Flowserve - Edward Valves

Design Basis Qualification of Equiwedge Gate Valves for Safety Related MOV Applications

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Problem

Motor operated gate valves installed in nuclear power plants that struggle to meet the performance criteria for a design basis event (DBE) or meet the DBE conditions, but at the expense of frequent valve repair.

Solution

The Flowserve-Edward Equiwedge gate valve represents the best gate valve design for critical, motor-operated isolation valve applications in nuclear power plants.

Introduction

Nuclear Regulatory Commission (NRC) Generic Letter 89-10 has had a significant impact on the U.S. nuclear power industry, and its testing requirements led to the need for repair or replacement of many safety-related motor operated valves (MOVs). NRC sponsored tests of representative gate valves like those used in many U.S. nuclear power plants have shown that some valves are "unpredictable" and subject to functional failure or damage under DBE conditions. Thus, problems were encountered with some conventional gate valves in the course of tests required by 89-10. The nuclear plant MOV concerns raised legitimate questions about the reliability of conventional wedge gate valves. This paper discusses an alternate design.

The Equiwedge gate valve was developed and introduced by Flowserve-Edward Valves, Inc. in 1975, so it is not a "new" design. Nevertheless, the Equiwedge design was subjected to extensive DBE testing to qualify it for service as a main steam isolation valve (MSIV), and Equiwedge MSIVs are employed in nuclear power plants on three continents. Except for use of linear actuators, the MSIV application involves basically the same DBE operational requirements as an MOV.

Background

NRC concerns with safety-related MOVs can be traced back many years, but they were intensified by the Three Mile Island incident where valves were held partially responsible for the problems. All types of valves have been studied, but the emphasis has been on gate valves because they are very widely used in nuclear plants. Of the many basic types of isolation (stop) valves, two types – globe and gate – predominate in high pressure, high temperature applications in power plants. There are many applications where globe valves have advantages, such as for throttling and flow control; however, gate valves have straight-through flow passages which offer an advantage over conventional globe valves in minimizing flow resistance.

Gate valves offer an advantage over globe valves in lower operating force requirements. While a globe valve disk has to buck the full differential pressure force head-on to either open or close, the gate in a gate valve need overcome only the frictional forces induced by pressure pushing it against the guides or seats as it slides across the flow stream.

While the valves installed in nuclear plants required a "pedigree" and sometimes an N-stamp, many were of designs that were far from new. Some problems that were only nuisances in typical fossil-fueled plant applications became serious in safety related motor operated gate valves in nuclear plants.

One major difference in the applications in older fossil-fueled plants was that many gate valves were used for component isolation and did not require operation against high flow or differential pressure. Some were only opened or closed under shutdown conditions when there was little or no differential pressure. Many had bypass lines with globe-type bypass valves that could be used to "balance" differential pressure before opening or closing of the main valve. Traditional gate valves generally performed reasonably well in such applications; at worst, a motor actuator might require an assist from the manual over-ride to unstick a jammed valve. However, some of the safety-related nuclear plant applications involve operation under postulated accident conditions that require opening or closing under high differential "blowdown" conditions.

Design Basis Qualification of Equiwedge Gate Valves for Safety Related MOV Applications

Equiwedge Gate Valve Development

The Equiwedge (Figure 1) has already accumulated an excellent service history of successful performance in thousands of applications worldwide. These applications range from common manually operated component isolation valves in fossil-fueled power plants through safety-related motor operated valves (MOVs) in nuclear power plants. Combined with Edward stored energy actuators, over 400 large Equiwedge gate valves have been furnished as quick-closing main feedwater isolation valves and main steam isolation valves (MFIVs and MSIVs) or for other similar safety-related applications in nuclear power plants worldwide.

Conventional Wedge Gate And Parallel-Slide Gate Valve Features

Prior wedge gate valves and parallel-slide valves each had design strengths and weaknesses. However, selection of either type required compromises. While both types had advantages that made them suitable for many services, the following features are principal disadvantages of each type:

• Conventional Wedge Gate Valves have a bad reputation for sticking in the closed position. Solid wedge gates can bind due to pipe loading reactions or due to thermal effects (e.g., body contraction due to cooldown after closure with hot fluid). Also, low or high pressure leakage can develop if pipe load reactions or thermal effects create "gaps" between the gate and the body seats. Valve designs with one-piece "flexible wedges" (Figure 2) clearly offer improved resistance to sticking and leakage, but the necessity of meeting acceptable stress criteria in high pressure valves imposes a serious limitation; one-piece wedges designed for high pressures tend to be rigid, regardless of shape.

• Parallel-Slide Gate Valves (Figure 3) have the fundamental disadvantage that the gate and body seating surfaces are in continuous contact over the full travel of the valve, from open to closed. Thus, the seating surfaces are also the guiding surfaces, and any scratches or gouges that result from wear are a source of leakage when the valve is closed.

Since most such valves in fossil-fueled plants were normally operated with very low differential pressures (using a bypass), this characteristic usually resulted in only minor scratches; however, some users indicate that parallel slide gate valves require more frequent seat refinishing than wedge gate valves. The continuous sliding of seating surfaces is a more serious concern in valves that must operate at very high differential pressures (such as safety related MOVs, MSIVs and MFIVs in nuclear power plants). Since the high differential conditions may not be encountered in normal operation, the problem might not be evident until a design basis event requires a safety related valve operation. With very high contact stresses at gate-to-seat interfaces, wear

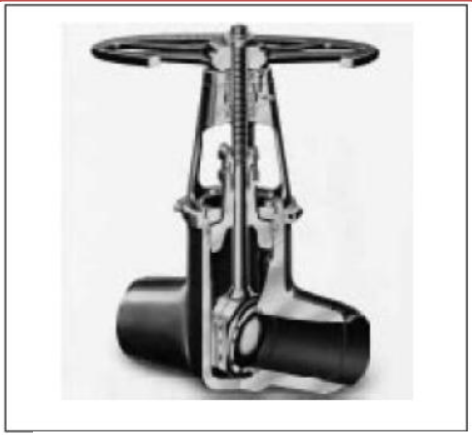

Figure 1: The Flowserve-Edward Equiwedge Gate Valve

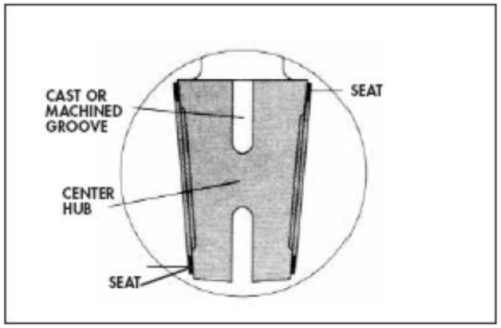

Figure 2: Flexible Wedge Gate Valve

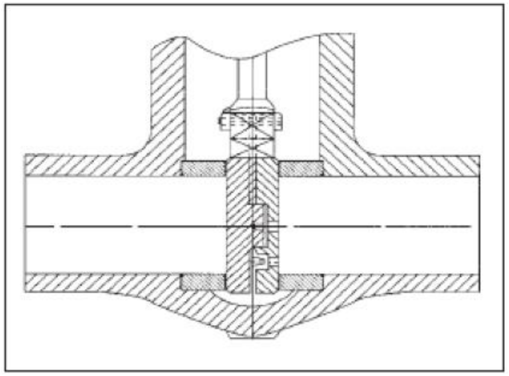

Figure 3: Parallel Slide Gate Valve

damage may result in galling that can cause large leak paths and possibly even prevent full valve travel.

Edward Equiwedge Gate Valve Features

The Edward Equiwedge concept “borrowed” the best feature of normal parallel-slide valves: two separate gates (Figure 4) that permit better inherent flexibility and freedom of each gate to align properly with its companion body seat. However, by using the traditional wedge seat arrangement in the valve body, the Equiwedge has a major advantage in low-pressure seat sealing.

The most important advantage of the Equiwedge gate valve over conventional wedge gate valves and any parallel-slide gate valve is in its gate guiding system. While some parallel slide valves employ supplementary gate guides to minimize cocking, most depend primarily on a varying contact pattern between the gates and seats to maintain gate alignment. Wedge gate valves require separate guide systems, but studies of prior designs revealed that there were several key issues in wedge gate valves guide system design, as listed in Table 1. It was recognized that these issues had a major bearing on the successful operation of a wedge gate valve with reasonable and predictable operating forces, particularly under high differential pressure conditions. The designers of the Equiwedge addressed all factors and evolved a design with strong guide rails on each gate half, engaging rugged guide grooves at each side of the valve body (Figure 5).

On opening or closing, there is relative sliding motion between the gate and body seating surfaces for only a very small portion of the valve travel. Outside this range, all sliding motion occurs between the hardfaced surfaces on the gate rails and the guide groove in the valve body. Unlike many conventional wedge gate valves, the guide surfaces in Equiwedge gate valves are designed (and test-proven) to support high differential pressure load, even when the valve is not seated.

Figures 6, 7 and 8 illustrate serious jamming problems that can develop in wedge gate valves with inadequate guiding systems.

Equiwedge Gate Valve Qualification Tests And Experience

Substantial testing was done before the Edward Equiwedge gate valve product line was introduced. The initial test programs clearly demonstrated that Equiwedge gate valves overcame the primary disadvantage attributed to prior wedge gate valves. Rigorous tests showed that these valves do not “stick” in the closed position; they require an opening force to ”unwedge” the gates, but this force is predictable and within the capabilities of valve actuators sized for closing (this wedging action is an advantage, because, once the valve is closed, sustained stem load is not essential for seat sealing). The testing program also clearly demonstrated that Equiwedge gate valves provide excellent seat sealing at both low and high differential pressures. In addition, demanding flow tests were conducted with water at pipe flow velocities well above the normal operating range. These tests showed very stable flow performance with freedom from flow induced vibration. The fully-open gate assembly has clearances in the guiding system, but there

Figure 4: Flexible Equiwedge Gate

Figure 5: Equiwedge Guiding System

was no evidence of any excitation or “rattling” due to fluid flow.

The hardface sampling test program led to the use of stellite 21 hardfacing on all gate and body seating and guiding surfaces in Equiwedge gate valves with high flow, high differential pressure operating requirements in nuclear safety related applications (the combination is standard in all stainless steel valves, regardless of the application).

Special Qualification Tests For Nuclear (MSIV And MFIV) Applications

After the Equiwedge design and laboratory friction tests were complete, it remained necessary to prove that the combination would work in an actual valve under high differential operating conditions. Before quoting these valves for safety-related nuclear applications, a size 16 valve with a prototype Edward linear MSIV actuator was subjected to flow interruption tests.

In extensive testing, the size 16 valve was closed repeatedly under “blowdown” conditions, typically in three to five seconds, discharging air from a 300 ft^3, 1500 psi reservoir. Instrumentation showed that the stem thrust required for closing was consistently within calculated predictions based on valve dimensions and friction coefficient data (friction testing of the selected valve trim materials had previously proven that valve testing with air was comparable to testing with steam). Seat leakage tests with air after numerous valve closures at high differential pressure gave excellent results at both high and low pressure (6.5 SCFH at 1500 psi, less than 0.2 SCFH at under 100 psig – essentially negligible air leakage in a large metal-seated valve); seating surfaces showed negligible damage, proving that the Equiwedge gate guiding system performed as designed.

The increased concern for valve safety and reliability that emerged in the early 1980s led to the demand for additional testing – on a full scale MSIV. A size 28x24x28 MSIV was subjected to two flow interruption test programs. This valve was closed repeatedly under blowdown conditions discharging air from a reservoir that had been expanded to over 900 ft^3. In this program, the valve demonstrated consistently successful operation with shutoff differential pressures up to 1180 psig, even while subjected to simulated linebreak pipe loading and seismic loads. Again, required actuator force was within calculated predictions. A second full-scale Equiwedge gate valve test program was conducted in France on the first size 30x24x30 MSIV constructed for a megawatt Electricite de France PWR plants. These tests did not involve flow interruption testing, but they included hot functional tests (including thermal transients) that demonstrated smooth opening and closing through 600 full stroke cycles and 400 exercise cycles. As in previous Equiwedge tests in the U.S., there was no evidence of valve “sticking” in the closed position.

Table 1- Key Factors in Wedge Gate Valve Guide System Designs

1. Guide Strength – Where a high differential pressure exists across the gate when it is not in contact with the body seats, the guides must support the full differential pressure load. **2. Gate Strength –** When all of the differential pressure reaction loaqds are on the guides, the gate becomes a simply supported beam.	**3. Guide Precision –** The precision of the guide system determines how the gate breaks and makes contact with the seats during opening and closing. **4. Guide Length –** The length of the guides and the elimination of “overhanging loads” is important to avoid gate cocking and locking in the guides.	**5. Guide Surface Materials –** The friction coefficient developed between these surfaces in a hostile fluid environment affects operating forces, and indentation under high localized load may lead to jamming. **NOTE:** Parallel-slide gate valves depend on seating surfaces to provide most of these critical functions.

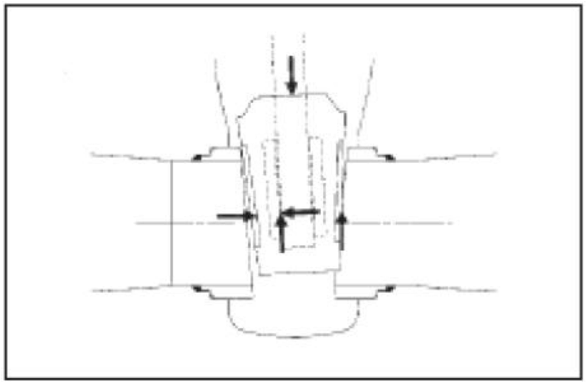

Figure 6: Gate Jamming due to guide distortion

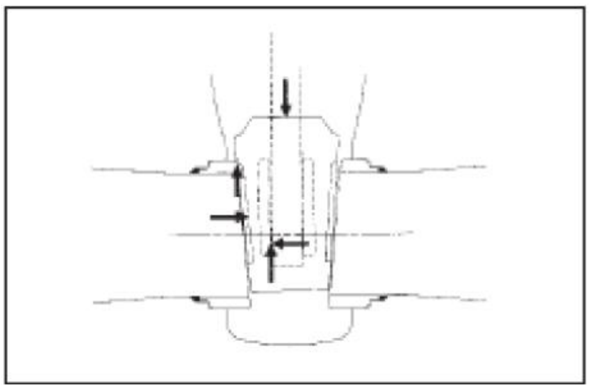

Figure 7: Gate Jamming due to upstream hooking

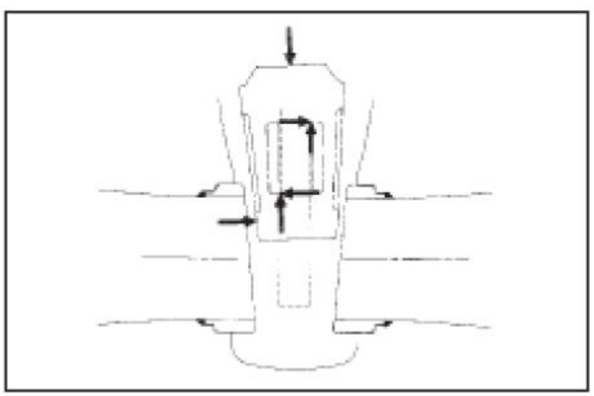

Figure 8: Gate Jamming due to overhung loads

Summary And Conclusions

Conventional wedge gate valves, while time-proven for fossil-fueled plant applications, have been found inadequate for many critical safety-related MOV services in nuclear facilities. Unlike fossil-fueled services, where these valves are generally cycled under low differential pressures, these nuclear applications require reliable operation with high differential pressure. This change required new answers from the valve manufacturing industry, and Equiwedge is Flowserve Edward's answer.

In addition to the results of the test programs described in this report and in the references, field experience with Equiwedge gate valves has been excellent. After several decades of service in both fossil-fueled and nuclear power plants, Edward Equiwedge gate valves have earned an excellent reputation for trouble free performance.

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