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Edward Valves

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Edward Cast-Steel Pressure-Seal Valves: Research and Development

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Edward Cast-Steel Pressure-Seal Valves: Research and Development

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ABSTRACT

For more than 45 years of the 86-year history of Edward Valves, large cast-steel valves have been furnished with pressure-seal bonnets or covers. Basic designs were supported by extensive research and development test programs, as well as by the best state-of-the-art analytical methods. With proper maintenance, time-proven standard designs seal well and produce few problems. Now, through application of new materials and analysis methods, a new design for the 1990s offers even better sealing performance and easier maintenance.

Why Pressure-Seal Valves?

The conversion of higher-pressure Edward cast-steel valves from bolted-bonnet to pressure-seal construction was prompted by customers' demands for lighter, more maintainable valves. This transition started at a time when fossil-fuel power plants were moving toward larger line sizes and higher pressures and temperatures. In the 1940s and early 1950s (before the advent of nuclear power) the quest for improved thermal efficiency in power production demanded high-pressure superheated steam plants, and the power demand surge after World War II resulted in larger unit sizes.

By that time, power plant designers had generally abandoned flanged *piping* connections and switched to welded construction in high-pressure systems to save cost and weight and to eliminate potential leakage sources. Massive flanged and bolted valve bonnets were as undesirable as pipe flanges. The need for occasional internal maintenance in large valves demanded bonnet closures that were not only reliably leak-tight but also easy to open and close when required.

Various types of compact closures were developed and used to some degree to meet the challenge. Threaded and seal-welded joints, as used in Edward Univalves®, were practical only in smaller sizes. Welded breach-lock closures were used in some larger valves, but they proved difficult to assemble and disassemble. The pressure-seal bonnet closure was the most successful of all the alternatives.

Edward was a leader in supplying large pressure-seal valves to the power industry (first U.S. patent filed April 1946), but many other manufacturers followed. In some cases, users found that pressure-seal valves with welding ends weighed only 40% as much as flanged-end valves with bolted bonnets. This weight saving paid off in reduction in pipe-support requirements, and the reduced weight of bonnet and closure parts paid off in easing maintenance in most cases. The basic pressure-sealing action of the bonnet gasket also resulted in reduced leakage in most cases and reduced maintenance work in tightening bolted joints.

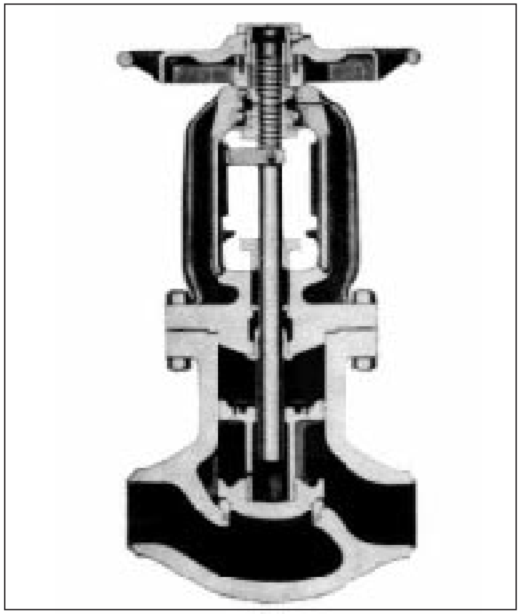


Figure 1: Large cast-steel valve with bolted-bonnet design, from Edward Catalog No. 103, June 1949.

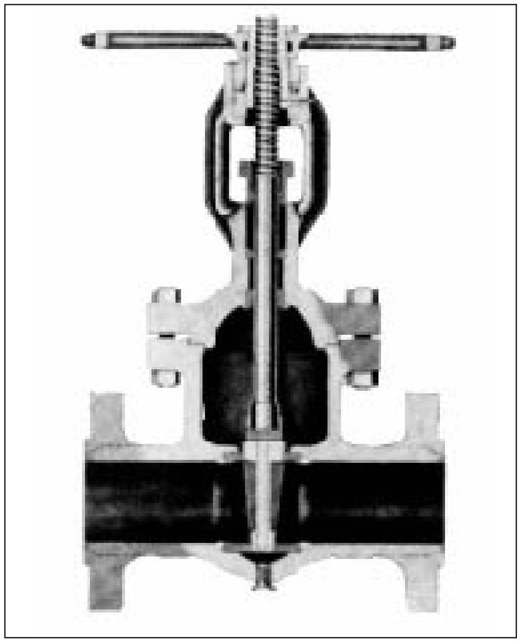


Figure 2: A second example from Catalog No. 103 of a bolted-bonnet, cast-steel valve.

Edward Cast-Steel Pressure-Seal Valves: Research and Development

Edward Pressure-Seal History

The first Edward valves were built in 1904, and the first Edward company was founded in 1908. Until almost 40 years later, all large cast-steel Edward valves employed bolted bonnets. *Figures 1 and 2* are illustrations from Edward Catalog No. 103 (June 1949). The complete line of standard globe stop, non-return, and gate valves in Classes 300 through 1500 used bolted-bonnet construction at that time.

Figure 3 shows a pressure-seal valve that was also illustrated in Catalog No. 103; Edward cast-steel valves were in the process of design modernization at that time. The first pressure-seal closure was designed in June 1944, and the first Edward pressure-seal valves were size 12, Figure 3507Y, angle stop-check valves (Class 1500) for the Dixon Station of Illinois Northern Utilities in 1945. Thus, Edward now has 45 years of experience in supplying Edward pressure-seal valves.

Pressure-seal valves were first publicized in Catalog No. 12-C (1947), but no design details were shown. Initially, they were offered *"...only for severe conditions..."*and manufactured on a custom basis. A complete line of all new Class 900, 1500, and 2500 globe stop, stop-check, and check valves was offered in Catalog 12-H (late 1949). This was timed with the introduction of other modern Edward design features still used today (integral stellite seats, flow-efficient body flow passages). Prior to 1949, some of these other features were provided as options or in special valves, but these premium features as well as the pressure-seal bonnet were standard in the new valve line.

Figure 4 is an illustration of a Figure 4007 angle nonreturn valve, and *Figure 5* shows the original Edward pressure-seal bonnet design (both from Catalog 12-H). The basic concept is the same as in later designs with wedge-shaped metal gaskets, but the threaded gasket retainer presented maintenance problems.

Edward laboratory report files from the 1949-1951 period contain a record of extensive high-pressure and high temperature tests on a number of pressure-seal

Figure 3: A pressure-seal valve from the June 1949 Edward Catalog.

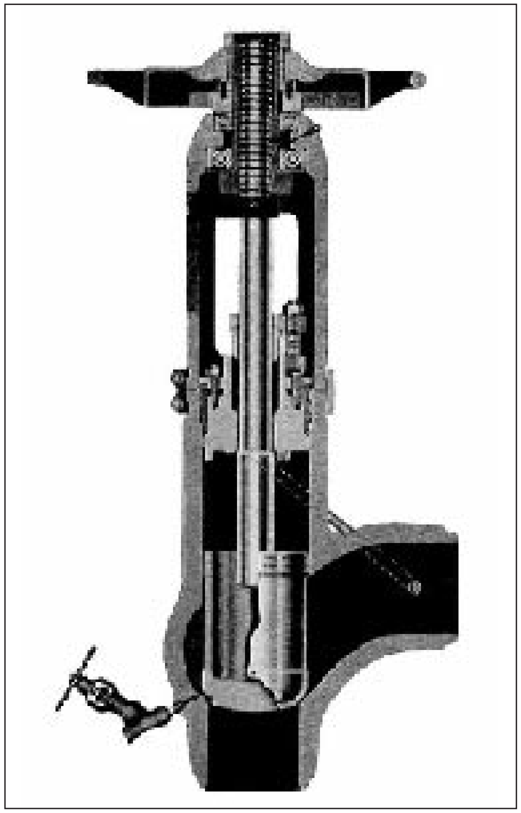


Figure 4: Figure 4007 angle non-return valve.

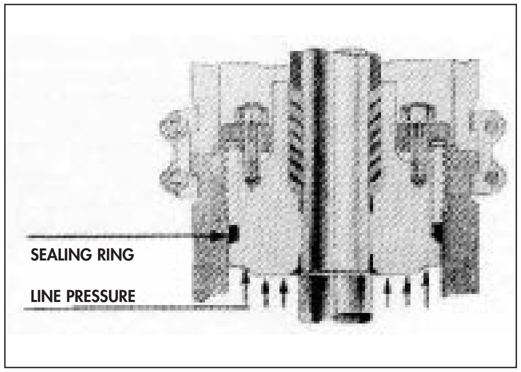


Figure 5: Original Edward pressure-seal design.

valves. These tests were used to develop the segmented gasket retainer and the gasket materials, platings, loadings, angles, and many other details that are still used today in Edward pressure-seal valves with metal gaskets.

Since Edward engineers did not have finite-element computer programs 40 years ago (in fact, they had no computers at all),

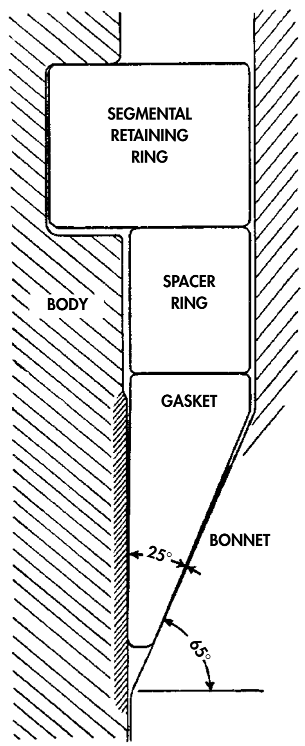
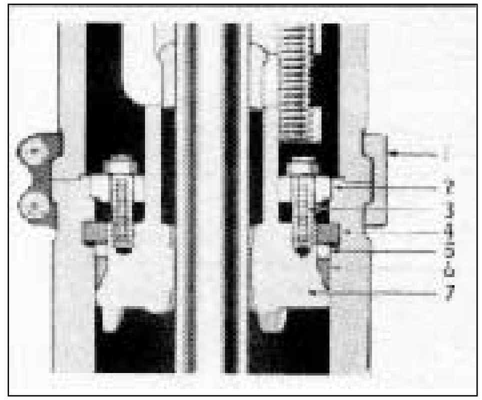


Figure 6: 1955 edition of Catalog 12-H illustrates bonnet features developed during the 1949-1951 Edward test program.



1. **YOKE LOCK RING**
   Firmly secures yoke to body and maintains alignment of EValthrust mechanism with body and seat bore. Used on large sizes only.
2. **BONNET RETAINER**
   Provides means for preloading the gasket to seal it until internal pressure is sufficient to seat it further.
3. **BONNET RETAINER STUDS**
   ASTM A194-47T-B7 bolting material combines high tensile strength with maximum toughness. Used on large sizes only.
4. **GASKET RETAINER**
   EV alloy (stainless steel) segmented-ring gasket retainer takes full Internal load, restraining upward movement of gasket and bonnet. Provides for ease of assembly or disassembly.
5. **SPACER RING**
   Provides for gasket alignment and separates segmented gasket retainer from gasket. Prevents soft iron gasket from being extruded into separations and clearances of gasket retainers.
6. **GASKET**
   Plated soft iron sealing gasket is deformed outward against the body wall, effectively sealing off the internal pressure.
7. **BONNET**
   Top closure to withstand Internal pressure and deform sealing gasket. Stainless steel A.I.S.I. Type 4 10 on screwed types 2-1/2 in to 4 in.

Figure 7: Details of Design

testing was necessary to verify structural integrity of pressure-seal valves as well as tight sealing. Since valves for superheated steam service would operate with metal temperatures in the “creep range,” the best available theory was used with pencils, paper, and slide rules to design the valves, but proof testing was necessary for confidence. Tests in that time period included creep tests of valves pressurized at more than three times their rated pressure in furnaces at temperatures up to 1150°F (620°C).

Figures 6 and 7, from a 1955 edition of Catalog 12-H, illustrate design features developed during the 19491951 Edward test program. Some of the design features that distinguish Edward pressure-seal closures from many competitive products were already incorporated:

- Malleable coating (plating) on gasket
- Corrosion-resistant inlay in body-gasket seating area
- Enlarged body bore above gasket to facilitate disassembly

By about 1950-1952, the complete line of standard Edward Class 900, 1500, and 2500 cast-steel globe valves had been converted to the new pressure-seal design, leaving bolted bonnets only in Class 600 and lower valves (except for a Class 1500 gate valve design that was discontinued in about 1970). Modified pressure seal closures were introduced in large (sizes 8 and above) Class 600 globe valves in the late 1950s and early 1960s.

Edward Cast-Steel Pressure-Seal Valves: Research and Development

When the Edward Equiwedge™ gate valve product line (Classes 600, 900, 1500, and 2500) was introduced in 1975[1], all valves were initially designed with pressure seal bonnet closures (some small Class 600 and 900 valves were later redesigned to use bolted flanges for cost reduction – not due to problems with the pressure seal joint). With 30 years of pressure-seal experience at that time, Edward designed the Equiwedge closures to a consistent set of design rules. Finite-element stress analysis assured body and bonnet stresses consistent with Code requirements. Thus, Equiwedge gate valves have the most modern of all the Edward pressure-seal bonnet designs.

Currently, in cast-steel valves, bolted bonnets are used only in Class 300 (all) and some smaller Class 600 and 900 valves of standard design. In small valves, the size and weight of parts do not present a maintenance problem, and bolted-bonnet valves are more economical in some cases. Bolted bonnets are also used on many small forged-steel valves for the same reasons. Bolted bonnet valves have also been furnished as "specials" to meet customer specifications, but these have generally been main steam isolation valves and other nuclear valves with pressure-class ratings lower than Class 900. Otherwise, the Edward cast-steel valve product line consists primarily of pressure-seal valves.

Are There Disadvantages With Pressure-Seal Bonnets?

There have been few problems with Edward pressure seal bonnets during the 45-year period since these products were introduced (15 years for Equiwedge). Still, there are people who condemn pressure-seal valves due to bad experience with leakage problems or maintenance difficulties. In many cases, this bad experience can be traced to problems with pressure-seal valves that did not have Edward nameplates – or the Edward testing heritage.

As previously noted, many valve manufacturers worldwide introduced pressure-seal valves within a few years of the time that the first Edward pressure-seal valves were offered, and few of these valves had the advantage of the years of research, development, and proof-testing of the Edward designs. For instance, the threaded gasket retainer ring that was used in the 1945-1949 Edward design (*Figure 5*) was used in some competitive designs for decades. Naturally, this feature led to maintenance problems in larger valves. Other inferior design features also produced more leakage problems than were experienced with Edward valves.

Another source of problems with pressure-seal valves in general (including Edward valves in some cases) is that maintenance requires different skills than those required with bolted-bonnet valves — not necessarily more skill, but special knowledge and training. Without proper attention to a few key points, leakage or other difficulties may be encountered. The most frequent problems have been:

- Some users attempt to use the same pressure-seal gasket when reassembling the valve after maintenance. This is very poor practice for any high-pressure gasket (even a spiral-wound gasket in a bolted closure), because the gasket is partially crushed to a new shape the first time it is loaded and will not be loaded the same way the second time. Sometimes the re-used gasket passes a hydrostatic test, and it may appear to work well for months or years. However, there is a very high probability that it will leak after the valve is exposed to thermal transients. Spare gaskets should be maintained in stock or ordered in advance of scheduled maintenance.
- Many users who do replace gaskets either make their own or have them made at a local machine shop. They generally use drawings based on measurement of used parts or incorporate design or material "improvements" of their own. They cite savings in cost or lead time as reasons for not purchasing genuine spare parts, but this can be expensive in terms of lost time due to leakage problems. Edward gaskets are made using dimensions, materials, and plating that are based on decades of testing and field experience.
- Even with careful handling, disassembly of a valve with a metal pressure-seal gasket may cause minor scratches in the body bore and sometimes on the surfaces of the bonnet which contact the gasket. Unless honed or polished, the scratches may be too large for the plating on the gasket to seal over, and they will be sites for leak paths. Leakage might be small at first (even unde-

tectable), but it often increases with time due to erosion. Careless handling or maintenance by un trained personnel may produce more severe damage to the sealing surfaces, requiring more extensive refinishing. With proper tools and training, these problems are easily overcome.

- Even when thoroughly tightened before pressurization, a pressure-seal gasket always yields slightly under pressure. This reduces the loading on the bolts which preload the gasket, and a metal gasket (with little inherent resilience) may subsequently leak at low pressure. When a new valve is manufactured by Edward, the bolts are tightened under hydrostatic test pressure to overcome this problem. When a valve is reassembled after maintenance in the field, the pressure-seal bolts should be retightened under working pressure to assure effective long-term sealing. This step is often forgotten in the rush of having many things to do when a plant is restarted after a maintenance outage and leakage may develop later.

Note:the requirement for retightening under pressure after maintenance may present a problem for some inside-containment valves in nuclear power plants. The valve may be inaccessible when it is first pressurized. For this reason, some Edward valves in this service have been equipped with special heavy-duty bolting to allow more complete preloading of the gasket before pressurization.

Everything considered, there are no significant disadvantages of standard Edward pressure-seal closures when compared to known alternatives, provided that users understand their function and assure that maintenance personnel are trained in the "different" skills discussed here. There are occasional maintenance problems, but this can also be said of valves with bolted bonnets (e.g., bolts lost or damaged, gasket reuse or use of improper replacement gasket, leakage due to damaged sealing surfaces, inadequate gasket loading due to high thread friction). As previously noted, pressure-seal closures offer the advantage of smaller and lighter parts to be handled, particularly with large, higher-pressure valves.

Four Rules For Good Pressure-Seal Performance

In summary, most "problems" with conventional pressure-seal bonnet closures have been overcome in the design of the current Edward pressure-seal valves. Light-weight parts provide easy maintenance and leakage-free service if the following four rules are followed:

1. Take reasonable care of body and bonnet sealing surfaces during disassembly to minimize galling and scratching, and polish or hone surfaces before reassembly with the new gasket.
2. Always use a new gasket when reassembling a valve after inspection or maintenance.
3. Use only Edward pressure-seal gaskets.
4. Tighten pressure-seal bolts to recommended torque values, first during bonnet assembly and again when full working pressure is applied.

Some maintenance people think these four rules can be bent or broken, but well-trained personnel find that these measures take little extra time, and the time spent is a good investment in trouble-free performance.

The Pressure-Seal Bonnet Closure Of The 1990s

While performance of standard Edward pressure-seal designs has been excellent, Edward has developed an even better pressure-seal design employing a live-loaded composite gasket. The sealing function is performed by flexible graphite instead of metal-to-metal contact in this new design. Edward research and testing of stem packings2 had shown that flexible graphite has the best sealing properties of known materials for high temperature, high-pressure service, and it was decided to use it in an improved bonnet pressure-seal. The new closure design (as applied to a large Class 2500 Equiwedge gate valve) is shown in *Figure 8*.

A development and testing program over a two-year period provided a proven design before it was introduced into production. With high-pressure, high-temperature steam-test facilities that were not available when their predecessors developed the first pressure seal bonnets, Edward engineers conducted exhaustive tests on test fixtures simulating three valve sizes and pressure classes - through size 14, Class 2500.

Major changes are rarely easy, so the engineers were at first surprised at the ease encountered in obtaining excellent sealing With pressure-seal gaskets employing flexible graphite. However, they quickly found that there was a major challenge in preventing extrusion of this material under the high loadings that are inherent in pressure-seal gasket designs. The clearances that are necessary for ease of maintenance in a valve with a pressure-seal bonnet offer an attractive "leak path," and the gaskets would seal perfectly in tests – until the sealing material was gone. After some initial tests, large volumes of flexible graphite ribbon were found inside and outside the test fixture. The engineering team was not satisfied until the anti-extrusion provisions in the composite gasket were developed and proven.

Confirmatory testing of the final design, using water at room temperature with extensive pressure cycling to 6250 psig (431 bar) and hydrostatic testing to 9375 psig (647 bar), showed both excellent sealing and resistance to extrusion of the flexible graphite. Tests with steam at 2300 psig (159 bar) and over 1000°F (538°C), with severe pressure and temperature transients, demonstrated outstanding sealing. Special instrumentation was developed to measure and quantify leakage of invisible superheated steam, and it showed peak leakage rates typically less than 1 ml/hr even at the worst periods in transient tests (much less under steady-state conditions). Under room-temperature test conditions, leakage was undetectable at either low or high pressure.

The development program for the new pressure-seal closure was not limited to just testing. Recognizing that the loading between the gasket, bonnet, body, and other parts was different in the new design, an extensive finite element analysis program was undertaken on both standard and new designs, using modern programs including ANSYS®. Analyses of existing designs reconfirmed the conservatism that had been previously proven by creep testing when the designs were first introduced. However, this analytical program was not just to analyze stresses; relative deflections of the parts under preload and pressure were analyzed, giving a much better understanding of how these parts react to complex loadings. These analyses were also used to optimize bonnet configurations from a stress standpoint.

As previously mentioned, the design shown in *Figure 8* is for a large Class 2500 Edward Equiwedge gate valve. Minor variations in construction are required for some other valve sizes and types, but the principle is the same in all cases. The composite gasket is die-formed from flexible graphite to a high density and fitted with integral anti-extrusion devices, resulting in a relatively rugged assembly for ease in handling during shipping and valve assembly. After installation into the Valve, the gasket is compressed to an even higher density by preloading with the bonnet bolts. Flexible graphite does not require wedging for sealing, but the small taper shown on the bonnet is provided for stress minimization. Belleville springs in this design provide "live loading" as pressure increases or decreases in service.

Since the new gasket does not require close metal-to-metal fits that may be subject to galling, maintenance is much easier and sensitivity to scratches on sealing surfaces is greatly reduced. Even if scratches occur, the flexible graphite seals over them much better than the soft plating on a metal gasket. During the test program, composite gaskets sealed over body and bonnet scratches that would not have sealed with a metal gasket. Further, the inherent resilience of compressed flexible graphite adds a significant supplementary live-loading feature in the new design. The gasket resilience and the spring-loaded bolts eliminate the need for retightening under pressure in all but the severest service conditions.

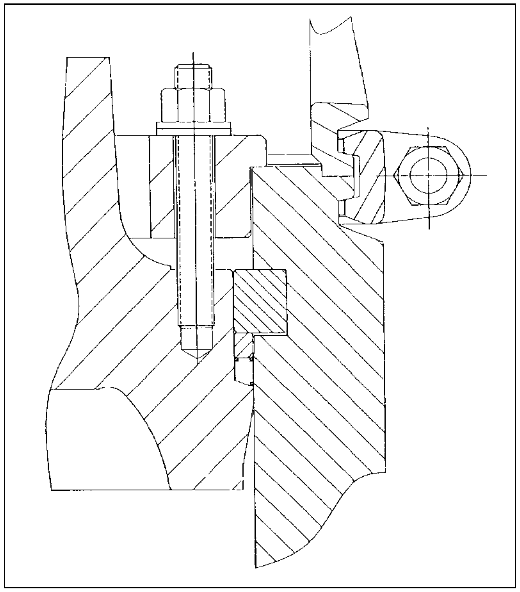


Figure 8: New flexible-graphite closure design, as applied to a large Class 2500 Equiwedge gate valve.

Edward Cast-Steel Pressure-Seal Valves: Research and Development

With these features, the new composite pressure-seal closure offers significant advantages over either a bolted closure or a conventional pressure-seal bonnet when a large valve must be disassembled, as for seat repair. With less damage to sealing surfaces and less sensitivity to minor scratches, it offers savings in both time and cost during maintenance outages. All that is necessary is reasonable care and attention to assembly instructions, including proper bolt torques for gasket preloading.

Like the original Edward pressure-seal closures of the late 1940s, the new composite pressure-seal design of the 1990s is being introduced first in valves exposed to the most severe service conditions. A number of Class 1500 and 2500 Equiwedge gate valves (sizes 3 through 18) have been converted to use the new design, beginning with valves shipped in May 1989, and there have been no problems. One existing valve in severe service was retrofitted with the new design, eliminating occasional leakage that had been encountered before. Other valve designs are being converted where customer specifications indicate very high service temperatures.

The new pressure-seal design of the 1990s provides both outstanding sealing and easier valve maintenance when required, and the four rules cited previously for satisfactory pressure-seal performance can be practically reduced to two:

1. Always use a new gasket when reassembling a valve after inspection or maintenance.
2. Use only Edward pressure-seal gaskets.

References

1. Roger D. Norden, "Development of the Rockwell Edward Equiwedge Gate Valve." Edward Technical Article V-Rep 75-5, 1975.
2. E. A. Bake and R. J. Gradle, "Tests of Asbestos-Free Stem Packings for Valves for Elevated Temperature Service." Edward Technical Article V-Rep 86-2, 1986.

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