

Valve Leakage Class

Control Globe Valve**Control Butterfly Valve****Control Ball Valve**

This article is based on data from ANSI / FCI 70-2-2013 and major manufacturers around the world and is written to assist engineers working on the plant area.

August, 2016

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Valve Leakage Class - ANSI / FCI 70-2

■ Preface

Control valves are designed to throttle flows and when the valve fully closed, there is no 100% perfect shutoff of leakage.

The shut off ability has to do with type of valve. Double seated control valves have very poor shut off capabilities. In addition - the guiding, the seat material, the actuator thrust, the pressure drop and the type of fluid all play part in how well particular control valves shuts off. The standards mentioned below do not establish requirements for leakage performance of valves during use.

Performance against long-term leakage depends on valve and application and can not be guaranteed.

● Seat Leakage Classifications

There are actually six different seat leakage classifications defined by ANSI/FCI 70-2 2006 (European equivalent standard IEC 60534-4).

The most commonly used are

- CLASS IV
- CLASS VI

CLASS IV is also known as metal to metal. It is the kind of leakage rate you can expect from a valve with a metal plug and a metal seat.

CLASS VI is known as soft seat classification. Soft Seat Valves are those where either the plug or seat or both are made from some kinds of composition material such as Polytetrafluoroethylene (PTFE) or similar.

● Valve Leakage Classifications

Class I - Valve Leakage Classifications

Identical to Class II, III, and IV in construction and design intent, but no actual shop test is made.

Class I is also known as dust tight and can refer to metal or resilient seated valves.

Class II - Valve Leakage Classifications intended for double port or balanced single port valves with a metal piston ring seal and metal to metal seats.

- 0.5% leakage of full open valve capacity
- Service dP or 50 psid (3.4 bar differential), whichever is lower at 50 to 125°F
- Test medium air at 45 to 60 psig is the test fluid

Typical constructions:

- Balanced, single port, single graphite piston ring, metal seat, low seat load
- Balanced, double port, metal seats, high seat load

Class III - Valve Leakage Classifications

Intended for the same types of valves as in Class II.

- 0.1% leakage of full open valve capacity
- Service dP or 50 psid (3.4 bar differential), whichever is lower at 50 to 125°F
- Test medium air at 45 to 60 psig is the test fluid

Typical constructions:

- Balanced, double port, soft seats, low seat load
- Balanced, single port, single graphite piston ring, lapped metal seats, medium seat load

Class IV - Valve Leakage Classifications

Intended for single port and balanced single port valves with extra tight piston seals and metal to-metal seats.

- 0.01% leakage of full open valve capacity
- Service dP or 50 psid (3.4 bar differential), whichever is lower at 50 to 125°F
- Test medium air at 45 to 60 psig is the test fluid

Typical constructions:

- Balanced, single port, Polytetrafluoroethylene (PTFE) piston ring, lapped metal seats, medium seat load
- Balanced, single port, multiple graphite piston rings, lapped metal seats
- Unbalanced, single port, lapped metal seats, medium seat load
- Class IV is also known as metal to metal

Class V - Valve Leakage Classifications

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 per minute per inch of orifice diameter per psi differential
- Service dP at *50 to 125°F*

Typical constructions:

- Unbalanced, single port, lapped metal seats, high seat load
- Balanced, single port, Polytetrafluoroethylene (PTFE) piston rings, soft seats, low seat load
- Unbalanced, single port, soft metal seats, high seat load

Class VI - Valve Leakage Classifications

Class VI is known as a soft seat classification. Soft Seat Valves are those where the seat or shut-off disc or both are made from some kind of resilient material such as Polytetrafluoroethylene (PTFE).

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 ranges from *0.15 to 6.75 ml per minute* for valve sizes *1 through 8 inches*

Typical constructions:

- Unbalanced, single port, soft seats, low load

Control Valve Leakage Classification - Overview

| Leakage Class Designation | Maximum Leakage Allowable | Test Medium | Test Pressure | Testing Procedures required for Establishing Rating |
|----------------------------------|-----------------------------------------------------------------------------|-------------------------------------------|-----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| I | X | X | X | Not required provided user and supplier agree. |
| II | 0.5% of rated capacity | Air or water at 50 - 125°F (10 - 52°C) | 45 -60psig(3.2 - 4.2barg) or max. operating differential whichever is lower | Pressure applied to valve inlet, with outlet open to atmosphere or connected to a lower head loss measuring device, full normal closing thrust provided by actuator. |
| III | 0.1% of rated capacity | Air or water at 50 - 125°F (10 - 52°C) | 45 -60psig(3.2 - 4.2barg) or max. operating differential whichever is lower | Pressure applied to valve inlet, with outlet open to atmosphere or connected to a lower head loss measuring device, full normal closing thrust provided by actuator. |
| IV | 0.001% of rated capacity | Air or water at 50 - 125°F (10 - 52°C) | 45 -60psig(3.2 - 4.2barg) or max. operating differential whichever is lower | Pressure applied to valve inlet, with outlet open to atmosphere or connected to a lower head loss measuring device, full normal closing thrust provided by actuator. |
| V | 0.0005ml per minute of water per inch of port diameter per psi differential | Water at 50 - 125°F (10 - 52°C) | Max. service pressure drop across valve plug, not to exceed ANSI body rating. (100psi pressure drop min.) | Pressure applied to valve inlet after filling entire body cavity and connected piping with water and stroking valve plug closed. Use net specified max. actuator thrust, but no more even if available during test. Allow time for leakage to stabilize. |
| VI | Not to exceed a mount shown in following table based on port diameter | Air or nitrogen at 50 - 125°F (10 - 52°C) | 50 psig or max. rated differential pressure across valve plug, whichever is lower | Actuator should be adjusted to operating conditions specified with full normal closing thrust applied to valve plug seat. Allow time for leakage flow to stabilize and use suitable measuring device. |

Class VI Seat Leakage Allowable

| Port Diameter | | Bubble per minute | ml per minute |
|----------------------|-----------|--------------------------|----------------------|
| inches | mm | | |
| 1 | 25 | 1 | 0.15 |
| 1 1/2 | 38 | 2 | 0.30 |
| 2 | 51 | 3 | 0.45 |
| 2 1/2 | 64 | 4 | 0.60 |
| 3 | 76 | 6 | 0.90 |
| 4 | 102 | 11 | 1.70 |
| 6 | 152 | 27 | 4.00 |
| 8 | 203 | 45 | 6.75 |
| 10 | 254 | 63 | 9.00 |
| 12 | 305 | 81 | 11.50 |

- * Bubbles per minute as tabulated are an easily measured suggested alternative based on a suitable calibrated measuring device such as a 1/4-inch O.D.x0.032-inch wall tube submerged in water to a depth of 1/8-inch to 1/4-inch. The tube end shall be cut square and smooth with no chamfers or burrs and the tube axis shall be perpendicular to the surface of the water. Other apparatus may be constructed and the number of bubbles per minute may vary from these shown, as long as they correctly indicate the flow in ml per minute.
- ** If the valve seat diameter differs by more than 2 mm (0.08 in) from one of the value listed, the leakage rate may be obtained by interpolation assuming that the leakage rate varies as the square of the seat diameter.

Comparison of Leakage Rate using Air / Nitrogen

| | Maximum Acceptable Leakage (ml/min) | | | | | | |
|----------------------|-------------------------------------|----------|----------------------|--------|--------|--------|---------------------|
| | ANSI / FCI70-2-2013 | | ISO 5208 3rd Edition | | | | API-598 9th Edition |
| Test Pressure (psig) | 50 | | 73 to 102 | | | | 60 to 100 |
| Valve Size (inch)* | Class V | Class VI | Rate A | Rate B | Rate C | Rate D | Low Pressure Test |
| 1 | 4.7 | 0.2 | 0 | 0.5 | 4.5 | 45 | 0 |
| 1.5 | 7.1 | 0.3 | 0 | 0.7 | 7.2 | 72 | 0 |
| 2 | 9.4 | 0.5 | 0 | 0.9 | 9.0 | 90 | 0 |
| 2.5 | 11.8 | 0.6 | 0 | 1.2 | 11.7 | 117 | 10 |
| 3 | 14.1 | 0.9 | 0 | 1.4 | 14.4 | 144 | 12 |
| 4 | 18.8 | 1.7 | 0 | 1.8 | 18 | 180 | 16 |
| 6 | 28.2 | 4.0 | 0 | 2.7 | 27 | 270 | 24 |
| 8 | 37.6 | 6.8 | 0 | 3.6 | 36 | 360 | 32 |
| 10 | 47.0 | 11.1 | 0 | 4.5 | 45 | 450 | 40 |
| 12 | 56.4 | 16.0 | 0 | 5.4 | 54 | 540 | 48 |
| 14 | 65.8 | 21.6 | 0 | 6.3 | 63 | 630 | 56 |
| 16 | 75.2 | 28.4 | 0 | 7.2 | 72 | 720 | 64 |

Comparison of Leakage Rate using Water (Pressure based on ASME class 300 carbon steel body rating 740 psig per ASME B16.34)

| | Maximum Acceptable Leakage (ml/min) | | | | | | |
|----------------------|-------------------------------------|--|----------------------|--------|--------|--------|---------------------|
| | ANSI / FCI70-2-2013 | | ISO 5208 3rd Edition | | | | API-598 9th Edition |
| Test Pressure (psig) | 740 | | 814 | | | | 814 |
| Valve Size (inch)* | Class V | | Rate A | Rate B | Rate C | Rate D | High Pressure Test |
| 1 | 0.37 | | 0 | 0.015 | 0.045 | 0.15 | 0 |
| 1.5 | 0.56 | | 0 | 0.024 | 0.072 | 0.24 | 0 |
| 2 | 0.74 | | 0 | 0.030 | 0.090 | 0.3 | 0 |
| 2.5 | 0.93 | | 0 | 0.039 | 0.117 | 0.39 | 10 |
| 3 | 1.11 | | 0 | 0.048 | 0.144 | 0.48 | 12 |
| 4 | 1.48 | | 0 | 0.06 | 0.18 | 0.6 | 16 |
| 6 | 2.22 | | 0 | 0.09 | 0.27 | 0.9 | 24 |
| 8 | 2.96 | | 0 | 0.12 | 0.36 | 1.2 | 32 |
| 10 | 3.70 | | 0 | 0.15 | 0.45 | 1.5 | 40 |
| 12 | 4.44 | | 0 | 0.18 | 0.54 | 1.8 | 48 |
| 14 | 5.18 | | 0 | 0.21 | 0.63 | 2.1 | 56 |
| 16 | 5.92 | | 0 | 0.24 | 0.72 | 2.4 | 64 |

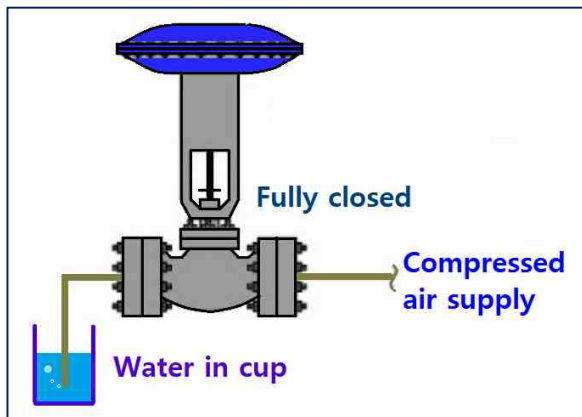
*Assumed full seat diameter for ANSI / FCI70-2-2013

● Bubble Test

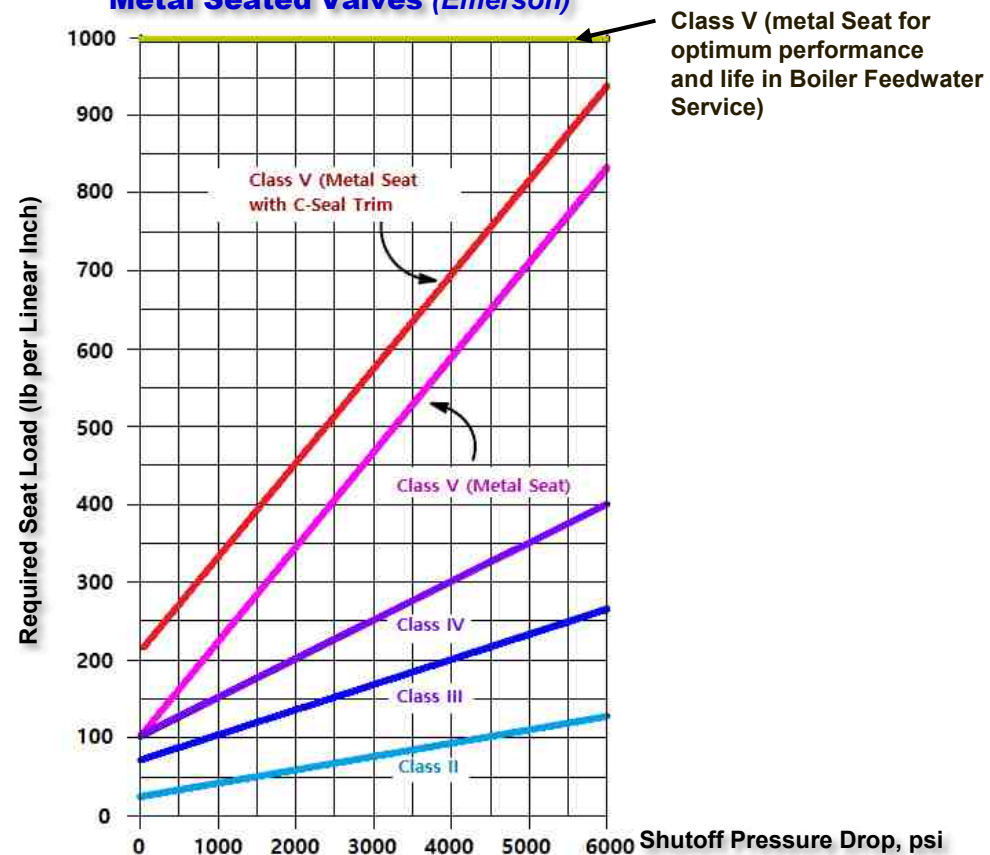
The “bubble test” used for Class VI seat leakage is based on the leakage rate of air or nitrogen gas past the closed valve seat as measured by counting the rate of gas bubbles escaping a bubble tube submerged under water. For a 6 inch valve, this maximum bubble rate is 27 bubbles per minute (or about 1 bubble every two seconds):

It is from this leakage test procedure that the term bubble-tight shut-off originates. Class VI shut-off is often achievable only through the use of “soft” seat materials such as Teflon rather than hard metal-to-metal contact between the valve plug and seat. Of course, this method of achieving bubble-tight shut-off comes at the price of limited operating temperature range and the inability to withstand nuclear radiation exposure.

Class VI Seat Leakage Test



Minimum required Seat Load for Metal Seated Valves (Emerson)



● **Experience on Anti-surge Valve** for Saudi Aramco Shaybah Gas Plant Project (EPC: Samsung E&C from 2013 to 2015)

The following is a description of the technology based on my experience working with the Aramco Shaybah Gas Plant.

If there is a conflict between Saudi Aramco specification and G-E specification, which is the manufacturer of the gas compressor, the compressor manufacturer's specifications should be applied first. The reason for this is that GE is a custom specification that allows for optimal compressor operation based on dynamic simulation, while the Saudi Aramco specification is a universal specification that applies when there is no separate requirement of the compressor manufacturer.

The beginning of the problem was a test that satisfies the specifications of the Aramco spec. and satisfies the 11 parameters required by the G-E spec. (Parameter # 1 Valve Full Opening Speed, # 2 Opening Speed: to 80%, # 3 Closing Speed, # 4 Opening Dead Time, # 5 Overshoot, # 6 Stiction Test, # 7 Response to A 0.5% Signal Step at 10% / 50% / 90% # 9 & # 10 Frequency Response tests: Phase / Gain, # 11 Solenoid Valve operation).

The Aramco specifications of the 3 items were so strict that they would be passed to the test by easing them to GE requirements. I would like to introduce Seat Leakage Class.

Seat Leakage Class (20" X 600#, 30" X 600#)

The specification of the Aramco usually requires Class V for metal to metal seats, but it must be treated with stellite for hard facing in plugs and seats in contact with fluid due to high delta P of valve. Plugs and seat rings strike these stellite areas with Class V strong Actuator Thrust Force, which damages the edge of the contact surface and so Leakage Class V is not easy to achieve in reality. Therefore, if customer wants a tight shut-off, a soft seat shall be applied to achieve Leakage Class V of the valve according to ANSI FCI 70-2.

The additional flow (0.009% of valve Cv), made by leakage rate of difference from Class IV (allowable up to 0.01% of valve Cv) and Class V (allowable up to water 0.0005ml/min. psi. port diameter inch), will be recycled to compressor suction and the comparable load will be added to compressor driver for compression due to the additional flow of leakage different rate if G-E's required Class IV is applied in lieu of Class V of Aramco's spec. Extremely additional minimal fuel gas consumption shall be supplied in case of Gas Turbine driven and extremely minimal electricity for electric motor driven.

However, any other problem or trouble for compressor operation cannot be foreseen although GE's relaxed leakage Class IV is applied.

But Aramco insisted on the purchase specification that eventually Severn Glocon UK had to wait for 3 to 4 months for trial and error to produce a seat ring (diameter: 16 ", 24").

1. For hard-facing of the seat ring, a plasma-welded stellite shall be applied.

In this case, due to the high heat generated, the seat ring must be deformed and so shall be flattened first. To achieve Class V, precision machining must be done on CNC.

Then it must be made as smooth as the glass surface by Lapping process.

2. Despite the fact that Class V was achieved in the first internal test, the Actuator's thrust force was so high that it failed to meet the Class V requirements when tested again under the inspector's witness.

3. Therefore, the large 30" valve eventually was relaxed to Class IV because no safety problem or economic loss in commercial operation is foreseen.

● **Control Valve vs. MOV (or Hydraulic Actuated)** **Shutoff Loading Requirements - ISA Guidelines**

➤ FCI-70

- **CLASS IV : 300 pounds force/linear inch**
- **CLASS V : 500 pounds force/linear inch**
- **CLASS VI : 1000 pounds force/linear inch(per MSS-SP-61)**

Flow leakage through the seat at the valve can lead to safety accidents as well as economic losses.

Regarding safety, leakage of explosive gas or toxic gas can lead to serious accidents.

Therefore, designation of Seat Leakage Class is selected taking into account these points.

Soft Seat

The achievement of the Class VI is possible without any problem. However, in continuous operation, the fluid temperature should not exceed 230 deg. C.

The valve opening / closing is extremely intermittent and the open time is 30 minutes or less, then it is approximately 300 deg. C is possible, although the fluid temperature exceeds 230 deg. C. This should be decided in consultation with the end-user.

Metal Seat

If the leaking class is increased without consideration of the plant operation, the pneumatic actuator may become excessively large, which may cause unnecessary additional manufacturing costs, and may also be a problem in the field installation.

1) **Pneumatic Actuating Control Valve** is driven by air pressure.

Actuator size is considerably increased in order to achieve Leakage Class VI. Fine damage or warping on the seat surface or plug surface due to excessive force of the Actuator because metal plug and metal seat presses each other, when the valve is opened and closed, and wear takes place when the fluid passes through the seat during the commercial operation, hence Class VI may not be actually implemented in the end. If it does not affect the safety as mentioned above, it is not needed to be specified as a Class VI. As the valve size increases, it is almost impossible to achieve Class VI by Metal Seat. Class VI will not be achieved because the large seat ring is deformed due to heat on the hard facing when the size gets larger.

If the actuator size becomes too large, the specification has to be changed to a Hydraulic Actuator (or Electro-Hydraulic Actuator)

The hydraulic actuator demands high cost and also the stroke speed is relatively very slow.

Application of the hydraulic actuator is mainly applied to the valve requiring high thrust force or torque force such as very high pressure valve (API10000 Wellhead Choke Valve and API10000 Ball Valve) or super large size Butterfly valve.

If the role of the valve is on-off, it is appropriate to designate it as MOV, but it should meet the electric safety specification, and so it should be appropriate for the explosion-proof grade.

2) For **On-Off Electric Motor Operated Valve (MOV)**, the valve constantly keeps the state of open or close, however the valve opens or closes when it is only in an emergency or plant shut-down, and also it is not a problem to achieve Leakage Class VI since the actuator generates sufficient thrust force or torque force.

In this case, it is not significantly limited by the valve size or pressure rating.