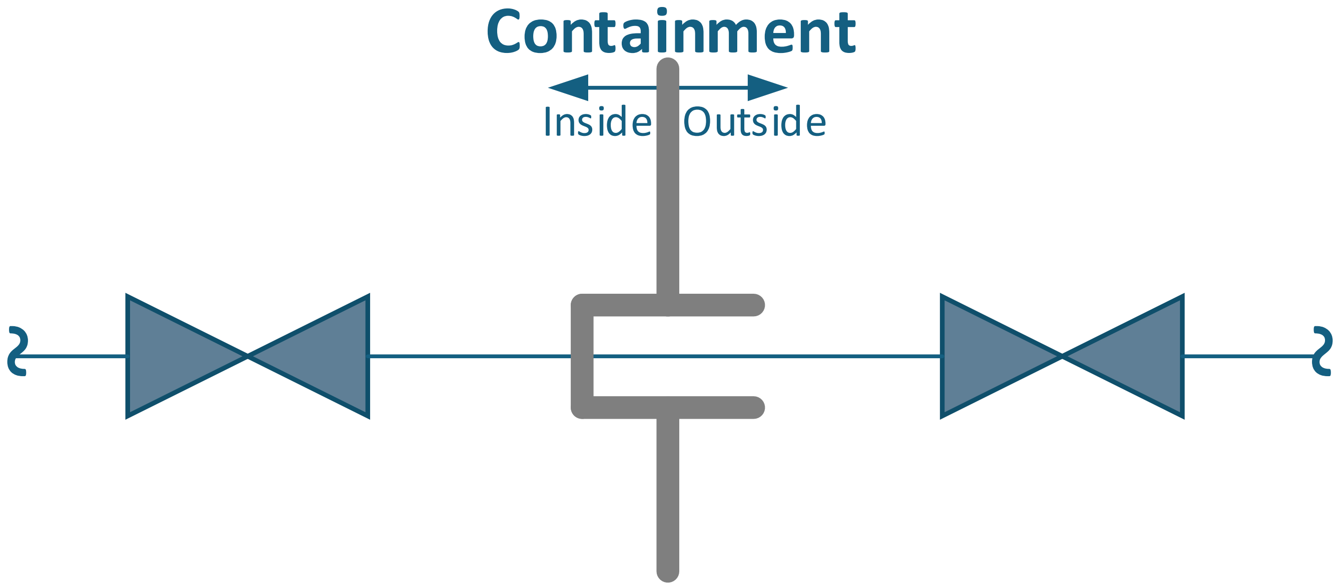
Appendix J Leak Rate: P_a vs P_{test}

2025 ASME/NRC OM Code Symposium



Presentation Agenda

Objective

Background

Approach and Methods

Results and Conclusions

Objective

Discuss Methods to Evaluate Leakage for Valves where:

- Pressure tends to increase the seat load, and
- Test pressure (P_{test}) is greater than the peak containment accident pressure (P_a).

Show, with reasonable assurance, that leakage obtained at P_{test} (higher differential pressure) is not expected to increase at P_a (lower differential pressure).

Background

Scope:

- Valves where a higher Local Leak Rate Test (LLRT) Differential Pressure (DP) results in increased sealing, such as a check valve or globe valve with flow over the seat.

Regulatory and Industry LLRT Guidance:

- Code of Federal Regulations 10CFR50 Appendix J, Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors.
- ANSI/ANS-56.8-1994, American National Standard for Containment System Leakage Testing Requirements.
- ASME OM Code, ISTC-3620 & -3630.

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Background

ASME OM Code, ISTC-3630:

- ISTC-3630(b)(4): "Leakage tests involving pressure differential lower than function pressure differentials are permitted in those types of valves in which service pressure will tend to diminish the overall leakage channel opening, as by pressing the disk into or onto the seat with greater force."
- ISTC-3630(b)(4): "When leakage tests are made in such cases using pressures lower than function maximum pressure differential, the observed leakage shall be adjusted to the function maximum pressure differential value."

What Does This Mean?

- ISTC-3630(b)(4) – Allows for adjustment of measured leakage ***UP*** when P_{test} is lower than P_a.
- Does ***NOT*** discuss scenarios where higher P_{test} pressure increases sealing in comparison to actual P_a pressure being lower (reduces sealing for certain valves).

Background

What Comes Next?

- Identification of valves where pressure assists in closing (sealing/seat load), and
- Evaluation of the reduction in sealing load for valves where P_{test} is ***HIGHER*** than P_a (accident pressure).

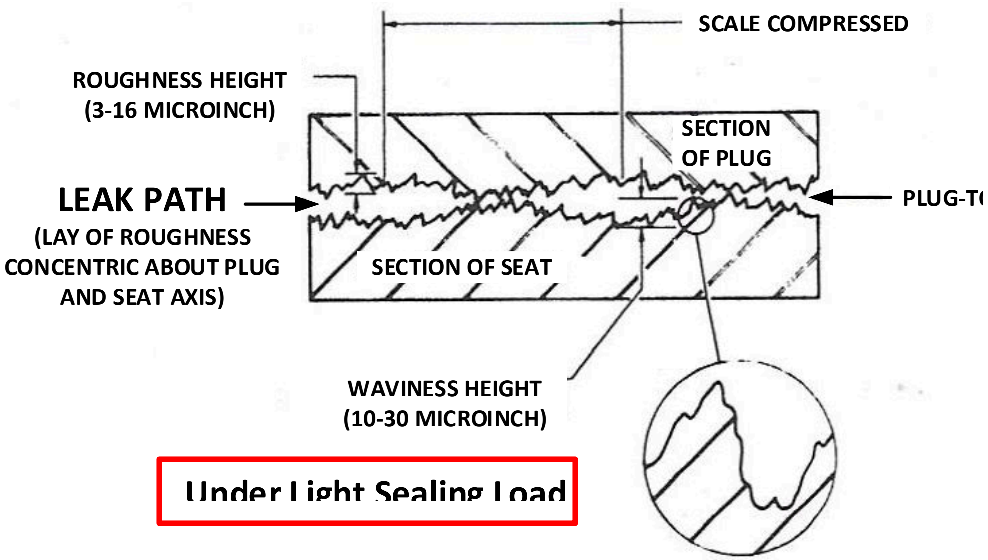
Leakage Dependencies:

- Seating surface finish (waviness and roughness)
- Seat materials (hard vs. soft)
- Seat contact width, and
- Seating load

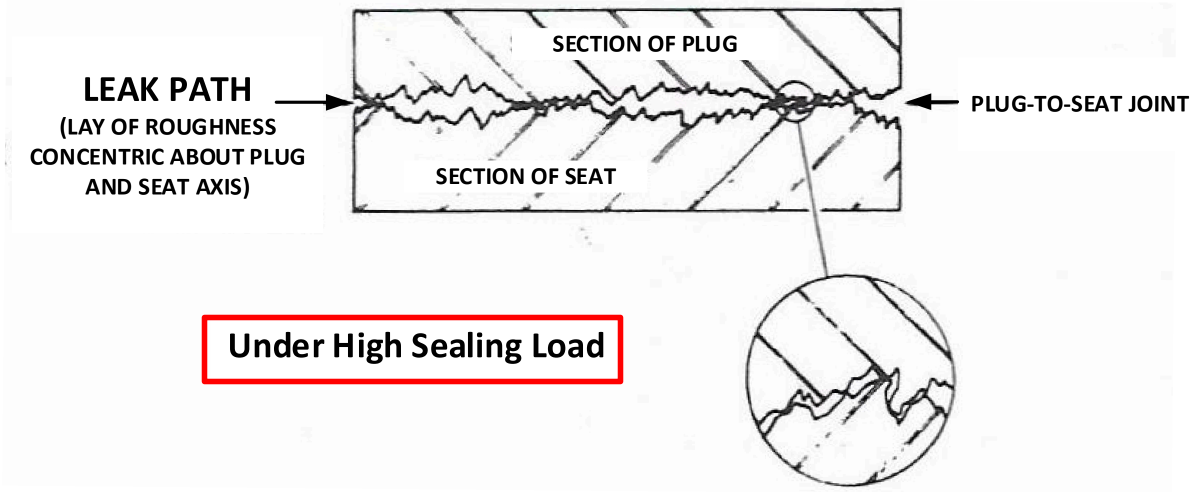
Higher seat loads would tend to decrease the size of microscopic flow passages at the seating interface and diminish the size of the leak passage.

Background

Leak Path Illustration (Ref. ISA Handbook of Control Valves):



Under Light Sealing Load



Under High Sealing Load

Approach and Methods

General Approach:

- **Gate and Globe Valves**: evaluate the reduction in seat load from P_{test} to P_a to determine if the size of the leak path is likely to enlarge to such the point where measured leakage will increase.
- **Tapered Plug Valves**: evaluate the total sealing force (sum of upstream and downstream seat load) within the range of LLRT test pressures to see if the upstream seat load is likely to completely relax.
- **Swing and Piston (lift) Check valves**: Determine the reduction in seating stress for soft-seated designs and the increase in leak path area for metal seated designs.

Analysis, industry data, and supporting test data (if available) are used.

Approach and Methods

General Approach:

- LLRT valves are proven to meet acceptable leakage criteria under the tested conditions which provides assurance that the seating surfaces are in good condition and that minimum seat loads (lb/in) required to achieve sealing have been obtained.
- ASME OM Code ISTC-3630 allows use of the following formula to estimate the leakage (L_{max}) when the test DP (DP_{test}) is lower than P_a (DP_{max}).

$$\frac{L_{max}}{L_{test}} = \sqrt{\frac{DP_{max}}{DP_{test}}}$$

  - Leakage is proportional to the square root of the test differential pressure.
  - Conservatively assumes the microscopic leak flow passages at the seating interface remain constant in size. Higher pressure would tend to decrease the size of the microscopic flow passages.

Approach and Methods

General Approach:

- In this analysis:
  - Seat load decreases with decreasing test differential pressure.
  - Amount of seat load decrease is limited to the portion of seat load produced by differential pressure and not from other contributions such as actuator or spring force and wedging.
- For a given leak flow path, the leakage, L, is proportional to the square root of the differential pressure according to ISTC-3630. A leakage coefficient proportionality constant, C_L, is given to relate the square root of the pressure differential to the leakage flow rate.

$$L = C_L \cdot \sqrt{DP}$$

Approach and Methods

General Approach:

- Over the small change in test air pressure between P_{test} and P_a, any physical properties of the air test fluid associated with C_L would be relatively constant (air density, etc.) such that only the change in leak flow passage size is important.
- Therefore, leakage at Condition 1 and Condition 2 can be determined as follows:

$$L_1 = C_{L1} \cdot \sqrt{DP1}$$
$$L_2 = C_{L2} \cdot \sqrt{DP2}$$

Approach and Methods

General Approach:

- To maintain the same leakage (L1 = L2) at test DP condition 1 (DP1) and test DP condition 2 (DP2), the following relationship between the leakage coefficient, C_L, and DP is obtained:

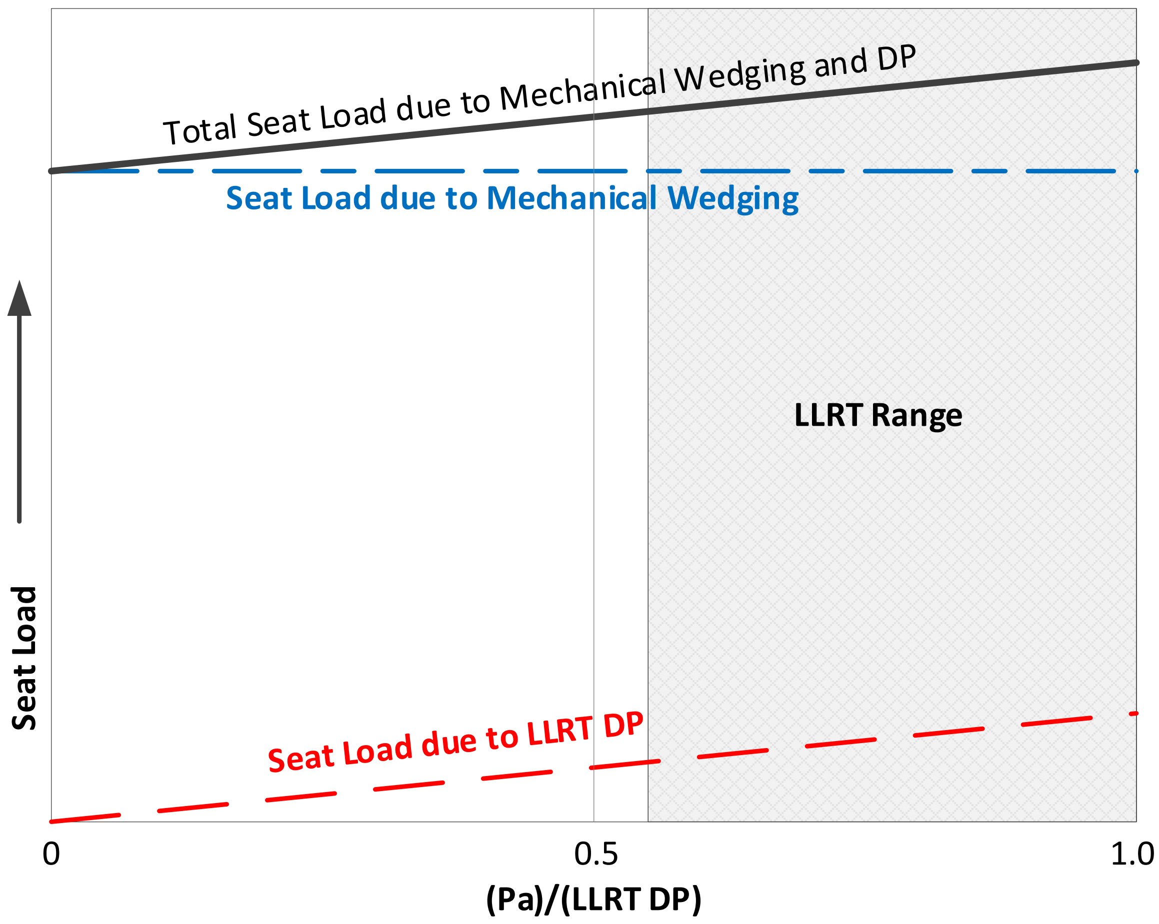
$$\frac{C_{L2}}{C_{L1}} = \sqrt{\frac{DP1}{DP2}}$$

Example: LLRT test DP changed from 16.5 psi to 9.0 psi then the leakage coefficient (C_{L1}) can increase by 35% before the measured leakage at the lower DP2 would increase from the measured leakage at the higher DP1.

Approach and Methods

Motor-Operated Wedge Gate Valves:

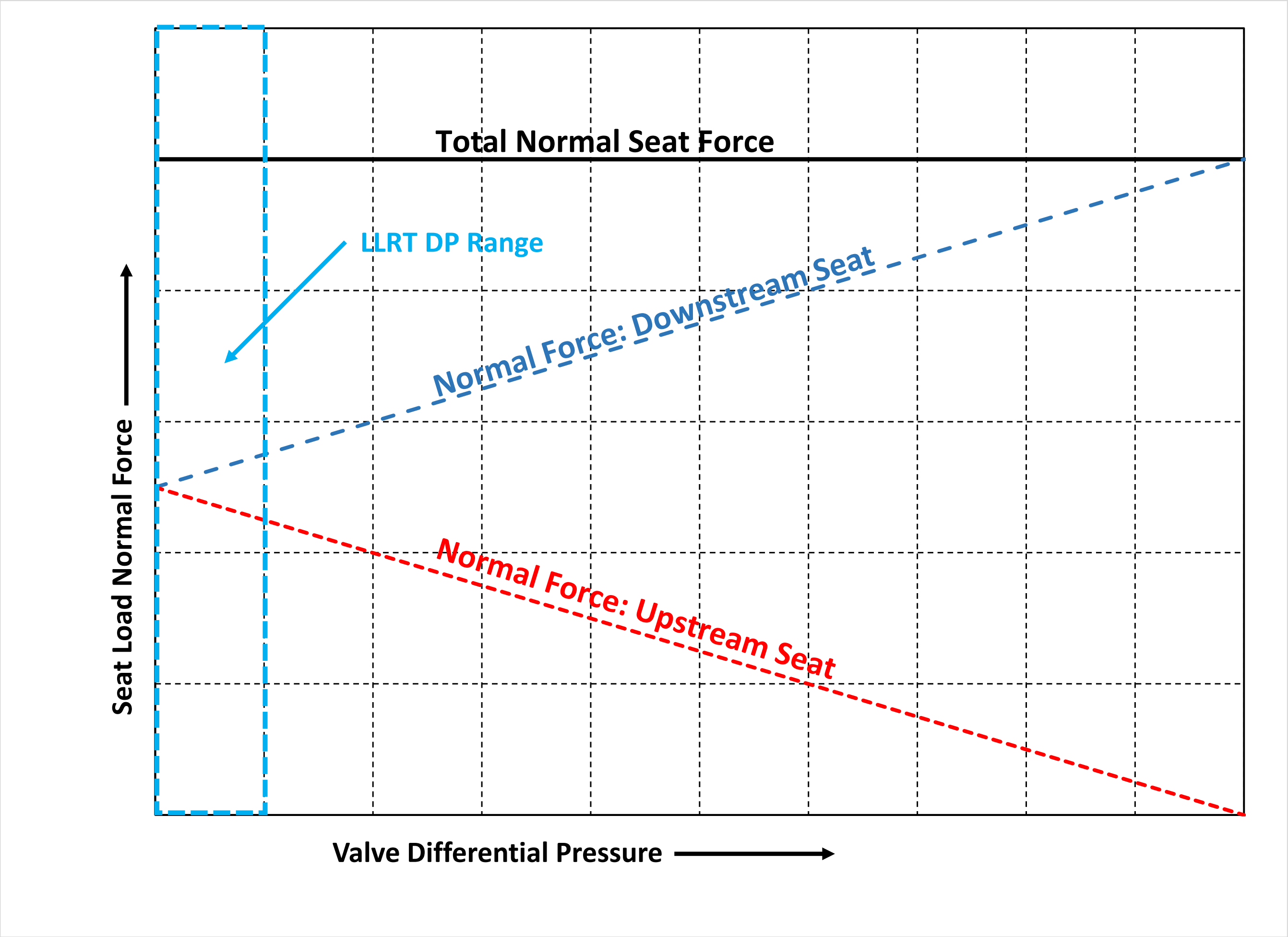
- Sealing load is applied by mechanical wedging and differential pressure (DP).
- For motor-operated valves (MOVs), the seat load due to mechanical wedging is much greater than that due to the LLRT DP.
- Evaluate the reduction in total sealing load due to changing from DP_{Test} to P_a and determine if this reduction is expected to increase the measured leakage.



Approach and Methods

Plug Valves:

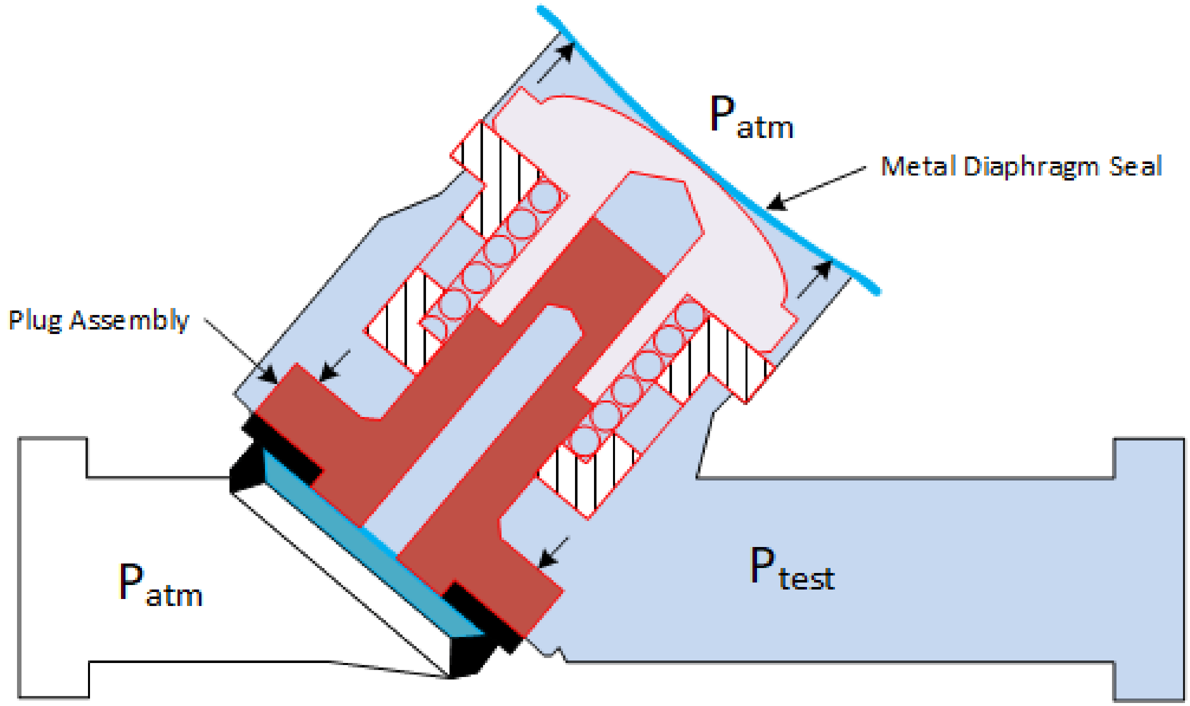
- Plug is pre-loaded into the seat.
- Differential pressure applied to the valve increases the seat load on the downstream seat and reduces the upstream seat load.
- For the low LLRT DP the net sealing load between the two seats remains the same such that overall leakage is not expected to increase from the higher to lower LLRT DP conditions.



Approach and Methods

Metal Diaphragm Valves:

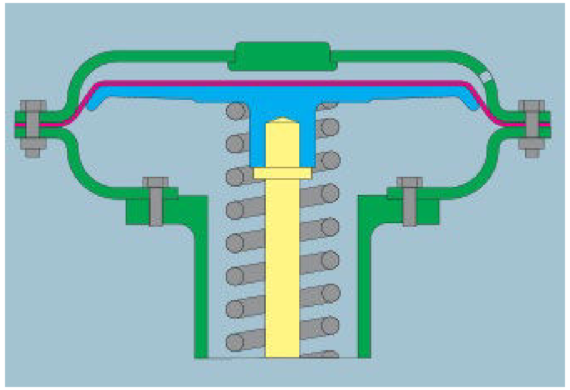
- Dish-shaped metal diaphragms which seal against the internal line pressure.
- Stem packing, if present, acts as a secondary seal. Examination shows pressure applied over-the-seat with the valve in the closed position will act equal and opposite on the plug and diaphragm seal to balance change in seat load as a function of P_{test}.
- Therefore, the slightly higher test pressure will not significantly increase the seat load for these valves.

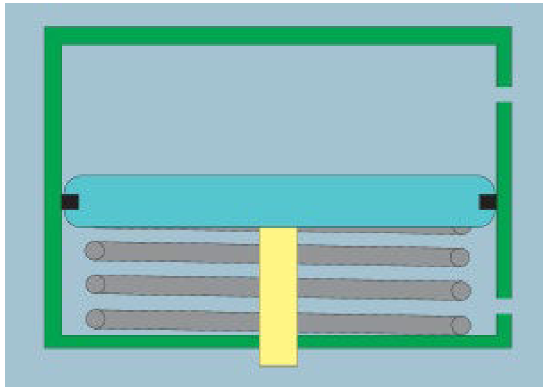


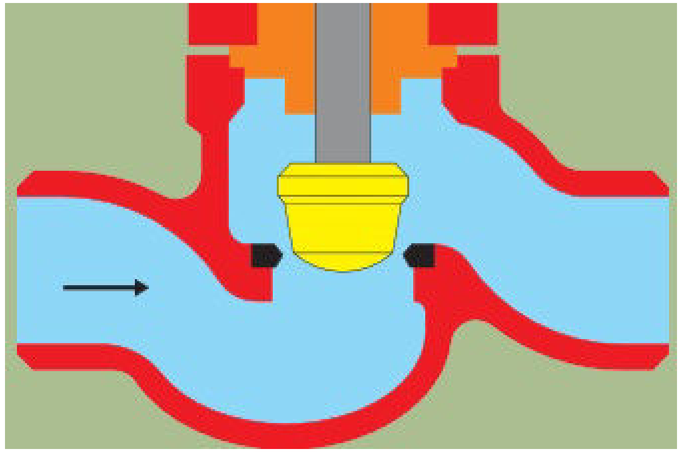
Approach and Methods

Air-Operated Globe Valves:

- Uses a similar approach as MOVs in that the seat load due to mechanical wedging is much greater than that due to the LLRT differential pressure.
- Evaluate the reduction in total sealing load due to decreasing the LLRT test DP to determine if an increase in the measured leakage is expected.
- The minimum recommended seat contact force per linear inch of mean seat joint circumference for metal seats from ISA Control Valve Handbook is used to help make the determination as to whether the reduction in test pressure results in an expected increase in seat leakage.



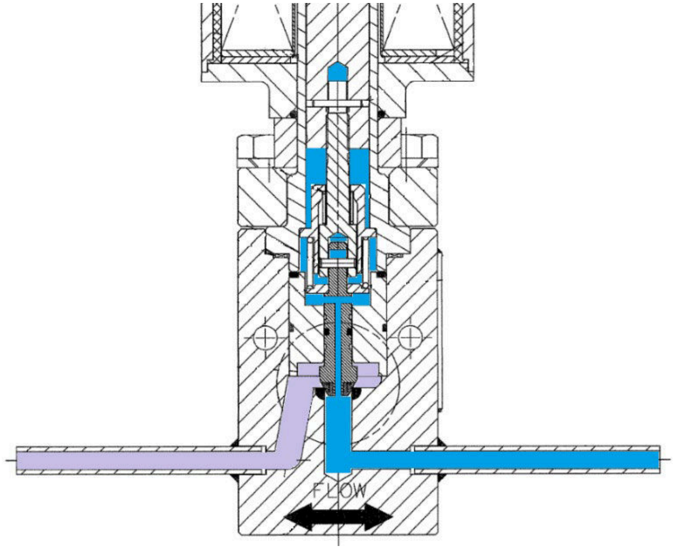


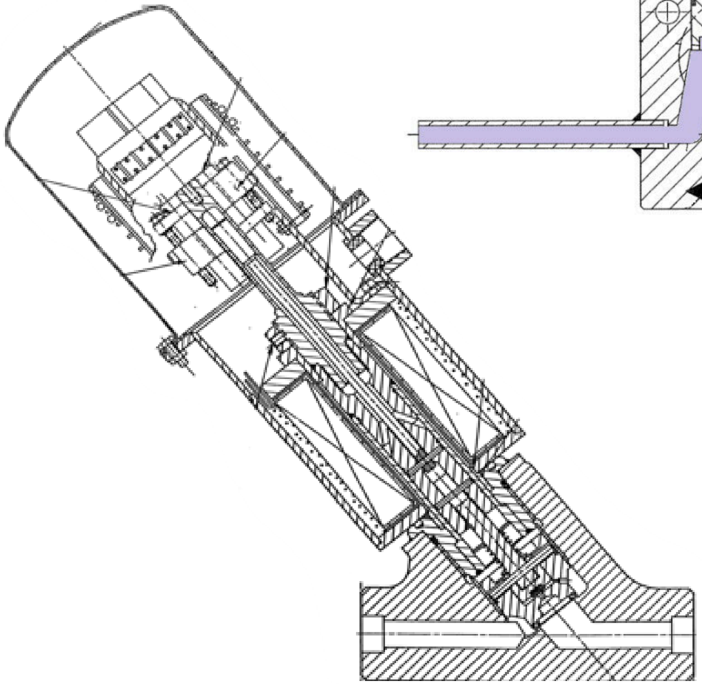


Approach and Methods

Solenoid-Operated Globe Valves:

- Solenoid-operated valves have a pressure equalizing port in the disc that connects the under-seat side of the disc to the valve bonnet.
- The seat diameter is similar to the disc stem diameter resulting in a near zero unbalanced area. The seat load is independent of the DP load in either direction (flow under-the-seat or flow over-the-seat) for some designs.
- Therefore, the seat load will remain at or near the same under the reduced LLRT pressure.





Results

Results for Subject Valves:

- The analysis results showed that increased measured leakage is not expected if the test pressure were reduced from DP_{test} to P_a psig.
  - MOV Gates Valves: < 5% total reduction in seat load.
  - Check (Swing and Lift) Valves: Varied by seat type (metal or-soft seated). Seat contact stress remained higher than differential pressures, calculated increase in leakage flow channel was less than 0.003% and not expected to have increased seat leakage.
  - AOV Globe Valves: Seat contact force (lb./in) remained higher than required for leakage class based on ISA Handbook Guidance, total reduction in seat load was < 3%.
- Hard-seated check valves were found to have low seating stresses and a significant decrease in seat load from DP_{test} to P_a conditions.
  - Although the results based on calculations and engineering judgment show that leakage is not expected to increase for these valves, a sample check valve was tested to support the calculation-based conclusions.
  - Test results were favorable and showed no increase in leakage.

Conclusions

Conclusions:

- The population of valves reviewed for this analysis showed that increased leakage is not expected with the lower accident pressure (P_a).
- Soft-seated and valves which utilize an o-ring seat/seal (check and solenoid globe) maintain a seat contact stress well above P_a and P_{test} pressures with the reduction is sealing load.
- Metal-Seated swinging disc check valves (depending on piping installation orientation) may be one of the more impacted valve types susceptible to leakage with a reduction in $P_{a,}$ although analysis and review of assumed surface asperities along the seat contact band predicted almost negligible change in leakage flow path.
- Heavily load valves (gate and globe) with Air and Motor-Operators experienced very minor seat loading changes between P_a and P_{test} pressures.