



LEAKAGE ACCEPTANCE RATES FOR METAL & SOFT SEATED VALVES ISO 5208/API 598/API 6D/MSS SP-61/FCI 70-2

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TESTING & LEAKAGE RATES OVERVIEW

From an engineering point of view, almost all valves leak by some measure. Valves may be said to be 'bubble tight' or 'zero leakage', but in actuality that is just a term that specifies the allowable leakage of that classification. From an engineering viewpoint there is no such thing as true zero leakage. Triple and quadruple offset butterfly valve manufacturers differentiate their product by claiming this style of valve actually is zero leakage. Bear in mind even solid glass 'leaks' 1cc every 3 years per square cm.

Did you know, API 6D/API 598/ISO 5208 do not always require a high pressure and a low pressure seat test to be done as a mandatory requirements for all valves types? Depending on size, type and class only either a high or a low pressure test but not both. KAMROO enforces all our manufacturers perform both testes.

In the past many products were rated with Cold Working Pressure (CWP) (i.e. 800 psi WOG which meant 800 psi working pressure for water, oil or gas service), instead of the ASME/ANSI pressure classes used today for most steel valves. Of course many 'commodity', low pressure screwed end valves up to 2000 psi are still produced in CWP WOG ratings.

The base test specification for most steel valves is API 598 'Valve Inspection & Test'. Most metallic seated valves larger than ANSI 50 NB (2") size have an allowable leakage rate shown in API 598 and ISO 5208. Soft seated valves such as ball valves must be zero leakage. Bronze gate, globe & check valves are usually only tested per MSS SP-61 'Pressure Testing of Steel Valves'.

Pipeline Valves, such as trunnion mounted ball valves, pressure balanced lubricated plug valves and pipeline slab gate valves are tested to API6D - 'Pipeline Valves'. API6D now references ISO 5208 leakage rates. The testing requirements differ slightly from API 598 (ISO 5208 is now mirrored to API598). The primary difference being 6D's focus on valves with zero allowable leakage on closure (seating) tests which is achieved as most of the valves built to API 6D are resilient seated. Of course metal seated valves are also accommodated as API 6D references ISO 5208 leakage rates.

However, metal seated API 6D and API 594 check valves do have a seat leakage allowance. API 598/ ISO 5208 does incorporate a zero leakage requirement for soft seated valves used in refineries and downstream but API 6D is generally specified for pipeline valves.

Conventional metal seated API midstream and downstream valves allow varying degrees of seat leakage. API 598/ ISO 5208. Examples of common ASME/ANSI valves used by Petroleum, Petrochemical & allied industries are:

- API 608 Floating Ball Valves
- API 600/API 603 Gate Valves
- API 623/ASME B16.34 Globe Valves (formerly BS1873)
- API 594/API 6D/ASME B16.34 Swing Check Valves (formerly BS 1868)
- API 594 Wafer Check Valves

EXPLANATION OF ZERO AND LOW LEAKAGE TEST STANDARDS

In general, specification such as API 598 (mirrored with ISO 5208) or API 6D (ISO 5208 leakage rates) that govern leakage for soft seated valves call for '0' bubbles of air or '0' drops of water under the specified test conditions over the minimum test time period. These valves are therefore sometimes referred to as 'zero leakage' valves. In reality, there really is no such thing as 'zero leakage', since microscopic amounts of material may indeed cross the seat or packing boundaries, especially if helium or hydrogen or other small molecule gases are used. Another common term for soft seated valves is 'bubble tight'.

Less frequently, the leakage performance for soft seated valves is referred to as Class VI (EN 60534-4), which is the tightest leakage under FCI 70-2, and generally applies to resilient seated control valves (as opposed to metal seated control valves or soft seated shut off valves). In fact, FCI 70-2 Class VI (EN 60534-4) (formerly ANSI B16.104) allows a small number of bubbles and drops per minute, increasing with valve size, during the test, whereas API 598 does not (for soft seat, but does for metal seat). FCI 70-2 Class VI (EN 60534-4) is for soft seated control valves but is frequently used as a leakage acceptance test criteria for metal seated isolation valves such as ball and butterfly valves. FCI 70-2 only requires a low pressure test, consequently closure and seat tests should also be done per API 598 (ISO 5208 leakage acceptance rates) or MSS SP-61. MSS SP-61 allows only 2.66 drops per minute per inch for isolation valves are disregarded as tight shut off for many types of industrial valves. It is superior to FCI 70-2 Class VI (EN 60534-4) (Table 7).

In fact even for metal seat valves the API 598 leak acceptance criteria for metal seated valves (excluding check valves) allows less leakage than FCI 70-2 (ISA-S75.19) Class VI (EN 60534-4). For zero leakage metal seated valves, API 6D (ISO 5208 Rate A) or API 598 soft seated zero leakage criteria can be specified (such as triple offset metal seated butterfly valves and some metal seated ball valves). Special provisions for zero leakage gate valves can also be specified to BS 6755 (now EN 12266-1) and ISO 5208 under special zero leakage classes. However, metal seated valves usually have some level of acceptable leakage when tested, defined first as some acceptable amount of liquid, under test conditions and over the time period of the test. Knife gate valves refer to MSS SP-81/MSS SP-151 leakage rates for metal seated (for resilient seat refer to MSS SP-61 or the manufacturer or client will nominate leakage).

ISO 5208 (EN 12266-1) supersedes BS 6755-1 and specifies acceptable leakage rates such as 'Rate A' and 'Rate B'. Rate A allows 'no visible leakage', similar to API 598 for resilient seated valves. API 6D now references leakage rates in ISO 5208 which in turn corresponds to leakage rates in EN 12266-1 (but only for class A, B, C, D, E, F & G).

COMMON VALVE TYPES & RELATED TEST STANDARDS

Valve Type	Common Test Standard
Steel ball, gate, globe and check valves	API 598/ ISO 5208
Steel ball, gate, globe and check valves	BS 6755*, ISO 5208 (EN 12266-1)
Cast Iron gate valves	API 598/ ISO 5208, MSS SP-70
Bronze gate, globe and check valves	MSS SP-80
Steel gate, globe and check valves larger than NPS 24"	ASME B16.34
Pressure seal gate, globe and check valves	ASME B16.34
Pipeline valves	API 6D/ ISO 14313, ISO 5208
Pipeline valves	API 6D/ ISO 14313, ISO 5208
Cast iron check valve	API 598/ ISO 5208, MSS SP-71
Cast iron globe valve	API 598/ ISO 5208, MSS SP-85
Cast iron plug valve	API 598/ ISO 5208, MSS SP-78
Steel ball valves	API 598/ ISO 5208
Steel butterfly valves	API 598/ ISO 5208
Cryogenic valves	API 598/ ISO 5208, BS 6364
Control valves	FCI 70-2, ISA-S75
Pressure relief valves	API 527, ASME PTC 25

Remark: ISO 5208 (EN 12266-1) supersedes BS 6755.

ANSI/FCI 70-2-2005 VALVE LEAKAGE CLASSIFICATIONS (Supersedes ANSI B16.104)

- Class I.** Identical to Class II, III, and IV in construction and design intent, but no actual shop test is made. www.kamroo.com
- Class II.** Intended for double-port or balanced single-port valves with a metal piston ring seal and metal-to-metal seats. Air or water at 45 to 60 psig is the test fluid. Allowable leakage is 0.5% of the rated full open capacity.
- Class III.** Intended for the same type of valves as in Class II. Allowable leakage is limited to 0.1% of rated valve capacity.
- Class IV.** Intended for single-port and balanced single-port valves with extra-tight piston seals and metal-to-metal seats. Leakage rate is limited to 0.01% of rated valve capacity (known as metal to metal). Test fluid is air or water, pressure 45 and 50 psig or the operating pressure if lower.
- Class V.** Intended for the same types of valves as Class IV. The test fluid is water at 100 psig or operating pressure. Leakage allowed is limited to 5 x 10⁻⁴ ml (= .0005ml) per minute per inch of orifice diameter per psi differential.
- Class VI. EN 60534-4** Intended for resilient-seating valves. The test fluid is air or nitrogen. Pressure is the lesser of 50 psig or operating pressure. The leakage limit depends on valve size and range from 0.15 to 11.5 ml per minute for valve sizes 1 through to 12 inches (known as soft seat classification). Class VI (EN60534-4) is also frequently used as a leakage benchmark for metal seated control and isolation valves where a tight degree of shut off is required

There are six seat leakage classifications defined by ANSI/FCI 70-2 (supersedes ANSI B16.104). The six valve Leakage classifications are as follows:

Table 1 - FCI 70-2 Leakage Rates Class VI (EN 60534-4)

Nominal Port Diameter (inches)	Allowable Leakage (ml Per Minute)	Allowable Leakage (Bubbles Per Minute)
1	0.15	1
1.5	0.3	2
2	0.45	3
2.5	0.6	4
3	0.9	6
4	1.7	11
6	4	27
8	6.75	45
10	9	63
12	11.5	81
14	21.6	/
16	28.4	/

Remark: Bubbles per minute is a suggested alternative to ml per minute; in which a 0.25 inch OD x 0.032 inch wall tube is submerged in water to a depth of 1/8" to 1/4". The tube is to be cut square and smooth with no imperfections and should be perpendicular to the surface of the water.

API 598 VALVE LEAKAGE RATES

API 598 (also mirrored by ISO 5208) from the American Petroleum Institute also covers testing/inspection requirements for gate, globe, check, ball, plug and butterfly valves. API 598 indicates that for shell and backseat tests (backseat only applies in the case of gate & globe valves), no visible leakage is permitted through body, body liner or joints; i.e. no visible evidence of drops or wetting of the external surfaces. In the case of 'metal to metal' butterfly valves, the client can specify the acceptable leakage rate. API 598 nominates a low pressure seat test of 80 psi and a high pressure seat* hydro-static test of 1.1x the maximum valve cold working pressure rating and a high pressure hydro-static test of 1.5 x the maximum valve cold working pressure rating.

Remark: The requirements on the body for seat testing under API 598 do vary according to valve type, size & class. For instance trunnion valves 150 NB (6") and over seat testing requirements are more stringent. Refer to our technical data sheet on test pressures for API 598. Having said that API 6D/ISO 5208 is the required standard for trunnion ball valves.

API 598's allowable seat leakage rates are as follows:

Table 2 - API 598 Valve Seat Leakage Rates

DN (MM)	NPS (in.)	All Resilient Seated Valves	All Metal-Seated Valves (except Check Valves)		Metal-Seated Check Valves	
			Liquid Test (drops/min.)	Gas Test (bubbles/min.)	Liquid Test (cc/min.)	Gas Test (m3/hr)
≤ 50	2	0	0b	0b	6	0.08
65	2 1/2	0	5	10	7.5	0.11
80	3	0	6	12	9	0.13
100	4	0	8	16	12	0.17
125	5	0	10	20	15	0.21
150	6	0	12	24	18	0.25
200	8	0	16	32	24	0.34
250	10	0	20	40	30	0.42
300	12	0	24	48	36	0.5
350	14	0	28	56	42	0.59
400	16	0	32	64	48	0.67
450	18	0	36	72	54	0.76
500	20	0	40	80	60	0.84
600	24	0	48	96	72	1.01
650	26	0	52	104	78	1.09
700	28	0	56	112	84	1.18
750	30	0	60	120	90	1.26
800	32	0	64	128	96	1.34
900	36	0	72	144	108	1.51
1000	40	0	80	160	120	1.68
1050	42	0	84	168	126	1.76
1200	48	0	96	192	144	2.02

Remark:

a. 1 Milliliter and 1 cc is considered equivalent to 16 drops for the liquid test.

b. There shall be no leakage for the minimum specified test duration.

For liquid test, 0 drop means no visible leakage per minimum specified test duration.

For gas test, 0 bubbles means less than 1 bubble per minimum specified test duration.

WARNING Even though leakage acceptance rates are shown under API 598 it is not mandatory to do high pressure hydrostatic seat test or a low pressure pneumatic seat test (see full details next page). This must be specified at time of order. KAMROO seat tests high and low pressure as standard but many manufacturers do not.

Table 3 - API598 Pressure Tests
Valves: DN (NPS) ≤ DN 100 (NPS 4) and ASME Class ≤ 1500
DN (NPS) > DN 100 (NPS 4) and ASME Class ≤ 600

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Test Description	Gate	Globe	Plug	Check	Floating Ball	Butterfly & Trunnion Ball
Shell	required	required	required	required	required	required
Backseat	required	required	NA	NA	NA	NA
Low-pressure Closure	required	optional c	required b	optional c	required	required
High-pressure closure	optional c f	required e	optional b c f	required	optional c f	optional c f

NOTE: NA = Not applicable.

- a The backseat test is required for all valves, except for bellows seals valves, that have the backseat feature.
- b For lubricated plug valves, the high-pressure closure test is mandatory and the low-pressure closure test is optional.
- c When the purchaser specifies an "option" test, the test shall be performed in addition to the required tests
- d The high-pressure closure test of resilient-seated valves may degrade subsequent sealing performance in low pressure service.
- e For power-operated and manually operated gear actuated globe valves, including non-return type globe valves, the high-pressure closure test shall be performed at 110% of the design differential pressure used for sizing of the operator
- f A high-pressure closure test is required for all valves specified to be double block and bleed valves.

Table 4 - API598 Pressure Tests
Valves: DN (NPS) ≤ DN 100 (NPS 4) and ASME Class >1500
DN (NPS) > DN 100 (NPS 4) and ASME Class > 600

Test Description	Gate	Globe	Plug	Check	Floating Ball	Butterfly & Trunnion Ball
Shell	required	required	required	required	required	required
Backseat	required	required	NA	NA	NA	NA
Low-pressure Closure	optional b	optional b	optional b	optional b	required	required
High-pressure closure	required	required	required	required	optional b c	required

NOTE NA = Not applicable.

- a The backseat test is required for all valves, except for bellows seals valves, that have the backseat feature.
- b When an "optional" test is specified by the purchaser, the test shall be performed in addition to the required tests.
- c The high-pressure closure test of resilient-seated valves may degrade subsequent sealing performance in low-pressure service.
- d For power-operated and manually operated gear actuated globe valves, including non-return type globe valves, the high-pressure closure test shall be performed at 110% of the design differential pressure used for sizing of the operator.
- e A high-pressure closure test is required for all valves specified to be double block and bleed valves.

MSS SP-61-2009 Test Standards and Leakage Rates

This is the test standard that covers other below listed MSS valve standards. The Manufacturer's Standardization Society also has a section on valve leakage in Section 5 of their 'Pressure Testing of Steel Valves - MSS SP-61-2009'. It covers on-off valves. Not control valves.

The following leakage rates are deemed acceptable by this testing standard:

For comparison purposes, the following are examples of leakage rates as noted in the MSS Specifications below:

- 10ml liquid = 2 teaspoons = 1/3 oz. = .001 liters
- 40ml liquid = 3 teaspoons = 1 1/2 oz. = .004 liters

METAL SEATED - GATE, GLOBE, BALL OR BUTTERFLY VALVES: 10 cc/hr per inch of nominal pipe diameter per hour. This equates to 2.66 drops/min/inch. For air test 1180 bubbles/min/inch is allowed. (e.g. A 6" globe valve is allowed to leak 60 cc/hr in a test). Metal Seated knife gate valves to MSS SP-81 are not included, refer to MSS-SP151 (see below) which allows 40ml/min/inch at 40 psi (275 kpa). All shut off or isolation valves specified to MSS-SP-61 must pass the above standards. The seat closure test must be performed at a fluid (liquid or gas) pressure no less than 1.1 times the 1000°F (380°C) rating rounded to the next 5 psi (0.5 bar).

The MSS SP-61 leakage rate is specified for resilient and metal seated check valves, however some manufacturers commonly specify a guaranteed maximum leakage for resilient seated check valves. For metal and resilient seated check valves the leakage rates referred to in MSS SP-81 for knife gate valves is often specified.

API 6D & ISO 5208 VALVE LEAKAGE RATES

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In the ISO 5208 Standard, account has been taken of the valve testing requirement needs of EN 12266 and API 598 with requirements referenced for PN designated valves for the former and Class designated valves for the latter.

There is a loosely defined correspondence between the leakage rate acceptance values of API 598 and the leakage Rate A as applied to DN ≤50, Rate AA-Gas and Rate CC-Liquid for other than metal seated check valves and for check valves: - Rate EE-Gas and Rate G-Liquid. Rates A, B, C, D, E, F and G correspond to values in EN 12266-1.

API 6D follows (see table 5) leakage rates specified in ISO 5208 covers pipeline valves. API 6D pipeline standards are a mirror/joint venture with ISO 14313 pipeline valve standards. ISO 5208 nominate several leakage rate levels (API 6D now refers to ISO 5208 leakage rates). The most common being zero leakage 'Rate A' for soft seated ball valves, pipeline (6D style) gate valves and lubricated plug valves. Refer to table 5 for leakage rates. API 6D/ ISO 14313 require a high pressure hydraulic body test (body 1.5x, seat 1.1x maximum valve cold working pressure) and a low pressure pneumatic test on the seat. No body leakage is allowed per ISO 5208 during body test. High pressure gas tests are regarded as 'special tests'. ISO 5208 (EN 12266-1) supersedes BS 6755.

Table 5 - Maximum Allowable Closure Test Seat Leakage Rate of API 6D/ISO 5208

Test Fluid	Unit Leakage	Rate A	Rate AA	Rate B	Rate C	Rate CC	Rate D	Rate E	Rate EE	Rate F	Rate G
Liquid	mm ³ /s	No visually detectable leakage for the duration of the test	0.06 X DN	0.01 X DN	0.03 X DN	0.08 X DN	0.1 X DN	0.3 X DN	0.39 X DN	1 X DN	2 X DN
	drops/s		0.0001 X DN	0.00016 X DN	0.0005 X DN	0.0013 X DN	0.0016 X DN	0.0048 X DN	0.0062 X DN	0.016 X DN	0.032 X DN
Gas	mm ³ /s	No visually detectable leakage for the duration of the test	0.18 X DN	0.3 X DN	3 X DN	22.3 X DN	30 X DN	300 X DN	470 X DN	3000 X DN	6000 X DN
	bubbles/s		0.003 X DN	0.0046 X DN	0.0458 X DN	0.3407 X DN	0.4584 X DN	4.5837 X DN	7.1293 X DN	45.837 X DN	91.603 X DN

API 6D - 2008 refers to ISO 5208 (2008-E) for leakage rates. EN 12266-1 also corresponds to ISO 5208 leakage rates but only for class A, B, C, D, E, F & G.

NOTE 1 The leakage rates only apply when discharging test fluid to the atmosphere.

NOTE 2 The closure leakage rate that applies is either that identified in a valve product standard or a leakage rate identified in a purchaser's valve procurement purchase order that is more stringent than that specified in the product standard.

NOTE 3 The meaning of "No visually detectable leakage" is that there is no visible weeping or leakage in the form of drops or bubbles.

NOTE 4 There is a loosely defined correspondence between the leakage rate acceptance values of API 598 and the leakage values Rate A as applied to DN < 50, Rate AA-Gas CC-Liquid for other than metal seated check valves and for check valves Rate EE-Gas and Rate G-Liquid. Rates A, B, C, D, E, F and G correspond to values in EN 12266-1.

NOTE 5 Double block & bleed leakage test is optional only and the client can specify the allowable leakage past the first seat for larger sizes.

NOTE 6 Valves tested in both directions.

Table 6 - Variations in Basic Test Parameters

Standard	Gas	Test Water Chlorides	Temperature
ASME B16.34	≥ 80 psi	NA	< 125 deg F
API 598	60 - 80 psi	≤ 100*	41 - 122 deg F
MSS SP-61	60 - 100 psi	NA	≤ 125 deg F
ISO 5208	6 bar +/- 1 bar (73 - 102 psi)	≤ 100*	≤ 5 deg C ≤ 40 deg C (41 - 106 deg F)
API 6D	NA	≤ 30** (by mass)	≤ 5 deg C ≤ 40 deg C (41 - 106 deg F)

Remark:

a. Austenitic stainless steel valves

b. Wetted components austenitic & duplex stainless steels

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