order to let the pressure in the inlet chamber reach atmospheric pressure;

— closing of the outlet connection and starting of a new cycle when the flow is ended.

The test apparatus shall incorporate valves upstream and downstream of the regulator being tested in order to permit introduction and venting of the test gas.

After completion of the test, the samples shall be subjected to the tightness tests in accordance with 6.12. The tightness test shall be performed at ambient temperature, − 20 °C and + 65 °C.

When the endurance test and the subsequent leakage tests have been completed, sealing elements such as diaphragms, bellows and O-rings, shall be subjected to a visual check for unacceptable wear and/or damage.

6.14.2.2 Shut-off function obtained by disconnecting the outlet connection (shut-off valve in the outlet connection and pre-set regulator)

The test shall be performed on three samples pre-aged at 65 °C for 5 days. For this test the VIPR shall be installed so that the inlet is connected to a source of test gas at p_{vt}. The pressure adjusting mechanism shall be set in order to reach the nominal pressure, p_2, and flow, Q_1. After performing the setting, the VIPR shall then be subjected to the required cyclic testing (see 5.12). Each cycle consists of:

— pressurization of the inlet connection at the test pressure, p_1, with the outlet connection closed;

— opening of the outlet connection after 3,5 s;

— closing of the supply line to the inlet connection after 5 s in order to let the pressure in the inlet chamber reach atmospheric pressure;

— closing of the outlet connection and starting of a new cycle when the flow is ended.

The test apparatus shall incorporate valves upstream and downstream of the regulator being tested in order to permit introduction and venting of the test gas.

After completion of the test, the outlet connection incorporating the shut-off valve shall be submitted to the following endurance test. With the inlet of the VIPR being pressurized at p_3 and the down stream line shut-off, the outlet connection shall be disconnected, the upstream and the downstream lines being under pressure. The duration of each cycle shall be not less than 1 min. 100 000 cycles shall be performed.

After completion of the test, the samples shall be subjected to the tightness tests in accordance with 6.12. The tightness test shall be performed at ambient temperature, − 20 °C and + 65 °C.

When the endurance test and the subsequent leakage tests have been completed, sealing elements such as diaphragms, bellows and O-rings, shall be subjected to a visual check for unacceptable wear and/or damage.

6.15 Test method for endurance of the non-return valve

The test shall be performed on three samples (same samples as above, see 6.14).

Pressurize the non-return valve, if provided, through the filling port to p_{vt}. Open and close the non-return valve as specified by the manufacturer. Return the pressure to atmospheric pressure. Repeat the operation 1 000 times.

After completion of the tests, these samples shall be subjected to the tightness tests in accordance with 6.12 and internal checks as above.

6.16 Test method for ignition

6.16.1 Number of samples

The test shall be performed on three samples.

6.16.2 Adjustable pressure VIPR

Before starting the test, keep the test VIPR at room temperature. Expose three samples of the VIPR through the filling connection to pressure shocks from industrial oxygen [minimum 99,5 % purity; hydrocarbons less or equal to 10 µg/g (10 ppm)]. Use the test equipment shown in Figure 7.

Increase the pressure from atmospheric pressure up to the test pressure in a time of $\left(20^{\ 0}_{-5}\right)$ ms measured prior to the test VIPR (see Figure 7). Use a test pressure equal to p_{vt}. Gas temperature to be (60 ± 3) °C.

Apply a series of 20 pressure shocks at intervals of 30 s. Apply each pressure shock for 10 s. After each pressure shock, return the test VIPR to atmospheric pressure, not by means of the pressure regulator but by an upstream venting valve. Between pressure shocks, hold atmospheric pressure for at least 3 s (see Figure 8).

During one test series, do not decrease the inlet pressure (test pressure) by more than 3 %.

If the shut-off valve is located as shown in Figure 9, carry out the tests under the following conditions:

a) non-return valve closed;

b) non-return valve opened and shut-off valve closed;

c) non-return valve opened, shut-off valve opened and pressure regulator valve opened;

d) non-return valve opened, shut-off valve opened and pressure regulator valve closed.

In all cases, the cylinder connection shall be plugged.

If the shut-off valve is located as shown in Figure 10, carry out the tests under the following conditions:

e) non-return valve (if fitted) closed;

f) non-return valve (if fitted) opened, shut-off valve closed and pressure regulator valve closed;

g) non-return valve (if fitted) opened, shut-off valve closed and pressure regulator valve opened;

h) cylinder connection plugged, non-return valve (if fitted) opened, shut-off valve opened and pressure regulator valve closed;

i) cylinder connection plugged, non-return valve (if fitted) opened, shut-off valve opened and pressure regulator valve opened.

After the test has been completed, the three test VIPRs shall be dismantled and carefully checked, including close examination of non-metallic components. They shall not show any traces of ignition.

6.16.3 Pre-set pressure VIPR

Test pre-set VIPRs in the normal delivery condition (with the pressure regulator valve opened) and with the outlet closed.

For VIPRs with flowmeters, repeat the test with the flow control valve fully opened.

If the shut-off valve is located as shown in Figure 9, carry out the tests under the following conditions:

a) non-return valve closed;

b) non-return valve opened and shut-off valve closed;

c) non-return valve opened and shut-off valve opened.

In all cases, the cylinder connection shall be plugged.

If the shut-off valve is located as shown in Figure 10, carry out the tests under the following conditions:

d) non-return valve (if fitted) closed;

e) non-return valve (if fitted) opened and shut-off valve closed, cylinder connection plugged;

f) non-return valve (if fitted) opened and shut-off valve opened.

After the test has been completed, the three test VIPRs shall be dismantled and carefully checked, including close examination of non-metallic components. They shall not show any traces of ignition.

6.17 Test method for resistance to acetylene decomposition

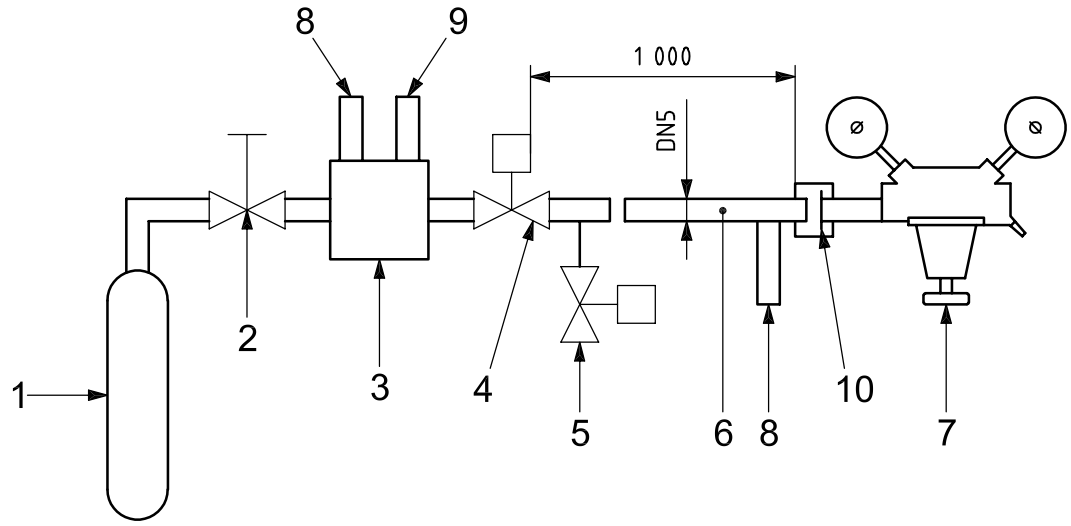
This test shall be performed in accordance with Annex A of ISO 7291:1999 for pressure regulators for manifold systems, through the filling connection.

6.18 Test method for flame resistance of the valve operating device

The operating device of the sample valve shall be exposed for 1 min to an LPG blowpipe flame of 150 mm length, such that the flame reaches a typical temperature of between 800 °C and 1 000 °C. The operating device shall be completely enveloped by the flame.

Although the valve operating device may be damaged during the test, the valve shall still be capable of being closed manually after sufficient cooling.

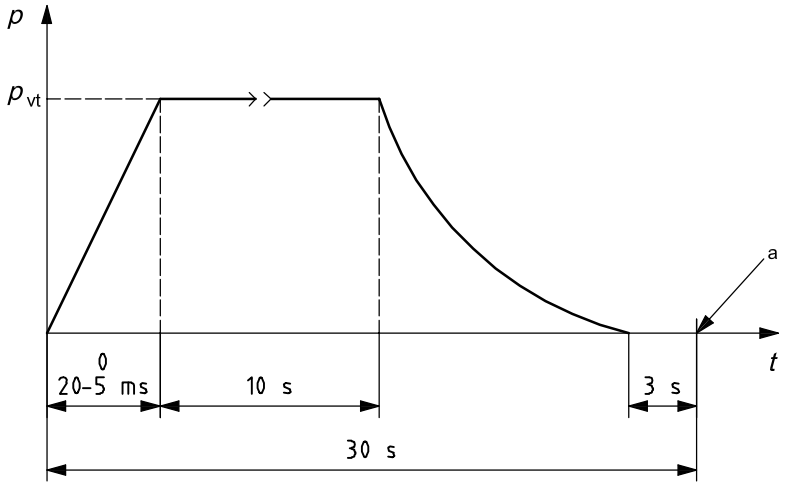
Dimensions in millimetres



Key

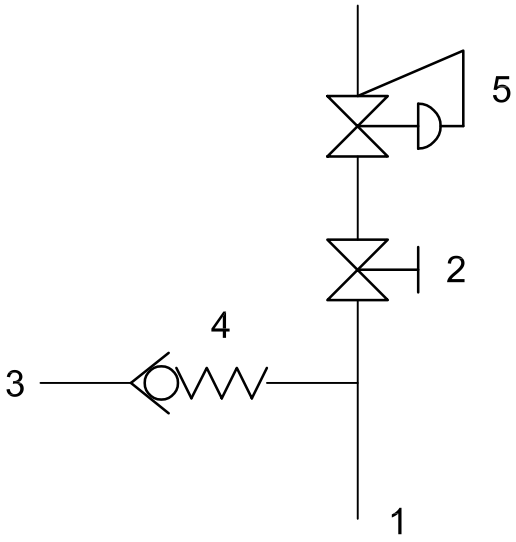
1 oxygen supply
2 inlet valve
3 high pressure vessel with device for preheating oxygen to (60 ± 3) °C
4 quick opening valve
5 outlet valve
6 connection tube
7 test sample
8 pressure transducer
9 thermometer
10 measuring point

Figure 7 — Test bench for ignition test



[a] Next pressure shock.

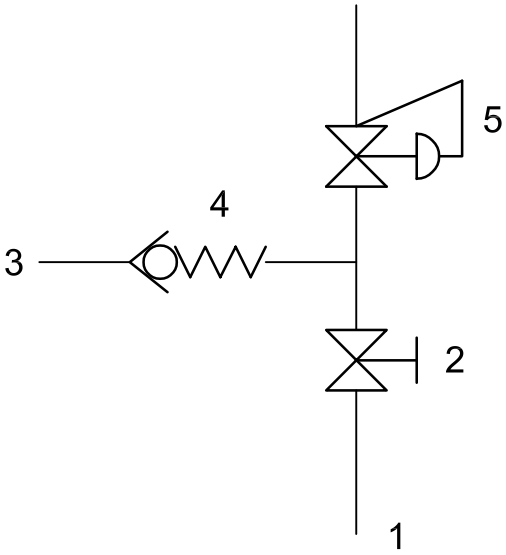
Figure 8 — Test interval



Key

1 cylinder connection
2 main shut-off mechanism
3 filling port
4 check-valve (if fitted)
5 pressure regulator

Figure 9 — Test arrangement 1 for ignition test



Key

1 cylinder connection
2 main shut-off mechanism
3 filling port
4 check-valve (if fitted)
5 pressure regulator

Figure 10 — Test arrangement 2 for ignition test

7 Marking

7.1 VIPRs shall be durably and legibly marked with the following:

a) coded identification of this International Standard *"ISO VR"*;

b) the manufacturer's identity and model designation;

c) year and month (or week) of manufacture;

d) identification of the cylinder/valve connection;

e) for VIPRs used without guard or cap, the maximum permitted package weight for which the valve has been tested;

f) the gas for which the VIPR is intended (use code in accordance with Table 5 of ISO 2503:1998).

7.2 The flow metering device shall be marked in accordance with ISO 2503.

7.3 Pressure adjusting devices and flowmeter control valves (if fitted) shall be clearly and durably marked with the direction for increasing pressure and flow.

8 Instructions

In order to provide the necessary information for safe use, the manufacturer of the VIPR shall make available to his customer(s) the following data:

a) technical description;

b) field of application;

c) explication of the markings;

d) performance;

e) instructions for fitting the VIPR to a cylinder;

f) instructions regarding the filling;

g) inspections and tests required before, during and after filling;

h) recommended spare part list and maintenance procedures;

i) scrapping instruction;

j) information to be transmitted to the final user:

   1) general safety information;

   2) field of application and limit of use;

   3) start-up operating instructions including required checks;

   4) correct use of the VIPR, including what to do in case of malfunction;

   5) end of use.

Annex A
(normative)

Valve impact test

In circumstances where cylinder valves are used in cylinders of water capacity greater than 5 l and where valve protection is not intended to be fitted during transportation, the following test shall be carried out. The purpose of this test is to ensure that the valve has sufficient inherent strength to withstand impacts that may occur during transport.

One valve, in the closed condition (closed to the torque used in the endurance test), shall be fitted in a gas cylinder neck equipped with the corresponding screw thread or a similar fixture (see Figure A.1) to a torque as used in service (see ISO 13341). The valve shall protrude from the cylinder neck, or fixture, by the same nominal amount as in service.

The valve shall be struck by a plummet weight tipped with a 13 mm diameter hardened steel ball at a minimum velocity of 3 m/s, resulting in an impact energy (in joules) equal to 3,6 times the total package mass (cylinder plus content) in kg, or 40 J, whichever is the greater; e.g. a package mass of 100 kg requires an impact test at 360 J.

The impact shall be at 90° to the longitudinal axis of the valve and coincident with a plane passing through the same axis.

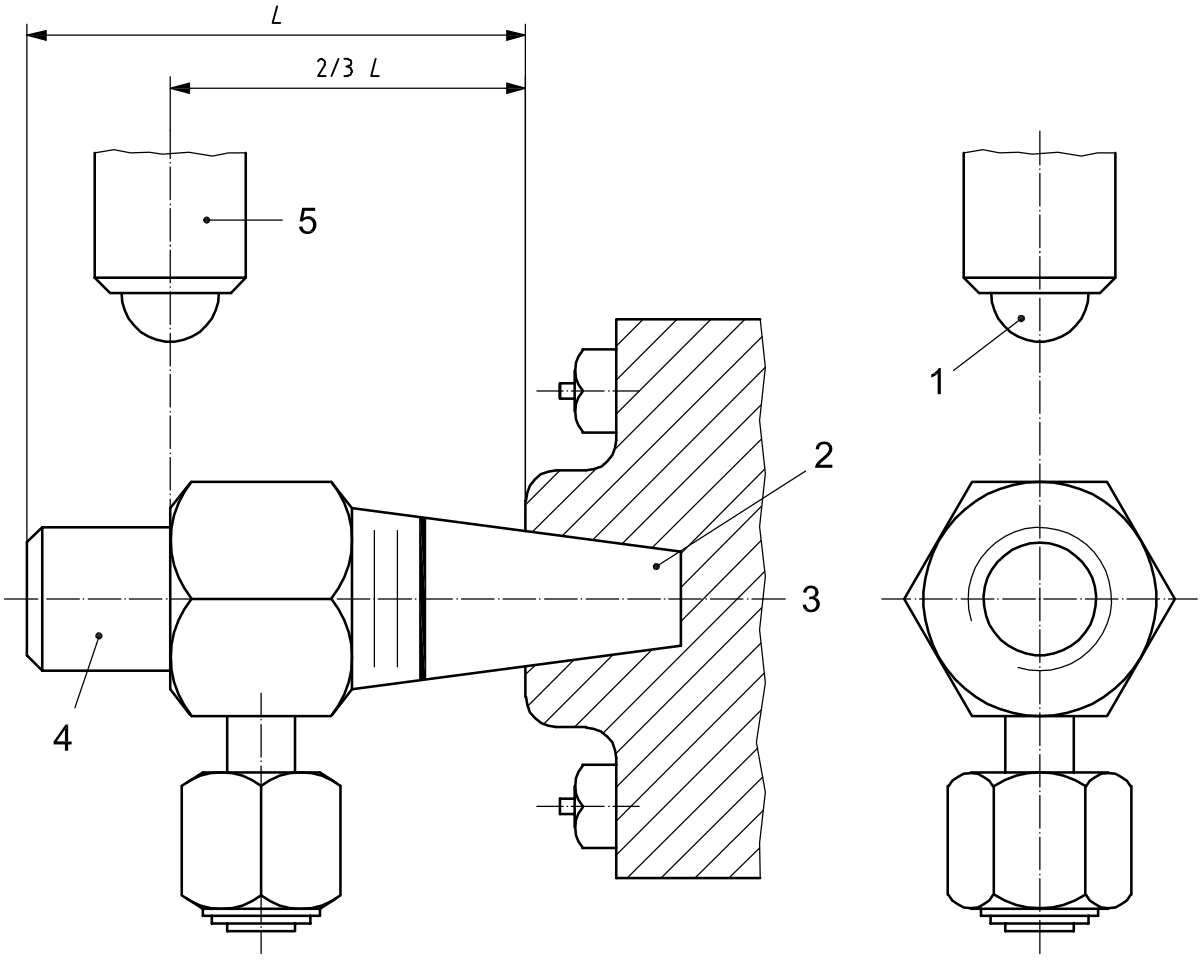
The point of impact shall be two thirds of the distance, L, from the plane where the valve stem thread meets the cylinder to the furthest point of the valve body, measured along the longitudinal axis of the valve (see Figure A.1).

The point of impact on the valve shall not be obstructed by features such as outlet connecting threads, pressure relief devices, handwheel, etc.

The valve shall be struck once only, and shall withstand the appropriate impact energy. Distortion due to impact is permissible.

After testing, the valve shall be removed from the test rig, it shall be fitted into a pressure supply and closed to the previous torque.

Valve test pressure, p_{vt}, shall be applied to the valve inlet. The leakage shall conform to 5.15.



Key

1 13 mm diameter hardened steel ball
2 fixture or cylinder
3 longitudinal axis
4 valve
5 plummet weight

Figure A.1 — Impact test

Annex B
(informative)

Endurance test

B.1 Test valves

Valves to be tested shall be at room temperature (typically between 15 °C and 30 °C). They will have previously been aged in accordance with the procedure specified in Table 3 (sequence 3).

B.2 Test medium

The endurance test shall be carried out with dry air or nitrogen filtered to at least 20 µm and at a dew point of less than − 40 °C atmospheric pressure.

NOTE If nitrogen is used, the risks of asphyxiation should be considered if a major leak occurs.

Tests shall not be carried out in a water bath or other liquid medium.

B.3 Test machine

B.3.1 Equipment

Figure B.1 shows a typical arrangement of computer-controlled equipment.

B.3.2 Speed and application of torque

The test machine shall be able to open and close the test valves at a speed of between 10 revolutions and 30 revolutions per minute.

At the end of the closing part of the test cycle, overtorque due to dynamic effects shall be no more than 10 % of the set figure.

B.3.3 Alignment

The valve and the machine spindles should be aligned in such a way that no significant side or axial load is put on the valve during the test.

B.3.4 Calibration

The calibration of the machine shall be verified before commencing and after completion of each endurance test.

B.4 Test cycle

B.4.1 Stroke of the endurance test

The test valve shall be cycled through its full stroke except that the spindle shall not get closer than 45° to the fully open position. This will ensure that the test machine does not apply torque in the fully open position.

B.4.2 Endurance test

This test shall be carried out at room temperature (typically between 15 °C and 30 °C) (see Table 3).

The endurance test of 2 000 cycles shall be carried out with the torque specified in 6.14 with a tolerance of $\pm$ 5 % in the closing direction only. The valve inlet shall be pressurized throughout the whole test to p_{vt} as defined in 3.22.

The valve outlet shall be connected to a venting device that remains closed during the closing and opening portions of the cycle.

After the valve has reached the closed position, the valve outlet shall be vented down to atmospheric pressure by opening the venting device. Once atmospheric pressure has been reached, the venting device shall be closed and the outlet pressure shall be measured and verified to be no more than 1 % of p_{vt} immediately before commencing the next cycle.

There shall be a pause of at least 6 s at each fully open and fully closed position of the test valve.

The average time rate shall be no more than 3 cycles per minute and no less than 1 cycle per minute for the duration of the test. Any break during the duration of the 2 000 cycle test that is longer than 5 min shall be recorded in the test report.

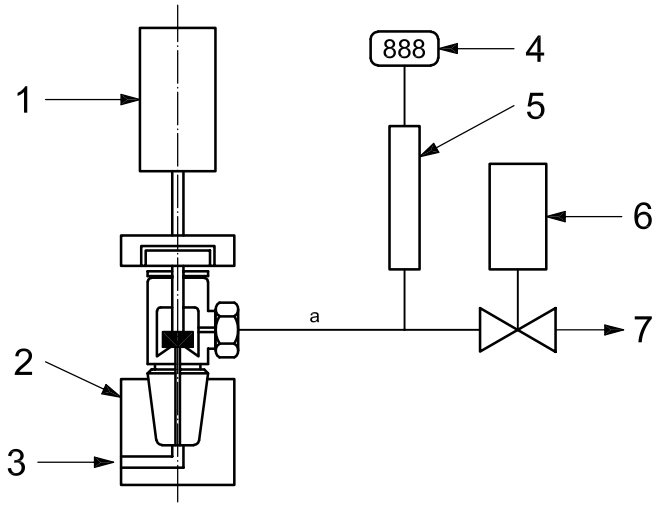
B.4.3 Record

The test cycle shall be recorded as an illustration. See Figure B.2.

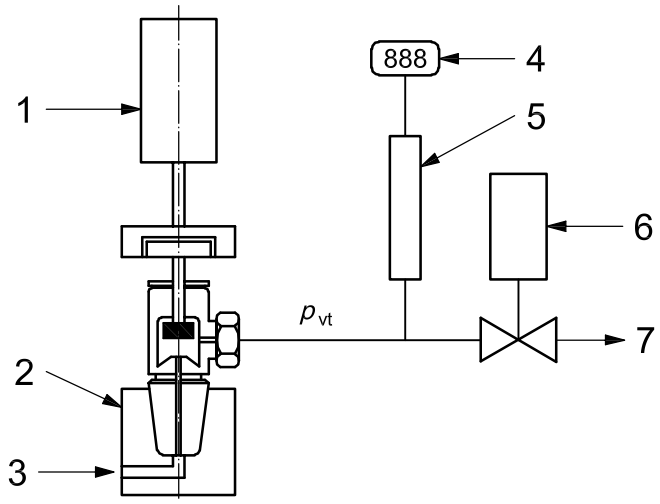
B.5 Measurements after the endurance test

The tests specified in Table 3, test sequences 5, 6 and 7 shall be completed. For these tests, the torque used during the endurance test shall not be exceeded.

The test valve shall then be examined in accordance with sequence 8.



a) Closed position



b) Open position

Key

1 DC motor with torque transmitter
2 adapter
3 input test medium
4 display
5 pressure transmitter
6 venting valve
7 outlet

a From p_{vt} to atmospheric pressure.

Figure B.1 — Typical arrangement of computer controlled equipment

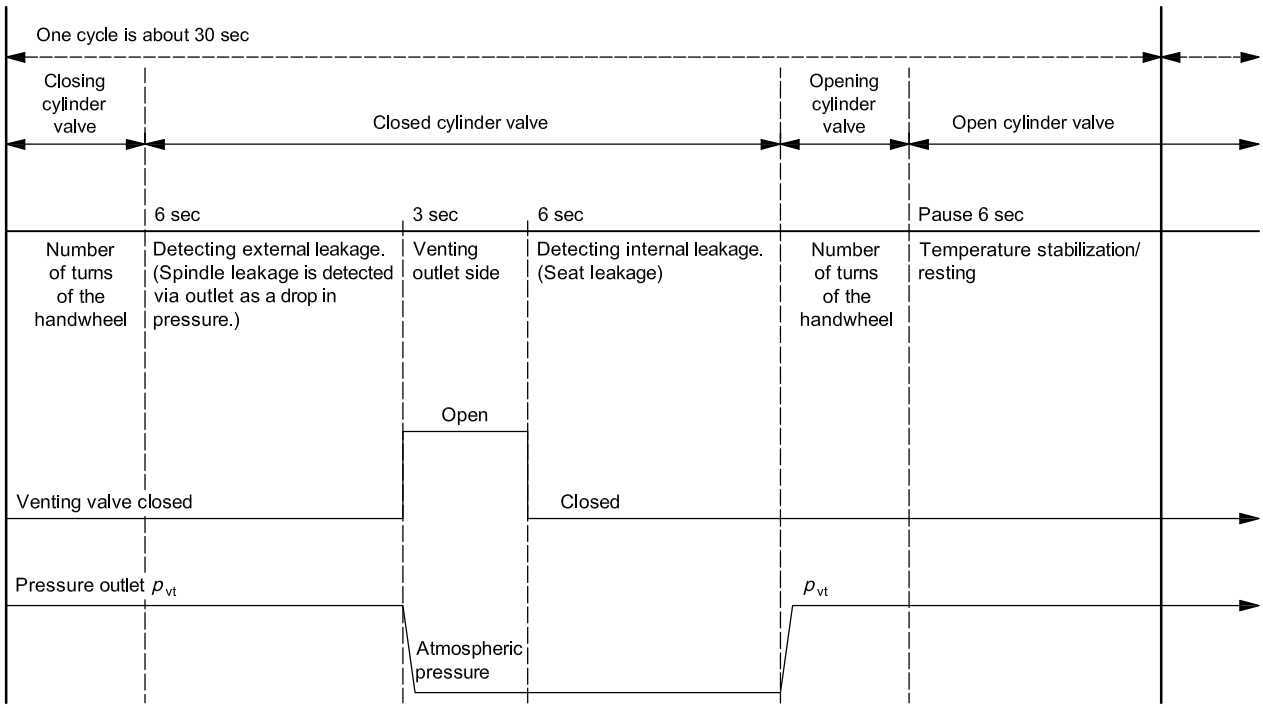


Figure B.2 — Diagram showing a typical cycle for an endurance test

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