



*Edward Valves*

## ***Edward Valves***

***Pressure Locking and Over-Pressurization  
of Double-Seated Valves***

*V-Rep 91-1*

# Pressure Locking and Over-Pressurization of Double-Seated Valves

E. A. Bake  
Research Manager  
Edward Valves  
First Published 1991

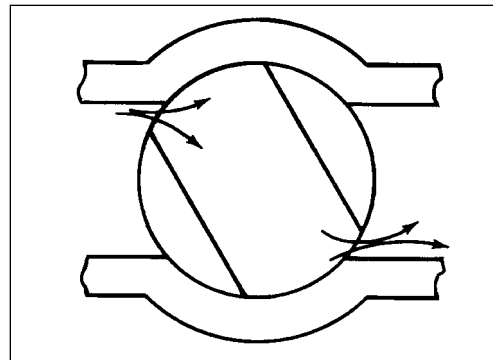
## ABSTRACT

Double-seated valves provide benefits over valves with single seats and create few disadvantages. However, field experience reveals that trapped pressure in the center cavity of these valves can be a source of occasional problems. Because actuators are normally sized based primarily on downstream loading, trapped pressure loading on both seats may greatly exceed design limitations and cause the valve to become pressure locked. Trapped pressure may also damage valves if over-pressurization occurs, through heating or freezing of the line fluid. Improvements in packing, bonnet seals, and seats have reduced the means of pressure relief in the center cavity. Fortunately, operating procedures and special design features may be employed to relieve trapped pressure and prevent both pressure locking and over-pressurization.

## Introduction

Plug valves, ball valves, and gate valves usually have two seats in series. There are many sub-types of each of these valves, and there is considerable variation in the sealing effectiveness of upstream and downstream seats in different designs. Two seats in series are often thought of as an advantage, and they sometimes provide genuine benefits. When a valve is opened, closed, or throttled with a high differential pressure, upstream and downstream ports provide two orifices in series to reduce the pressure drop across each port (*Figure 1*). When closed, two seats in series may provide a sealing advantage in the event one of the seats is damaged.

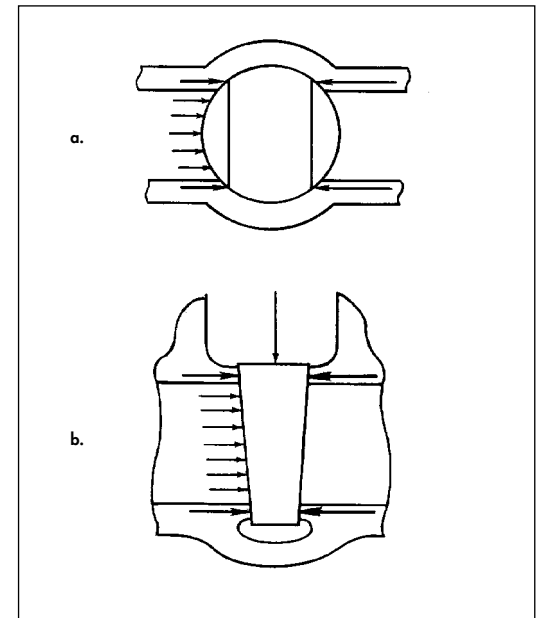
While problems with double-seated valves are not usually common or serious, there are some rather simple characteristics of these valves that should be considered by system designers as well as valve users. Failure to attend to these characteristics may lead to valve malfunction or, in some cases, hazardous conditions.



**Figure 1:** Horizontal cross section of throttled ball valve showing two orifices in series.

## Seat Sealing Effectiveness

Before discussing potential problems with double-seated valves, it may be helpful to consider the forces that influence the effectiveness of the individual seats. *Figure 2* illustrates simplified force balances on closed floating ball and gate valves. Note that the differential pressure acting across the closure member (ball or gate) provides a sealing force on the downstream seat at the low pressure side of the valve. Thus, these valves are sometimes referred to as downstream sealing.



**Figure 2:** Simplified force balance diagram on closed valves:  
a. Floating ball valve  
b. Wedge gate valve

# Pressure Locking and Over-Pressurization of Double-Seated Valves

Since the seating forces due to differential pressure may be inadequate to produce effective tight sealing when differential pressure is low, it is common practice to assemble floating ball valves with interference (e.g. controlled "squeeze" on soft seats) which provides some upstream seating force. In wedge gate valves, as illustrated, stem load and wedging produce a loading on upstream seats. Gate valves with parallel seats sometimes employ springs or internal wedges to provide supplemental loading for low pressure sealing. Thus, while all of these valves are normally considered as downstream seating, there is usually moderate to significant loading which provides some sealing effectiveness of upstream seats as well.

The sealing of two seats in series can produce a pressure trapping condition which, in turn, can produce an increase in the force required to open a valve — pressure locking. Heating or freezing of trapped fluid between the two seats may also produce conditions that are hazardous to pressure boundary parts of a valve.

## Pressure Trapping

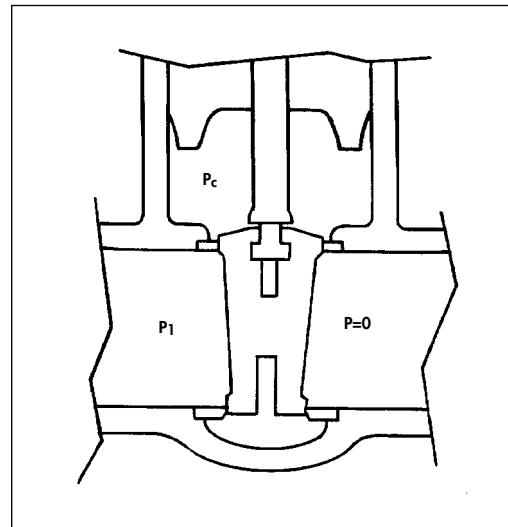
Referring to *Figure 3*, consider the scenario which accompanies and follows closure of a double-seated valve. A "flexible wedge" gate valve is shown in the illustration, but other double-seated valves react similarly to one degree or another.

If the valve is closed with a high line pressure and the downstream pressure decreases slowly, the pressure in the valve center cavity,  $P_c$ , immediately after closure would be substantially the upstream line pressure,

$P_1$ . If the valve is closed under a flowing condition, the center cavity pressure after closure might be less than the upstream pressure due to "Bernoulli effects" or pressure drop across the upstream port during closure.

The behavior of the center cavity pressure after closure depends on many things, such as (1) temperature, (2) type of line fluid, and (3) individual valve design characteristics. For example:

- If the line fluid is either a liquid or gas at ambient temperature (and there is no subsequent temperature change), the pressure  $P_c$  would remain constant unless there is seat leakage.



**Figure 3:** Horizontal cross section of closed flexible wedge gate valve, showing upstream pressure  $P_1$  and center cavity pressure  $P_c$ .

- If the downstream seat leaks to the depressurized side of the valve, the center cavity pressure would decrease, but, since the upstream seat often seals less effectively than the downstream seat, it could "feed" the center cavity to maintain the pressure. Precise prediction of this pressure after closure is impossible, but it would tend to remain near the upstream pressure.
- If the line fluid is at an elevated temperature, the valve would normally tend to cool and approach ambient temperature after closure and cessation of flow. The fluid in the center cavity would tend to contract, reducing  $P_c$ . The behavior will be affected significantly by the type of line fluid:
  - If the fluid is a liquid (e.g. hot water), the pressure would decrease rapidly, possibly approaching a vacuum and producing a vapor cavity. If the upstream seat is not effective at high differential pressure, leakage into the center cavity would tend to offset this pressure decrease in time. Precise prediction of  $P_c$  is not possible, but the center cavity would normally be liquid filled after cool-down, with a pressure near the upstream pressure  $P_1$ .
  - If the fluid is a gas (e.g. hot air), the pressure would tend to decrease slowly in proportion to the absolute temperature. As in the case of closure with a liquid, upstream seat leakage would tend to offset this decrease, and the center cavity would be filled with gas after cool-down at a pressure near  $P_1$ .

# Pressure Locking and Over-Pressurization of Double-Seated Valves

- If the fluid is a condensable vapor (e.g. steam), the process in the center cavity after closure is complicated by condensation when the pressure decreases to the saturation pressure of the trapped line fluid. As in the case of closure with a liquid or gas, upstream seat leakage would tend to offset the decrease in  $P_c$  due to cooling, but the incoming leakage would also condense.

In the vapor case, prediction of center cavity pressure after cool-down is again impossible, but it would normally be near  $P_1$ . Significantly, the center cavity would be partially or completely full of condensate (e.g. water), even with a vapor in the upstream line.

To explore the pressure trapping issue further, consider what happens if the system (boiler, chemical process) containing a closed double-seated valve is shut down, letting  $P_1$  go to zero. The fluid left in the center cavity after closure (above) would be trapped indefinitely until relieved by leakage. If a valve in a hot line cools off further after shutdown, pressure may be relieved by contraction of liquid or condensation of vapor, but significant pressure might remain trapped in the valve cavity in some cases; in the case of a gas, the stored energy would remain significant. This could occur with any type of double-seated valve; as shown in *Figure 4*, both seats in some types of valves can be loaded by the center cavity pressure  $P_c$ , thus enhancing seat tightness and increasing probability of long-term pressure trapping.

Since the pressure trapped within double-seated valves may not be foreseen, two conditions might present hazards during shutdown if not properly attended to:

1. Leakage from the trapped center cavity might complicate maintenance on nearby equipment. This could be of concern if the trapped fluid is flammable or hazardous in any other way.
2. Opening of the valve during shutdown could cause an unexpected energy release due to relief of trapped pressure to the upstream and downstream lines. This would be of particular concern with trapped gas.

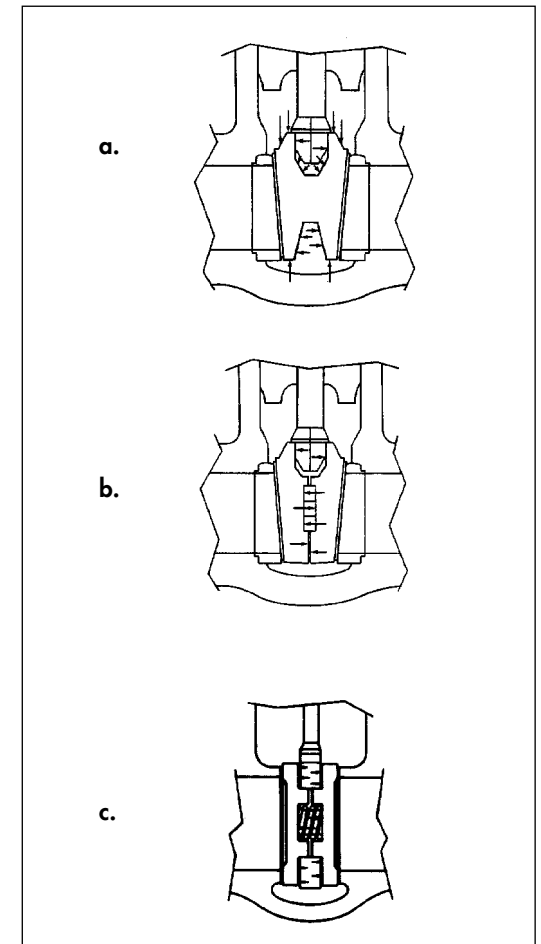
## Pressure Locking

Pressure trapping in the center cavity of some valve types can lead to another problem if not foreseen and attended to. In the case of the gate valves illustrated in *Figure 4*, note that the seating loads applied to *both* seats would tend to increase the stem load required for opening.

Gate valves and actuators are normally designed for opening with a differential pressure applied as shown in *Figure 2*, with loading primarily on the downstream seat. The load required for opening is obviously a function of the seat area, the differential pressure, and the friction coefficients at sliding interfaces on seats and guides. Actuators may not be sized to open a valve against full system pressure  $P_1$  if operation is required only for component isolation during shutdown.

Since the seating loads shown in *Figure 4* are applied to both seats, the opening

force with a trapped pressure  $P_c$  may be as much as twice that required with the same pressure as an upstream pressure. If



**Figure 4:** Cross sections of closed valves to show seat sealing loads with both sides of valve de-pressurized:

- a. Flexible wedge gate valve
- b. Split wedge gate valve
- c. Parallel slide valve

# Pressure Locking and Over-Pressurization of Double-Seated Valves

alone due to Charles' law. Since the volume of the liquid expands with heating, the volume available for gas contracts, tending to make the combination more completely liquid on a volume basis. For example, pressurized water increases in volume by approximately 16% if heated from 70 to 400°F, so an "air bubble" occupying 10% of the volume of the center cavity of a cool, de-pressurized valve would not be of much help if subjected to significant heating.

- **Valve stem packing leakage will prevent excessive pressure increase.** Hard asbestos-base packings like those used with older high pressure valves often leaked moderately at pressures around 15 times the valve pressure rating, and this would limit the pressure increase due to liquid thermal expansion. Newer graphitic stem packings typically seal much better; this is normally considered an improvement, but it increases the risk of over-pressurization.

*Note: Some experienced engineers recommend loosening packing gland bolts when closed gate valves are heated. However, Edward experience shows that previously compressed graphitic packings often continue to seal well on a stationary stem, even with a loose gland. Thus, loose gland bolts will not ensure safety when a valve is heated.*

- **Valve cover gasket leakage will prevent excessive pressure increase.** Conventional low pressure valves with bolted bonnets and compression gaskets may leak if internal pressure overcomes

the bolt preload and causes bolt stretch, However, pressure-seal bonnets commonly used on higher pressure valves typically seal tighter with increasing body pressure.

- **Seat leakage, upstream or downstream, will prevent excessive pressure increase.** Some old design, solid wedge gate valves had difficulty sealing simultaneously on both the upstream and downstream body seats because of dimensional inaccuracies or inability to accommodate valve body flexure. Some flexible wedge gate valves also lack sufficient flexibility to seal well at both sides. However, some modern flexible wedge valves and most two-piece wedge and parallel seat gate valves have sufficient freedom to seat upstream and downstream, particularly with high center cavity pressure. Thus, seat leakage cannot be counted upon to prevent over-pressurization.

## Some Cases Of Field Problems

Several instances have shown that hazardous pressures may be developed in valves with trapped liquids where temperature increases of several hundred degrees Fahrenheit may occur. In one power plant experience, all internal dimensions in a high pressure gate valve were found to have exhibited a permanent strain (yield) of over one percent after it had undergone a boiler startup, while closed, with water trapped between the seats (from a prior hydrostatic piping test). Since the valve itself had passed a hydrostatic test without damage at, 15 times its 100°F pressure

rating after manufacture, it has been estimated that the pressure was 2 to 3 times the valve rating when it was heated in the start-up incident,

The valve described above had failed to open due to pressure locking (see above), and the damage due to over-pressurization was not recognized until the valve was inspected to investigate the failure to open. There was no catastrophe, but the pressure had exceeded the valve rating by so much that it is obvious that the safety factor was significantly reduced. This valve was salvaged and returned to service, but extensive rework was necessary to repair the damage that had occurred due to over-pressurization.

In another power plant experience, minor external damage was observed in a gate valve during plant construction. The valve was outside, and it was closed while water-filled after hydrostatic testing. An unexpected cold weather condition produced an ambient temperature below the freezing point of water. Internal inspection of the valve after this incident revealed severe yield of pressure boundary parts, not unlike the conditions observed in the valve that had been overpressurized (above). This valve was also salvaged and returned to service, but extensive rework was required.

## Requirements Of Codes And Standards

A number of codes and standards address possibilities of over-pressurization from a safety standpoint. For example pipe could be damaged by heating of trapped fluid

# Pressure Locking and Over-Pressurization of Double-Seated Valves

between two closed valves or in an isolated dead-end run. The Power Piping code, ASME B31.1, requires piping design to withstand the increased pressure or a provision for pressure relief where expansion of a fluid may increase the pressure (paragraph 101.4.2). Since valves are recognized as piping components, this code requirement may be interpreted to require the piping designer to consider possible thermal expansion in double-seated valves.

With specific reference to valves, ASME/ANSI B16.34 (*Valves – Flanged, Threaded, and Welding End*) references double-seated valves and states that it is the responsibility of the purchaser to provide means to assure that the allowable pressure is not exceeded due to thermal expansion (paragraph 2.3.3). These means may involve design, installation, or operating procedures. For example, partial opening of a double-seated valve during start-up is cited as a procedural method to address the problem.

Since codes primarily cover pressure boundary safety, not functional reliability, the possibility of failure of a valve to open due to pressure locking is not addressed in any known binding standard. Since the capacity of an actuator to open a valve might be exceeded by pressure locking without exceeding a safe pressure boundary rating, system designers and valve users should consider this point carefully.

## Prevention Of Pressure Lock And Hazardous Center Cavity Pressure

There is, at this time, no known single "ideal" means of preventing pressure lock

or hazardous center cavity pressures in double-seated valves. Nevertheless, as noted at the outset, there are few serious problems. Most piping designers and valve users address the problem in accordance with the standards mentioned above to avoid safety hazards, and INPO SOER 84-7 provides good guidelines on avoidance of pressure lock to nuclear power plant operators.

While the methods for avoiding problems are not new to many people in the valve and piping industries, the fact that problems are still encountered occasionally suggests that these solutions are not known widely enough. The specific functional requirements of a valve should be considered carefully in selecting the best approach. Several of the measures in common use and their advantages and disadvantages will be addressed:

- **Operating procedures**

As suggested in ASME/ANSI B16.34, special plant operating procedures, such as partially opening double-seated valves before starting a heat-up of a piping system, may be quite effective in preventing hazardous over-pressurization.

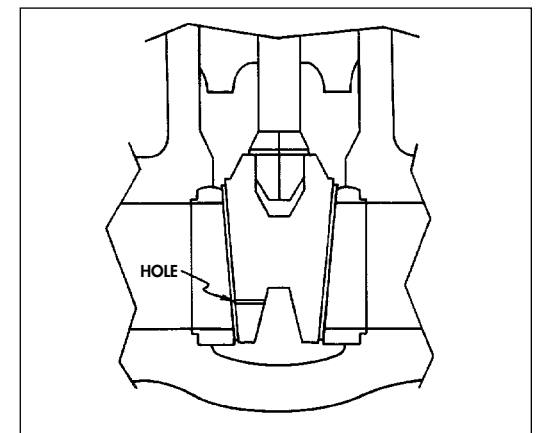
This approach requires (1) identification of valves that may be most hazardous, with trapped liquid, (2) cracking valves away from fully seated positions with handwheels or actuators before start-up, and (3) resealing of valves that must remain closed after heating. This may produce unacceptable leakage in some component isolation valves, and the leakage during start-up may cause seat dam-

age due to erosion. There might still be pressure locking problems during shut-down with both sides of valves depressurized. However, no special valve features are required, and the valve retains bidirectional shutoff capabilities.

- **Hole in upstream side of gate or ball**

A hole can be drilled in the upstream side of a flexible wedge, two-piece wedge, or parallel seat valve gate as shown in *Figure 5*; a similar change can be effected in the ball in a floating ball valve.

This change effectively bypasses the upstream seat, assuring that the center cavity pressure is the same as the upstream pressure. Since these valves are primarily downstream sealing, the only loss in normal unidirectional applications is the extra insurance that would be provided by the upstream seat in the event of downstream seat damage.

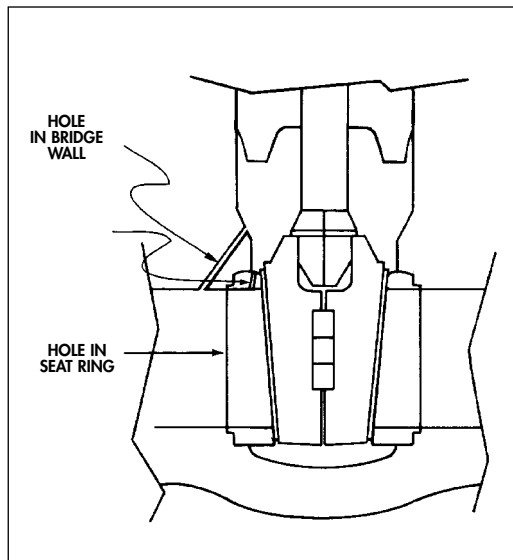


**Figure 5:** Illustration of hole in upstream gate of gate valve.

# Pressure Locking and Over-Pressurization of Double-Seated Valves

While this change may be the simplest one for correction of a field problem or for use of a standard valve out of stock, one disadvantage is that the gate or gate assembly cannot be reversed; reversing a gate assembly is one common method of extending life of parts after extensive valve maintenance, but placing the gate with the hole on the downstream side would cause leakage.

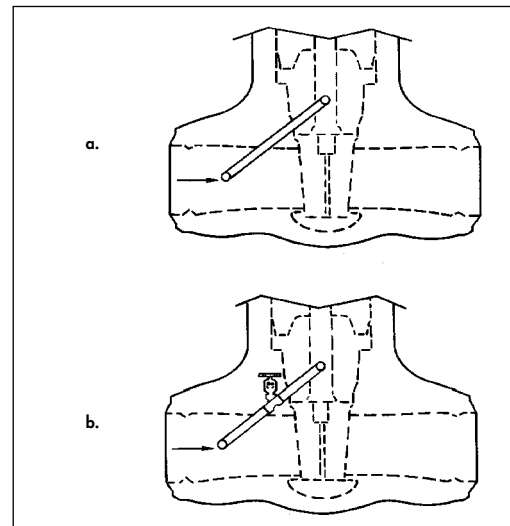
As in the case of following changes with internal and external equalizers, the hole in the upstream part of the gate makes the valve unidirectional to some degree. High leakage would be experienced with many valves if the differential pressure is ever reversed, although the amount of leakage may be limited by the



**Figure 6:** Illustration of hole in upstream seat ring or bridge wall in gate valve (internal equalizer).

orifice size used for the hole. Some wedge gate valves seal reasonably well at their upstream seats with low and moderate pressures, so a valve with a hole might be suitable for some reversed pressure conditions. High reversed pressures would probably cause significant leakage in all gate valves and might over-stress gates not designed for high differential on the upstream side. If this change is to be made to correct a problem with an installed valve, the manufacturer's recommendations should be obtained.

- Hole in seat insert or body bridge wall at upstream side (internal equalizer)



**Figure 7:** Illustration of pipe between gate valve center cavity and upstream nozzle (external equalizer).

- a. Without valve
- b. With valve

A hole in the valve body or seat insert, as shown in *Figure 6*, bypasses the upstream seat in the same manner as a hole in the upstream side of a gate. A similar change could probably be effected in a ball valve.

As compared to the hole in the gate, this change is preferable from, a long term maintenance standpoint, because the gate or gate assembly could be reversed for extended life. The body drilling would be difficult in an installed valve, but it is easily accomplished during manufacturer of a new valve. The only concern is to be sure that the valve is marked and installed in the proper direction.

This feature might be difficult to modify in a valve in line if there were ever a system change that would require sealing in the reversed direction.

- Pipe connecting center cavity to upstream valve nozzle (external equalizer) – without or with valve

The external equalizer pipe, shown in *Figure 7a*, also bypasses the upstream seat. The directional nature of the valve should be obvious to one viewing the valve. It can be incorporated in a new valve, or with more difficulty to an installed valve. This feature would be relatively easy to modify in line if there is a system change requiring reversed seat tightness.

As shown in *Figure 7b*, a valve (typically a small globe valve) can be installed in the external equalizer and be left normally open (locked open if necessary) to



# Pressure Locking and Over-Pressurization of Double-Seated Valves

provide the upstream seat bypassing function. Closure of the small valve would permit reversed seat tightness for special purposes (e.g. hydrostatic testing of downstream piping); obviously procedures would have to be enforced to assure opening of the valve before normal operation.

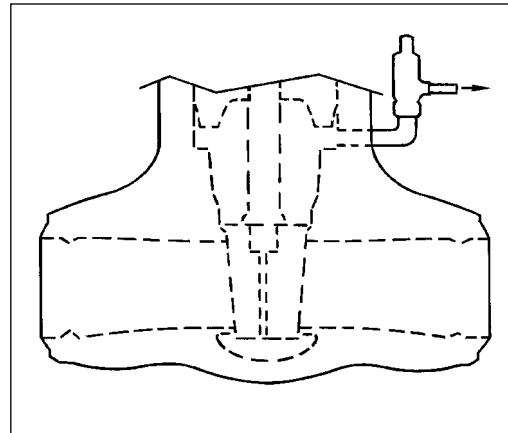
- **Connect pressure relief valve to center cavity and connect with piping to a safe discharge point.**

A relief valve may be used, as shown in *Figure 8*, to prevent hazardous over-pressurization of double-seated valve bodies. Codes and standards applicable to over-pressure protection devices have to be checked and complied with. The set point has to be enough above the highest normal operating pressure to prevent weepage and inadvertent operation. Since this approach requires an active component (the relief valve), it is not recommended unless the preceding passive approaches are not acceptable.

Since the valve center cavity could trap a pressure up to the relief valve set point, pressure locking could still interfere with valve opening with reduced upstream pressures. Thus the relief valve would offer pressure boundary safety, but it would not ensure operational reliability.

## Summary

Double-seated valves have established histories of safe and successful operation in a multitude of applications in general industrial service, as well as in power plants, refineries, and petrochemical facilities. The two seats provide benefits, but some relatively simple technical issues should be considered to prevent problems due to trapped fluid between the seats. Piping system designers, valve users, and valve manufacturers should cooperate to establish the best measures to assure reliability, safety, and sealing effectiveness if a potential problem is identified. Since individual valve applications involve specific functional requirements, a combination of the measures cited above (operating procedures and design features) may be necessary to provide best performance.



**Figure 8:** Illustration of relief valve connected to gate valve center cavity.

## Footnotes

1. Trunnion mounted ball valves, as commonly used in pipeline services, employ trunnions to support the main differential pressure loading, and they are normally upstream sealing. These valves are outside the scope of this article.
2. Institute Of Nuclear Power Operations (INPO), Significant Operating Experience Report (84-7, Pressure Locking and Thermal Binding of Gate Valves, December 14, 1984.





Flowserve Corporation has established industry leadership in the design and manufacture of its products. When properly selected, this Flowserve product is designed to perform its intended function safely during its useful life. However, the purchaser or user of Flowserve products should be aware that Flowserve products might be used in numerous applications under a wide variety of industrial service conditions. Although Flowserve can (and often does) provide general guidelines, it cannot provide specific data and warnings for all possible applications. The purchaser/user must therefore assume the ultimate responsibility for the proper sizing and selection, installation, operation, and maintenance of Flowserve products. The purchaser/user should read and understand the Installation Operation Maintenance (IOM) instructions included with the product, and train its employees and contractors in the safe use of Flowserve products in connection with the specific application.

While the information and specifications contained in this literature are believed to be accurate, they are supplied for informative purposes only and should not be considered certified or as a guarantee of satisfactory results by reliance thereon. Nothing contained herein is to be construed as a warranty or guarantee, express or implied, regarding any matter with respect to this product. Because Flowserve is continually improving and upgrading its product design, the specifications, dimensions and information contained herein are subject to change without notice. Should any question arise concerning these provisions, the purchaser/user should contact Flowserve Corporation at any one of its world-wide operations or offices.

For more information about Flowserve Corporation, contact [www.flowserve.com](http://www.flowserve.com) or call USA 1-800-225-6989.

**FLOWSERVE CORPORATION**  
**FLOW CONTROL DIVISION**  
**Edward Valves**  
1900 South Saunders Street  
Raleigh, NC 27603 USA

**Toll- Free Telephone Service**  
(U. S. and Canada)  
Day: 1-800-225-6989

**After Hours Customer Service**  
1-800-543-3927

**US Sales Offices**  
Phone: 919-832-0525  
Facsimile: 919-831-3369  
Facsimile: 919-831-3376

**Visit Our Website**  
[www.edwardvalves.com](http://www.edwardvalves.com)

