

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

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.

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 allowable in API 598. 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 API 6D - 'Pipeline Valves'. The testing requirements differ slightly from API 598. The primary difference being 6D's zero allowable leakage on closure (seating) tests which is achieved as most of the valves built to API 6D are resilient seated. However, pipeline full port metal seated API 6D check valves do have a seat leakage allowance. API 598 does incorporate a zero leakage requirement for soft seated valves used in refineries and downstream but API 6D is generally specified for pipeline valves.

There are no API standards for globe valves or check valves (except full port API 6D style swing check valves). Hence valve manufacturers make globe valves to British standard BS 1873 'Steel Globe and Check Valves for The Petroleum, Petrochemical and Allied Industries'. BS 1868 is more commonly used for check valves. However, most manufacturers supplying cast steel ANSI B16.5 flanged or ANSI B16.25 butt-weld globe and check valves test them to API 598 and often specify wall thickness to API 600 or API 603 or 'dual conforming' to either/or: - ANSI B16.34, BS 1868, BS 1873 or API 600.

EXPLANATION OF ZERO AND LOW LEAKAGE TEST STANDARDS

In general, specification such as API 598 or MSS SP-61 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, 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 (formerly ANSI B16.104) allows a small number of bubbles per minute, increasing with valve size, during the test, whereas API 598 and MSS SP-61 do not (for soft seat, but does for metal seat). FCI 70-2 Class VI 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 or MSS SP-61.

In actual 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 Class VI above 150NB (6") and 50NB (2") and under. For zero leakage metal seated valves API 6D 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-SP81 leakage rates for metal seated (for resilient seat it's up to manufacturer and client to nominate leakage).

ISO 5208 (EN 12266-1) supersedes BS6755-1 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 IS 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
Steel ball, gate, globe and check valves	BS 6755*, ISO 5208 (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"	ASME B16.34
Pressure seal gate, globe and check valves	ASME B16.34
Pipeline valves	API 6D, ISO 5208
Cast iron checks	API 598, MSS SP-71
Cast iron globes	API 598, MSS SP-85
Cast iron plugs	API 598, MSS SP-78
Steel ball valves	API 598
Steel butterfly valves	API 598
Cryogenic valves	API 598, BS 6364
Control valves	FCI 70-2, ISA-S75,
Pressure relief valves	API 527, ASME PTC 25

*ISO 5208 (EN 12266-1) supersedes BS 6755

ANSI/FCI 70-2-1976 VALVE LEAKAGE CLASSIFICATIONS

(supersedes ANSI B16.104)

There are six seat leakage classifications defined by ANSI/FCI 70-2-1976 (supersedes ANSI B16.104). The six valve leakage classifications are as follows:

- Class I.** Identical to Class II, III, and IV in construction and design intent, but no actual shop test is made.
- 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 5×10^{-4} ml (= .0005ml) per minute per inch of orifice diameter per psi differential.
- Class VI.** 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 is also frequently used as a leakage bench mark for metal seated control and isolation valves where a tight degree of shut off is required.

Table 1 - FCI 70-2 Leakage Rates Class VI

Nominal Port Diameter (inches)	Allowable Leakage (ml Per Minute)	Allowable Leakage (Bubbles Per Minute)
1	0.15	1
1.5	0.30	2
2	0.45	3
2.5	0.60	4
3	0.90	6
4	1.70	11
6	4.00	27
8	6.75	45
10	9.00	63
12	11.5	81
14	21.6	
16	28.4	

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 (9th edition 2009) 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* hydrostatic test of 1.1x the maximum valve cold working pressure rating and a high pressure hydrostatic test of 1.5x the maximum valve cold working pressure rating.

*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. 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 (9th edition 2009) 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	0 ^b	0 ^b	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	0.50
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

a) 1 millilitre 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 API598 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. Of course APV does this as standard but many manufacturer's don't.

Table 3 - 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	Valve Type					
	Gate	Globe	Plug	Check	Floating Ball	Butterfly and Trunnion Mounted Ball
shell	required	required	required	required	required	required
backseat ^a	required	required	NA	NA	NA	NA
low-pressure closure	required	optional ^c	required ^b	optional ^c	required	required
high-pressure closure ^d	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 - 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	Valve Type					
	Gate	Globe	Plug	Check	Floating Ball	Butterfly and Trunnion Mounted Ball
shell	required	required	required	required	required	required
backseat ^a	required	required	NA	NA	NA	NA
low-pressure closure	optional ^b	optional ^b	optional ^b	optional ^b	required	required
high-pressure closure ^d	required	required ^d	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.						
^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.						

MSS SP-61 VALVE LEAKAGE RATES

MSS SP-61-2009 - The Manufacturer's Standardisation Society also has a section on valve leakage in Section 5 of their 'Pressure Testing of Steel Valves - MSS SP-61-1999'.

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

METAL SEATED - GATE, GLOBE, BALL OR BUTTERFLY VALVES: 10 cc/hr per inch of nominal pipe diameter per hour. (e.g. A 6" globe valve is allowed to leak 60 cc/hr in a test). Metal Seated knife gate valves are not included, refer to MSS-SP81 which allows 40ml/min/inch at 40 psi. 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).

METAL SEATED CHECK VALVES: Do not require a seat test (except for stop check valves), however some manufacturers commonly specify a guaranteed maximum leakage.

API 6D/ISO 5208 VALVE LEAKAGE RATES

API 6D follows see table 5) leakage rates specified in ISO 5208 covers pipeline valves. API6D pipeline standards are a mirror/joint venture with ISO 14313 pipeline valve standards. API 6D and 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 3 for leakage rates. API 6D and ISO 5208 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 during body test. Low pressure and 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 ISO 5208:2008(E)/API 6D* (2008)

Test fluid	Unit leakage rates	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	0,006 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		0,000 1 x DN	0,000 16 x DN	0,000 5 x DN	0,001 3 x DN	0,001 6 x DN	0,004 8 x DN	0,006 2 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	3 000 x DN	6 000 x DN
	bubbles		0,003 x DN	0,0046 x DN	0,045 8 x DN	0,340 7 x DN	0,458 4 x DN	4,583 7 x DN	7,129 3 x DN	45,837 x DN	91,673 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 direction.

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)

* austenitic stainless steel valves, ** wetted components austenitic & duplex stainless steels

Table 7 - Leakage Comparison Metal vs Soft Seat

Diameter		API 598 (9th ed. 2009) Metal Seated		API 6D & ISO 5208*** Metal Seated		API 598/API 6D & ISO 5208**** Soft Seated	FCI 70-2 (2006) Class VI		FCI 70-2 (2006) Class V	MSS SP-61 (2009)
mm.	inch.	Liquid	Air (*)	Liquid ml/min	Air** bubbles/min	Liquid/Air	Air bubbles/min	Liquid ml/min	Liquid	Liquid or Air
50	2"	0	0	0.30	Smaller sizes refer to Table 3	0	3	0.45	5 x 10 ⁻⁴ ml (=.0005ml) per minute per inch of valve size per PSI differential pressure	10 ml liquid or 10 cc gas per inch of valve size per hour
80	3"	6	12	0.46		0	6	0.90		
100	4"	8	16	0.61		0	11	1.70		
150	6"	12	24	0.91		0	27	4.00		
200	8"	16	32	1.21		0	45	6.75		
250	10"	20	40	1.52	Leakage rate class client to select for larger sizes	0	63	11.10		
300	12"	24	48	1.83		0	81	16.00		
350	14"	28	56	2.14		0	-	21.60		
400	16"	32	64	2.44		0	-	28.40		
450	18"	36	72	2.74		0	-	-		
500	20"	40	80	3.05		0	-	-		
600	24"	48	96	3.66	0	-	-			
750	30"	60	120	4.57	0	-	-			
900	36"	72	144	5.48	0	-	-			
1000	40"	80	160	6.40	0	-	-			

API 598 leakage is in drops/min (liquid) and bubbles/min (air)

API 6D corresponds to ISO 5208 - 2008 leakage rates, ISO 5208 in turn corresponds to EN 12266-1 leakage rates but only for class A, B, C, D, E, F & G

FCI 70-2 Class VI does not define leakage above 400 NB (16")

FCI 70-2 Class VI test is performed always at 3 bar independently from the valve rating

(*) API 598 air test is required for metal seated ball and butterfly valves but is optional on globe & check valves

(**) API 6D air test optional for metal seated

(***) API 6D refers to ISO 5208 'Rate D' for metal seated, leakage rates which also aligns with EN 12266-1

(****) API 6D refers to ISO 5208 (2008 - E) 'Rate A' for soft seated, zero leakage which aligns with EN 12266-1

Rough guide: - 1 ml = approximately 16 drops, 1 cc = approximately 25 bubbles, 1cc = 1ml

