

HERMETICITY OF VALVES

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1. Introduction

The request of hermeticity of valves is often confusing and create wrong expectations to the user. In this paper the most common hermeticity test for valves are described and a comparison between the different test standards is intended. A real comparison is very difficult to provide because the different standards test under different conditions, which very often are not comparable.

From an engineering point of view, almost all valves leak by some measure. A “zero leakage” do not exist, since small amounts of material may indeed cross the seat, especially if helium or hydrogen or other small molecule gases are used. Soft seated valves are commonly defined as “bubble tight”, while most metal seated valves larger than DN 50 (NPS 2”) have an allowable leakage rate (according to API 598 or API 6D). In the ISO 5208 standard there are special zero leakage classes also for metal seated valves.

It should be noted in the engineering design that API 600-2001 (ISO 10434–1998) specifies that the sealing performance of the valve is tested in accordance with ISO 5208, but the leakage in tables 17 and 18 is equivalent to API 598–1996, not ISO 5208. Therefore, when API 600 and its sealing performance test API 598 standard are selected for the engineering design, the version of the standard must be clarified to ensure the uniformity of the standard content.

The relevant guidelines of API 6D (ISO 14313) for valve leakage are: “soft seated valves and oil-seal plug valves shall not exceed ISO 5208 A (no visible leakage), metal seat valves shall not exceed ISO 5208(1993) D unless otherwise specified.” Note in the standard: “special applications may require leakage less than ISO 5208(1993) class D. Therefore, leakage requirements higher than the standard shall be given in the order contract.

The standard ANSI / FCI 70-2 are normally used for control valves but can also be defined by the user for on-off valves.

This description is not intended to replace the norms, the test standards in its last version, selected by the user, must be followed when testing a valve.

Not all hermeticity classes described in the norms are possible at all type of valves, the manufacturer must verify from case to case which class is possible and under which conditions.

The hermeticity test is done under laboratory conditions on a test rig. Leakages under process conditions are not defined. Leakages after a long use of a valve depend on the process conditions and cannot be guaranteed by the manufacturer of the valve.

Test standards for common valve types are:

Steel ball, gate, globe and check valves	ISO 5208 / API 598 / EN 12266-1
Cast iron gate valves	API 598 / MSS SP-70
Bronze gate, globe and check valves	MSS SP-80
Steel gate, globe and check valves larger than NPS 24" (DN 600)	ASME B16.34
Pressure seal gate, globe and check valves	ASME B16.34
Pipeline valves (API 6D)	ISO 5208
Steel ball valves	API 598
Steel butterfly valves	API 598
Cryogenic valves	API 598 / BS 6364
Control valves	FCI 70-2 / EN 60534-4
Pressure relief valves	API 527 / ASME PTC 25

In this description only the standards and procedures for on-off valves are described. Procedures for control and pressure relief valves are included.

Which test, and under which procedures the valve must be tested can be defined by

- the user
- norms like API (used in the USA), EN 12266-1 (used in Europe) or other local regulations

The norms refer to a specific test procedure like

Norm	Applicable for	Test procedures
EN 12266-1	On-off valves	ISO 5208
API 6D	Ball, check, gate and plug valves used in pipelines	ISO 5208
API 608	Ball valves for industrial service	API 598
API 609	Butterfly valves	API 598
API 602	Gate, globe and check valves in dimensions < ND 100 (4")	API 598
EN 1349	Control valves	EN 60534-4
API 6D	Control valves	ANSI / FCI 70-2



Measuring units used for the test

Leakage flow measurement with gas:

1 bubble/min = 60 bubbles/sec = 0,15 ml/min = 2,5 mm³/sec
1 bubble/sec = 0,0166 bubble/min = 9 ml/min = 150 mm³/sec
1 ml/min = 6,66667 bubbles = 400 bubbles/sec = 16,66667 mm³/sec
1 mm³/sec = 0,06 ml/min = 0,4 bubbles/min = 24 bubbles/sec

Leakage flow measurement with water

1 drop/min = 60 drops/sec = 0,0625 ml/min = 1,042 mm³/sec
1 drop/sec = 0,0165 drops/min = 3,75 ml/min = 62,4 mm³/sec
1 ml/min = 16 drops/min = 960 drops/sec = 16,66667 mm³/sec
1 mm³/sec = 0,06 ml/min = 0,96 drops/min = 57,60 drops/sec

2. ISO 5208 – 2015

International Organization for Standardization ISO 5208 specifies examinations and tests that a valve manufacturer needs to act upon in order to establish the integrity of the pressure boundary of an industrial metallic valve and to verify the degree of valve closure tightness and the structural adequacy of its closure mechanism.

There are 10 leakage rates specified in ISO 5208: A, AA, A, B, C, CC, D, E, EE, F, G and the rate A is the highest grades. There is a loosely defined correspondence between the leakage rate acceptance values of API 598 and leakage value rate A as applied to DN 50, rate CC-liquid for other than metal-seated check valves and for check valves rate EE-gas and rate G-liquid. Rate A, B, C, D, F and G correspond to values in EN 12266-1.

Required hermeticity test

The ISO 5208 do not define different conditions for soft seated or metal seated valves. The requirements are the same independent of the material that provides the sealing.

The ISO 5208 standard can be used for all type of on-off valves, it is not used for control valves.

The testing requirements for industrial steel valves are:

Temperature of test fluid		Test with water	Test with gas
		5°C to 40°C	5°C to 40°C
Minimum test duration	DN ≤ 50 (NPS ≤ 2")	15 sec (60 for check valves)	15 sec (60 for check valves)
	DN 65 to 150 (NPS 2.5" to 6")	60 sec	60 sec
	DN 200 to 300 (NPS 8" to 12")	120 sec	120 sec
	DN ≥ 350 (NPS ≥ 14")	120 sec	120 sec
Minimum test pressure		1.1 x nominal pressure of the valve	1.1 x nominal pressure of the valve or 6 ± 1 bar



Acceptance criteria

No visible leakage for $DN \leq 50$ ($NPS \leq 2''$). Allowable leakage rates as per below table.

Test fluid	Unit	Rate A	Rate AA	Rate B	Rate C	Rate CC
Liquid	mm ³ /sec	No visually detectable leakage for the duration of the test	0,006 x DN	0,01 x DN	0,03 x DN	0,08 x DN
	drops/sec		0,0001 x DN	0,00016 x DN	0,0005 x DN	0,0013 x DN
Gas	mm ³ /sec		0,18 x DN	0,3 x DN	3 x DN	22,3 x DN
	bubbles/sec		0,003 x DN	0,0046 x DN	0,0458 x DN	0,3407 x DN

Test fluid	Unit	Rate D	Rate E	Rate EE	Rate F	Rate G
Liquid	mm ³ /sec	0,1 x DN	0,3 x DN	0,39 x DN	1 x DN	2 x DN
	drops/sec	0,0016 x DN	0,0048 x DN	0,0062 x DN	0,016 x DN	0,032 x DN
Gas	mm ³ /sec	30 x DN	300 x DN	470 x DN	3000 x DN	6000 x DN
	bubbles/sec	0,4584 x DN	4,5837 x DN	7,129 x DN	45,837 x DN	91,673 x DN

3. API 598 (2009)

This standard cover inspection, examination, supplementary examinations and pressure test requirements for soft seated, non-metallic seated (e.g. ceramic) and metal-to-metal seated valves of the gate, globe, ball, check and butterfly types.

This standard supplements the API Standards, but it may also be applied to other type of valves by agreement between the user and the manufacturer

Test required

The test listed in the following table shall be performed in accordance with written procedures that comply with the standard

Test	Valve type					
	gate	globe	plug	check	Floating ball	Butterfly and trunnion guided ball
Low pressure	optional	optional	optional	optional	required	optional
High pressure	required	required	required	required	optional	required

When an optional test is specified by the user, the test shall be performed in addition to the required test.

A high pressure test is required for all valves specified to be double block and bleed valves.

Testing requirements

	Sizes	Test with water	Test with gas
Temperature of test fluid		5°C to 50°C	5°C to 50°C
Minimum test duration	DN ≤ 50 (NPS ≤ 2")	15 sec (60 for check valves)	15 sec (60 for check valves)
	DN 65 to 150 (NPS 2.5" to 6")	60 sec	60 sec
	DN 200 to 300 (NPS 8" to 12")	120 sec	120 sec
	DN ≥ 350 (NPS ≥ 14")	300 sec	120 sec
Minimum test pressure		1.1 x nominal pressure of the valve	4 to 7 bar



Acceptance criteria

No visible leakage for soft seated valves. Allowable leakage rates as per below table for metal seated valves.

Size		Metal seated valves except check valves			Metal seated check valves		
DN	NPS	Test with liquid in drops/min	Test with liquid in ml/min	Test with gas in bubbles/min	Test with gas in ml/min	Test with gas in m3/h	Test with gas in ml/min
≤ 50	≤ 2"	0	6	0	0	0,08	1333
65	2 ½"	5	7,5	10	1,5	0,11	1833
80	3"	6	9	12	1,8	0,13	2167
100	4"	8	12	16	2,4	0,17	2833
125	5"	10	15	20	3,0	0,21	3500
150	6"	12	18	24	3,6	0,25	4167
200	8"	16	24	32	4,8	0,34	5667
250	10"	20	30	40	6	0,42	7000
300	12"	24	36	48	7,2	0,50	8333
350	14"	28	42	56	8,4	0,59	9833
400	16"	32	48	64	9,6	0,67	11167
450	18"	36	54	72	10,8	0,76	12667
500	20"	40	60	80	12	0,84	14000
600	24"	48	72	96	14,4	1,01	16833
650	26"	52	78	104	15,6	1,09	18167
700	28"	56	84	112	16,8	1,18	19667
750	30"	60	90	120	18,0	1,26	21000
800	32"	64	96	128	19,2	1,34	22333
900	36"	72	108	144	21,6	1,51	25167
1000	40"	80	120	160	24,0	1,68	28000
1050	42"	84	126	168	25,2	1,7	28333
1200	48"	96	144	192	28,8	2,02	33667

4. FCI 70-2 (2013)

American national standards/American instrument association standards ANSI/FCI 70-2 (ASME B16.104) is applicable to the control valve seal grade requirements. Metal-elastic seal or metal seal should be selected in engineering design according to the characteristics of the medium and the opening frequency of the valve. Metal seated valve seal grades should be stipulated in the order contract. The rates I, II, III are used less only when lower level are acceptable, generally the rate IV is used at least or V and VI for higher requirements.

In the classes I till V the test can be done with water or gas, in the highest class VI only with gas.

Class IV is normally specified for metal to metal sealings (e.g. in the API 6D).

Class V is practically not used anymore and refers to the Class IV but with defined leakage rates.

Class VI is used at soft seated valves. Soft seated valves are those where the seat or shut-off disc or both are made from resilient material such as Teflon or similar elastomer.

For the Class I there are no test requirements defined but can be agreed between the user and the manufacturer.

For class II till IV the test can be done with water or gas (air or nitrogen).

The ambient temperature during the test must be between 10°C and 50°C.

The pressure during the test must be between 3 and 4 bar or 5% of the maximal differential pressure during operation, whichever is smaller.

Acceptance criteria

Acceptable leakage for the Class II: 0,5% of the maximum flow (e.g. 12100 ml/min for a 2" valve)

Acceptable leakage for the Class III: 0,1% of the maximum flow (e.g. 2420 ml/min for a 2" valve)

Acceptable leakage for the Class IV: 0,01% of the maximum flow (e.g. 242 ml/min for a 2" valve)

For the Class V the test is done with water.

The ambient temperature during the test must be between 10°C and 50°C.

The pressure during the test must the maximum differential pressure during operation, not to exceed the ANSI body rating.

Acceptable leakage: 0,0005 ml/min per inch of the valve nominal diameter per psi of differential pressure.

Hermeticity class VI

Test made with gas (air or nitrogen).

The ambient temperature during the test must be between 10°C and 50°C.

The pressure during the test must be between 3 and 4 bar or 5% of the maximal differential pressure during operation, whichever is smaller.

Acceptable leakage according to following table:

Diameter		Leakage in ml/min	Leakage in bubbles/min
ND	NPS		
≤25	≤1"	0,15	1
32	1,5"	0,30	2
50	2"	0,45	3
65	2,5"	0,60	4
80	3"	0,90	6
100	4"	1,70	11
150	6"	4,00	27
200	8"	6,75	45
250	10"	11,10	74
300	12"	16,00	107
350	14"	21,60	144
400	16"	28,40	189

For larger diameters, the allowed leakages are not defined in the norm.

Valid for all leakage classes is

- The leakage is measured once the valve has stabilized at the test pressure
- The nominal diameter is the one of the valve.

5. EN 12266-1 (2012)

This standard specifies the pressure tests, test methods and acceptance criteria – mandatory requirements. It meets the requirements of ISO 5208 for seal classification but lacks AA, CC and EE ratings.

Test with gas		
Temperature of test fluid		5°C to 40°C
Minimum test duration	DN ≤ 50 (NPS ≤ 2")	15 sec (60 for check valves)
	DN 65 to 150 (NPS 2.5" to 6")	60 sec
	DN 200 to 300 (NPS 8" to 12")	120 sec
	DN ≥ 350 (NPS ≥ 14")	120 sec
Minimum test pressure		1.1 x nominal pressure of the valve or 6 ± 1 bar

Acceptance criteria

Test fluid	Unit	Rate A	Rate B	Rate C	Rate D
Liquid	mm ³ /sec	No visually detectable leakage for the duration of the test	0,01 x DN	0,03 x DN	0,1 x DN
	drops/sec		0,00016 x DN	0,0005 x DN	0,0016 x DN
Gas	mm ³ /sec		0,3 x DN	3 x DN	30 x DN
	bubbles/sec		0,0046 x DN	0,0458 x DN	0,4584 x DN

Test fluid	Unit	Rate E	Rate F	Rate G
Liquid	mm ³ /sec	0,3 x DN	1 x DN	2 x DN
	drops/sec	0,0048 x DN	0,016 x DN	0,032 x DN
Gas	mm ³ /sec	300 x DN	3000 x DN	6000 x DN
	bubbles/sec	4,5837 x DN	45,837 x DN	91,673 x DN

6. MSS SP-61 (Manufacturers Standardization Society)

This standard has a section which describes the permissible leakage of ball, globe, gate and butterfly valves.

It should be noted that SP 61 is often used for inspection of “fully open” and “fully closed” steel valves, but not for control valves. MSS SP61 is not usually used for testing industrial valves.

For valve with soft seats, the hermeticity requirement is the same as the API 598, as well as the shell pressure test.

Acceptance criteria

For metal seated valves the permissible leakage is 10 ml/hr (0,166 ml/min or 2,766 mm³/sec) per inch of nominal diameter.

NPS	1"	1,5"	2"	2,5"	3"	4"	6"	8"	10"	12"	14"	16"
DN	25	40	50	65	80	100	150	200	250	300	350	400
Leakage in mm ³ /sec	2,76	3,32	5,53	6,91	8,30	11,07	16,60	22,13	27,66	33,20	38,73	44,26

For gate valve with metal seats, the value is 40 ml/min per inch of diameter at a pressure of 40 psi (3 bar)

The leakage allowed by the check valve can be increased by 4 times

The hermeticity test must be done with water at 1.1 the nominal pressure of the valve.

7. Testing of cryogenic valves – BS 6364

The test of cryogenic valves, defining the cryogenic service for a temperature < -60°C.

Valves cryogenic tests are performed in dedicated chambers that are filled with liquid nitrogen to reach the desired temperature. According to the requirements, the test must be conducted by submerging the valve body into liquid nitrogen, at a temperature of ca -196°C.

The hermeticity test is done in several steps:

Step 1 – at ambient temperature

Test done with nitrogen (N₂) at a pressure of 6,9 bar

Test done with helium (He) at a pressure of the nominal pressure of the class.

The test duration is of 0,25 min for diameters up to DN 50 (2"), of 0,5 min for diameters up to DN 200 (8") and of 1,0 min for larger diameters.

The acceptance criteria are:

For the test done with nitrogen apply the criteria of ISO 5208 Rate A

For the test done with helium the acceptable leakage is $\leq 1000 \text{ mm}^3/\text{sec} \times \text{DN}$

Step 2 – test at the specified temperature (till -196°C)

Test done with helium (He) at a pressure of the nominal pressure of the class.

The test duration is of 0,25 min for diameters up to DN 50 (2"), of 0,5 min for diameters up to DN 200 (8") and of 1,0 min for larger diameters.

The acceptance criteria is: $\leq 1000 \text{ mm}^3/\text{sec} \times \text{DN}$

The valve must be actuated 20 times, and the required actuation torque should be measured at the first and last cycle.

Step 3 – test with the valve at room temperature (the cooling must be done in still air)

Test done with helium (He) at a pressure of the nominal pressure of the class.

The test duration is of 0,25 min for diameters up to DN 50 (2"), of 0,5 min for diameters up to DN 200 (8") and of 1,0 min for larger diameters.

The acceptance criteria is: $\leq 1000 \text{ mm}^3/\text{sec} \times \text{DN}$

The required actuation torque should be measured again.