Pressure Seal Bonnet Valve Maintenance Guide

1009701

Plant Maintenance Support

Reduced Cost

Equipment Reliability

Pressure Seal Bonnet Valve Maintenance Guide

1009701

Technical Update, December 2004

EPRI Project Manager

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REPORT SUMMARY

Background

In 2003, EPRI NMAC conducted a survey of site representatives to determine what component maintenance guides would be most useful to plant personnel. The survey identified pressure seal bonnet valves maintenance issues as sixth with respect to adding high to medium value to the plant. To address this issue, an additional survey of what areas had not been previously addressed by earlier EPRI documents was completed. It was determined that while there were several guides that discussed pressure seal bonnet valve, none provided the detail to properly maintain them.

Objectives

The objective of this guide is to provide detailed information to personnel involved with pressure seal bonnet valves maintenance. It provides insights to experienced personnel as well as basic information, guidance and instructions to less experienced personnel assigned to the maintenance and operation of pressure seal bonnet valves.

Approach

A detailed review of industry literature, product information, and standards was conducted to identify the various designs, applications, and maintenance practices associated with pressure seal bonnet valves. Utility and industry failure databases were surveyed to determine specific problems and commonly encountered failure mechanisms. Based on these reviews a draft was prepared and presented for Task Advisory Group member feedback.

Results

This guide provides information to help power plant maintenance personnel understand the basic principles of pressure seal bonnet valve design and operation. It identifies problems with pressure seal bonnet operation and maintenance and uses that information to provide troubleshooting strategies. Finally, it provides inspection and monitoring techniques to implement a preventive maintenance program.

EPRI Perspective

Pressure seal bonnet valve O&M continues to be a challenge to reliable plant operations. The guide provides the tools necessary to understand the special problems of pressure seal bonnet valve maintenance. The most important activities associated with these valves are insuring the sealing area is proper, clearances are kept small, and sufficient pretorque is applied to the bonnet nuts both as a preload and after the valve has been put in service (hot retorque). Troubleshooting is basically determining what important activity has not been accomplished including the adequacy of the preload.

Graphite gaskets provide an excellent solution to many long standing problems. While they must be used with an understanding of their limitations, if these limitations are accounted for, a vast majority of applications are possible.

Keywords

Pressure seal valve

Troubleshooting

Reliability

Condition Monitoring

ABSTRACT

This guide provides information to help power plant maintenance personnel understand the basic principles of pressure seal bonnet valve design and operation. It identifies problems with pressure seal bonnet operation and maintenance and uses that information to provide troubleshooting strategies. It covers both metal gaskets and graphite gaskets, including precautions for graphite replacements. Finally, it provides inspection and monitoring techniques to implement a preventive maintenance program.

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EPRI would also like to recognize Greg Harttraft, Oyster Creek Generating Station, Exelon Corporation, and Malcolm Gonzales, now of Turkey Point Nuclear Power Plant, Florida Power & Light, for their paper *Maintenance of Pressure Seal Bonnets*, presented at the Fifth EPRI Valve Technology Symposium in June 1995, that forms the basis for Chapter 3.

NMAC was supported in this effort by Bill Slover.

CONTENTS

1 INTRODUCTION

1.1 Background

In 2003, EPRI NMAC conducted a survey of site representatives to determine what component maintenance guides would be most useful to plant personnel. The survey identified pressure seal bonnet valves maintenance issues as sixth with respect to adding high to medium value to the plant. To address this issue, an additional survey of what areas had not been previously addressed by earlier EPRI documents was completed. It was determined that while there were several guides that discussed pressure seal bonnet valve, none provided the detail to properly maintain them.

1.2 Guideline Approach

The approach included the following process:

- Review EPRI and industry literature, product information, and standards to identify various designs, applications, and maintenance practices associated with pressure seal bonnet valves.
- Survey utility and industry failure databases to determine specific problems and commonly encountered failure mechanisms.
- Recommend condition monitoring/preventive maintenance, and troubleshooting methods that will meet the task objectives.

1.3 Highlighting of Key Points

Throughout this report, key information is summarized in "Key Points." Key Points are bold lettered boxes that succinctly restate information covered in detail in the surrounding text, making the key point easier to locate. The primary intent of a Key Point is to emphasize information that will allow individuals to take action for the benefit of their plant.

The Key Points are organized according to the three categories:

- O&M Costs
- Technical
- Human Performance

Each category has an identifying icon, as shown below, to draw attention to it when quickly reviewing the guide.

Key O&M Cost Point

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

Key Technical Point

Targets information that will lead to improved equipment reliability.

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.

Section 7 contains a listing of all key information in each category. The listing restates each Key Point and provides reference to its location in the body of the report. By reviewing this listing, users of this guide can determine if they have taken advantage of key information that the writers of this guide believe would benefit their plants.

2 PRESSURE SEAL BONNET VALVE DESIGN AND OPERATION

2.1 Introduction

This section describes the basic pressure seal gasket, principle of operation, joint design variations and design that occur and how maintenance will be affected. Materials will be discussed including the use of seal ring plating, body inlays and body bore finish.

2.2 Description of the Pressure Seal Valve

In the May 1946 edition of the ASME publication, *Mechanical Engineering*, [1] an announcement occupies a space of 4 inches: "New Pressure-Seal Valves. This design incorporates important changes and some departures from previous conventional types of construction." The pressure seal valve described was the result of the need for increased pressures and temperatures in power plants. The 900 and 1500 pressure class were becoming more common in power plant construction. While the bolted bonnet valve could be used, efforts to reduce weight, and hence cost, resulted in the pressure seal design still seen in use today. Figure 2-1 shows a typical design using a metal pressure seal gasket.

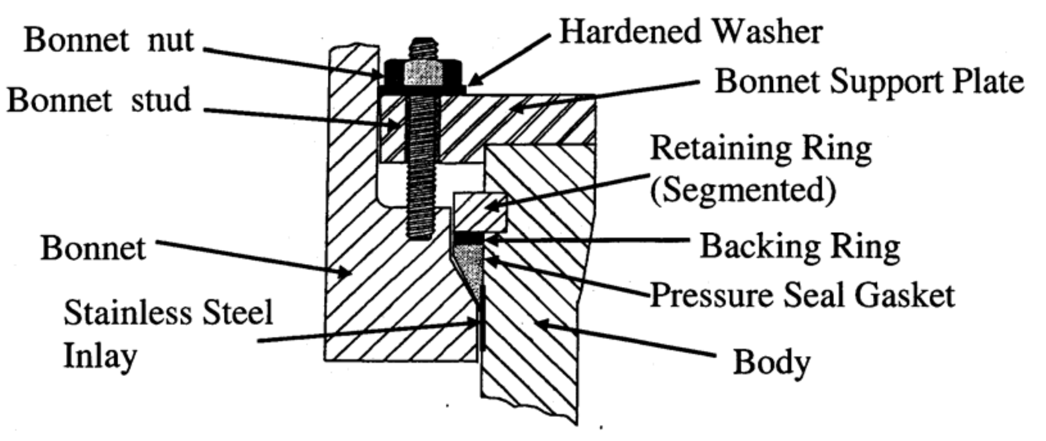

Figure 2-1
Typical Pressure Seal Gasket

The parts of the typical joint and their purpose are as follows:

Pressure seal gasket: a ring, usually shaped in a wedge as shown in Figure 2-1, made from metal or expanded graphite. If it is metal, it is usually manufactured from a soft steel (e.g., AISI 1005) or iron, and usually plated with a soft, corrosion resistant, material such as lead or silver. Pressure seal gaskets have variations as shown in Figure 2-2.

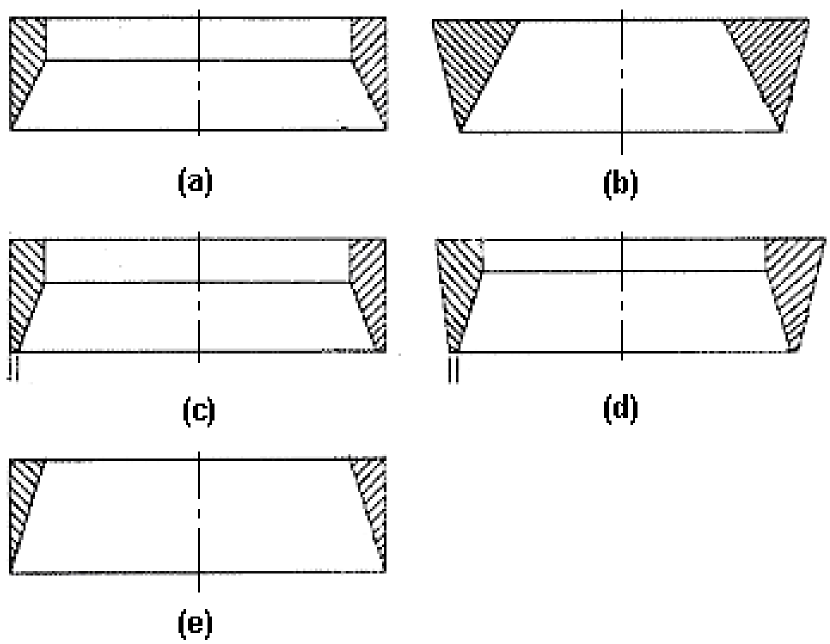

Figure 2-2
Pressure Seal Gasket Variations

Retaining ring: a ring, continuous or segmented that in most designs stops the upward movement of the gasket as the bonnet is pulled up during preloading or operation. An exception to this is shown in Figure 2-7. The more commonly used is the segmented ring as shown in Figure 2-3. A continuous ring is shown in Figure 2-6(c).

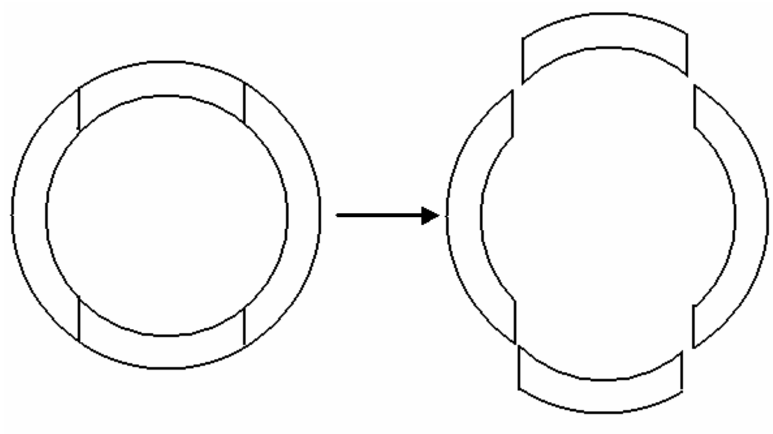

Figure 2-3
Segmented Retaining Ring

Backing ring: a ring that provides an interface between the retaining ring and gasket, usually when the retaining ring is segmented.

Bonnet support plate: a circular flat plate with equally spaced holes that rests on top of the body and provides a surface for the bonnet nuts to act against.

Bonnet studs/nuts: a set of equally spaced studs threaded into the top of the bonnet and together with nuts, used to pull the bonnet up against the pressure seal ring.

Stainless steel inlay: a cladding of stainless steel, usually a series 300, that provides a corrosion free sealing surface.

Hardened washer: A washer that has been manufactured to a standard, e.g., ASTM F436, and has been hardened, e.g., Rockwell C38-45. Note that this is not normally provided by the valve manufacturer, but is shown in Figure 2-1 as a recommendation. A discussion on the use of hardened washers will be found in Section 3.8.

2.3 Principle of operation

2.3.1 Overview

The basic design of the pressure seal gasket joint is the wedge. The wedge-shaped pressure seal gasket moves relative to the bonnet as shown in Figure 2-4. As the name implies, the sealing action is increased by the action of the internal pressure acting on the underside of the bonnet, opposite to a standard bolted bonnet gasketed joint. An initial force (preload) is applied either by pulling the bonnet up, while preventing the gasket from moving up, or by pushing the gasket down, while preventing the bonnet from moving down. This illustrated in Figure 2-5 (a) and (b) respectively. The most common method is shown in Figure 2-5 (a).

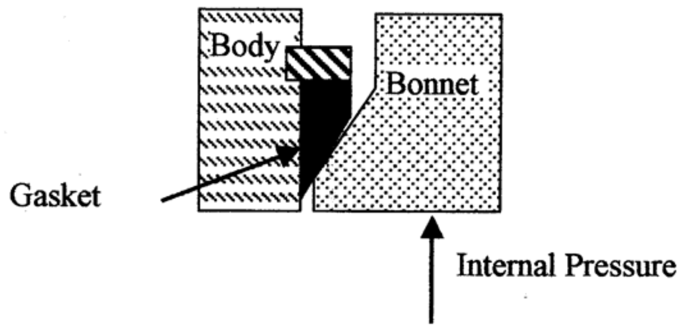

Figure 2-4
Pressure Seal Gasket Joint Basic Design

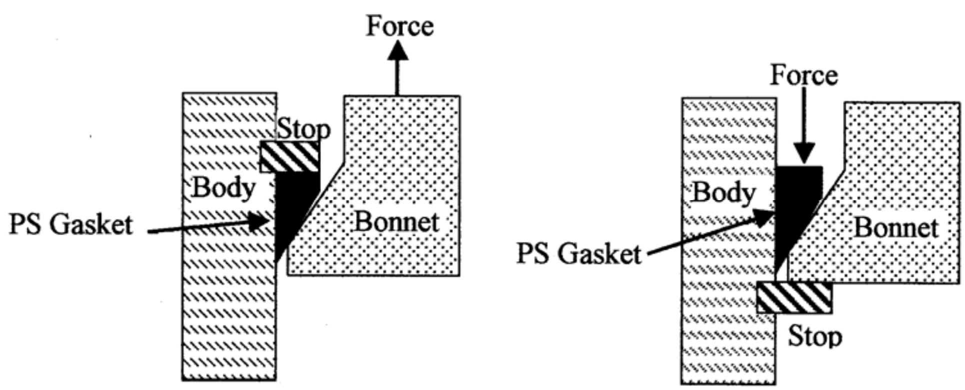

Figure 2-5
Methods of Causing Pressure Seal Gasket Preloading

Valve designs that use the method of Figure 2-5 (a) are shown in Figures 2-6. A design using the method of Figure 2-5 (b) is shown in Figure 2-7.

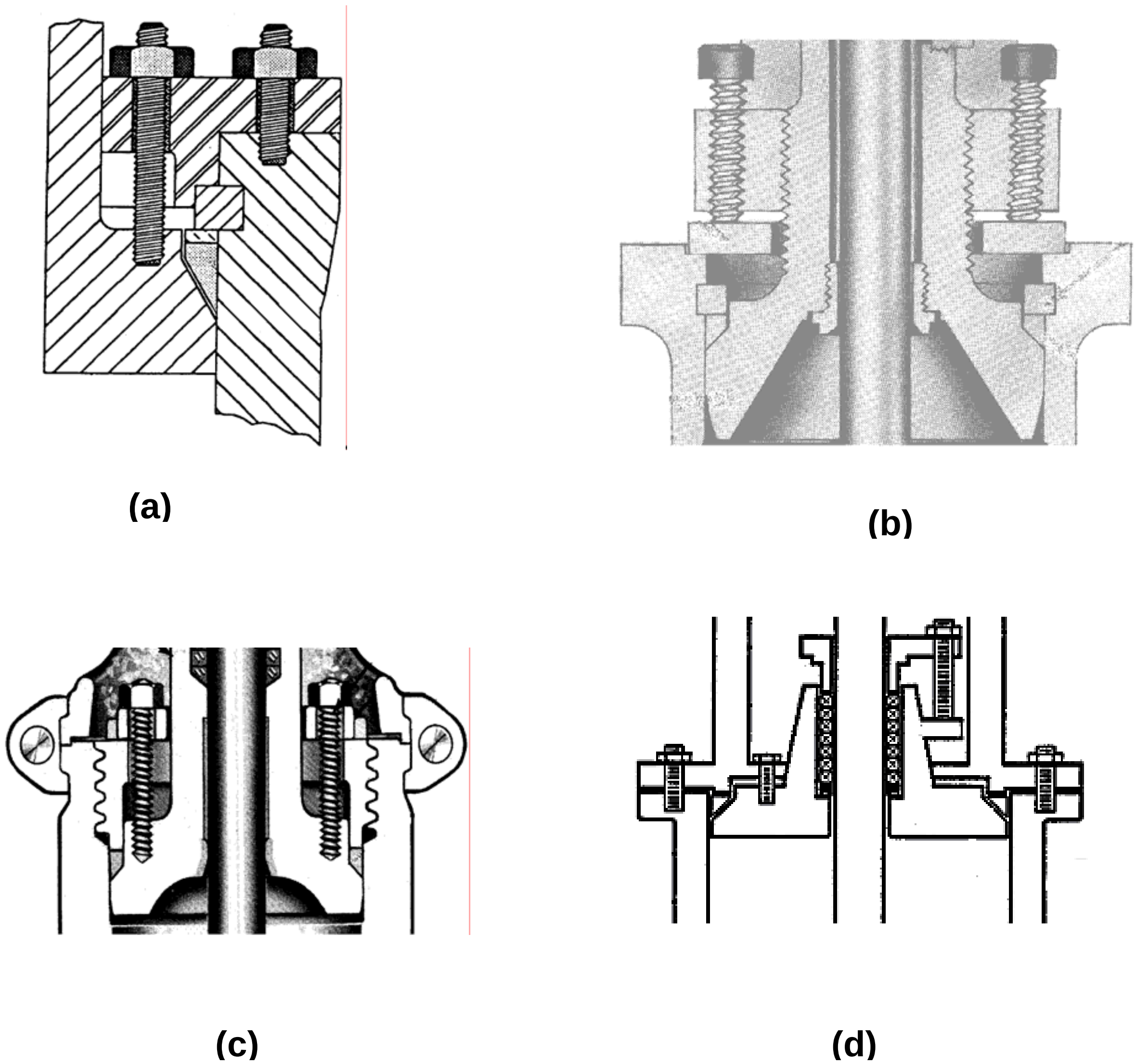

Figure 2-6
Designs Using the Preload Method of Figure 2-5(a)

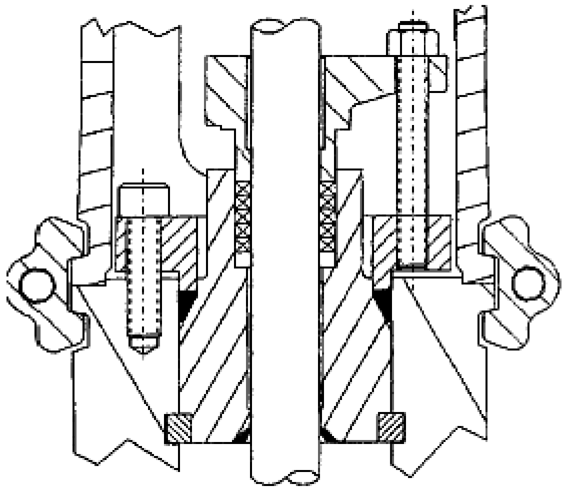

Figure 2-7
Design Using the Preload Method of Figure 2-5(b)

2.3.2. Bonnet to Gasket Sealing

The seal (contact and preload) between the bonnet and gasket occurs simply because of the geometry, i.e. the gasket sits on the bonnet. In order to maximize the seating stress on the bonnet, the contact area is minimized. This is done by making the angle of the bonnet slightly different from the angle of the gasket. This difference is on the order of 1-5°. The result is that the gasket contacts the bonnet circumferentially in a very narrow width.

2.3.3 Body to Gasket Sealing

Body to gasket sealing is much more difficult to achieve than bonnet to gasket sealing. Because there must be some clearance between the gasket and the body to facilitate installation and removal (which is also the case for the bonnet), the tip must initially be forced outwardly (radially) to close this clearance. Then an additional force must be applied to cause the sealing action.

This ability to seal depends several factors. The more important factors include the following:

- Pressure seal gasket angle
- Pressure seal gasket material strength
- Tip design
- Use of soft metallic plating
- Pull up stud forces
- Body and bonnet contact area finish
- Body/gasket clearance

Pressure Seal Gasket Angle

The most effective parameter to change is the gasket angle as shown on Figure 2-8.

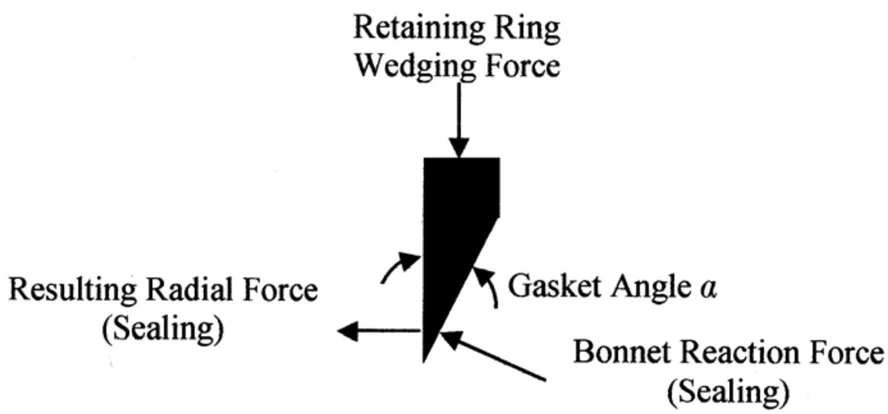

Figure 2-8
Gasket Angle and Sealing Forces

Simple force analysis shows that, absent friction, the resulting radial force (see Figure 2-8) created by the bonnet contact is equal to the retaining ring wedging force times the cotangent of gasket angle. Since the cotangent is larger at smaller angles, the amount of force created is larger with smaller gasket angles. Therefore, smaller gasket angles are desirable.

However, there is a limit on how small the angle can be. The bonnet reaction force also causes an opposing friction force to exist between the bonnet and the gasket. Similarly, there is a friction force created by the resulting radial force between the body and the gasket. These friction forces act against any vertical motion, up or down. Hence, this friction force resists the wedging action caused by preloading and pressure. If the angle is too small, this friction force can be large enough to resist the unwedging action of bonnet making removal difficult or impossible without damaging the body. As a result, the smallest angles commonly found are in the 20-25° range.

Tip Design

Related to the amount of force that can be applied to the body/gasket sealing surface and hence the pressure seal angle is the design of the tip. Most designs incorporate the design as shown in Figure 2-2 (a). This was the designed first introduced in 1946.

Figure 2-2 (c) show a variation that can be a problem. Since the dilation of the ring not only depends on the amount of force applied, but also the thickness of the cross-section of the tip, Figure 2-2 (c) will require more radial force to achieve the same dilation. A picture of such a ring is shown in Figure 2-9. On the other hand, Figures 2-2 (b) and (d), will tend to seal better because they do not rely solely on the dilation of the ring to cause sealing.

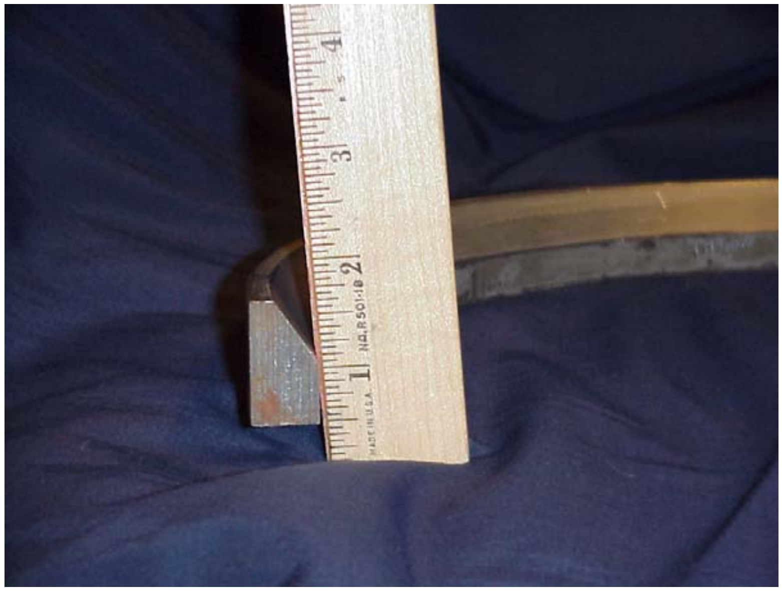

Figure 2-9
Tip Design Problem

Pressure Seal Gasket Material Strength

A lower pressure seal gasket material strength provides two benefits. First, it is easier to cause the gasket to expand (dilate). Second, because the hardness of the material is directly proportional to its strength, a lower strength material means a softer material. A softer material is able to conform to the variations of the surface being sealed. Typically, when the gasket material is made softer and the retaining ring is segmented, the top of the gasket requires an intermediate ring of a harder material in order to distribute the top loading of the gasket evenly.

Use of Plating

Plating is effectively a way to make the material act as if it were soft. By using a soft plating (≈0.001 inches, 25 microns) such as silver, the surface of the gasket is better able to conform to the surface of the body and hence better able to seal. In addition, the plating is typically corrosion-resistant and allows a wider variety of seal ring materials to be selected.

Bonnet Stud Forces

Increasing the number of studs and/or the size of the studs allows greater forces to be used during the preload operation. This can help to establish better conditions for sealing when the bonnet is pressurized. Personnel assembling the valve can also affect this force by good bolting practices, such as proper lubrication on the threads and nut mating surface, cleanliness, stud/nut condition, and proper torquing procedures.

Body and Bonnet Contact Area

The area of the body that the gasket contacts should be machined and free of corrosion. The dominant practice is to provide a series 300 (18-8) stainless steel inlay on the body contact band. The recommended surface finish is typically 32 Ra (0.81 microns). See Section 3.4.

Body/gasket clearance

The body gasket clearance must be kept to a minimum without causing difficulties with disassembly/assembly. Valve manufacturers have different tolerances for this gap and their values should be used. If vendor information is not available, clearance recommendations are contained in Section 3.4.

3 PROBLEMS AND MAINTENANCE OF PRESSURE SEAL BONNET VALVES

3.1 Introduction

This section describes maintenance methods that will increase the likelihood of leak free valve operation. A survey of INPO EPIX reported problems was conducted to identify problems of operation and maintenance. Of approximately 80 events involving pressures seal valves, only ten identified leakage issues. These ten events are summarized in Section 10. Of those, eight were attributable to maintenance. While this seems to indicate few problems, it probably does not show the true picture of maintenance-induced problems. This is because pressure seal leakage would be identified as part of Post Maintenance Testing and therefore not reported as an EPIX failure. This section addresses these issues and is largely based on [2], which was presented at the EPRI Fifth Valve Technology Symposium in 1995.

This section will cover the following topics:

- Proper removal of the old gasket
- Condition assessment of the old gasket and body sealing area
- Inspection and measurement of the new gasket and body sealing area
- Reassembly
- Retightening of the bonnet nuts after placing the valve in service
- Major repairs/modifications
- Other maintainability improvements

This section supplements instructions provided by the valve manufacture, and is not intended to replace them.

The nomenclature of Section 3 is based on Figure 3-1.

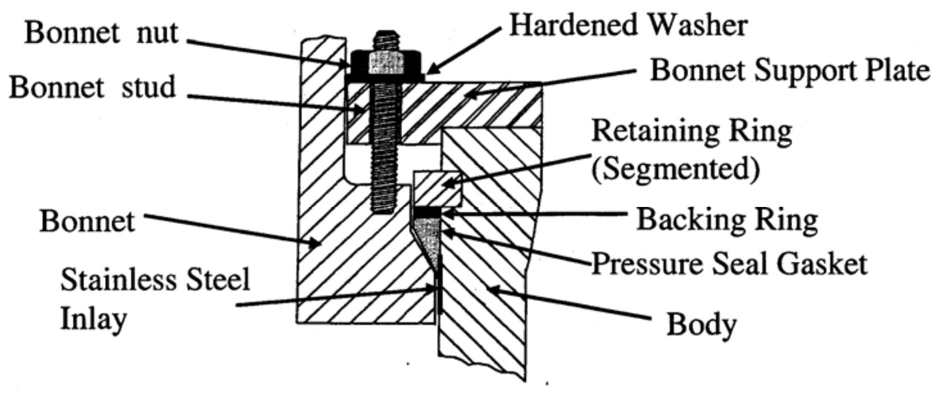

Figure 3-1
Basic Pressure Seal Assembly

3.2 Proper Removal of the Old Gasket

The following generic steps are recommended in pressure seal gasket removal:

- Before disassembly, inspect for leakage.
- Once leakage has been documented, apply plant approved penetrating oil to the retaining ring and gasket sealing area when accessible.
- Measure the valve stroke. This measurement will provide a valuable reference to be used during reassembly by assuring that the valve bonnet is at the proper location for the pressure seal gasket to contact the body-sealing surface.
- Use a torque wrench to check the bonnet nut torque to see if they are tight. If they are found loose, then check maintenance history records to find out when the valve was last disassembled and what torque value was used during the last reassembly. Also, check to see if the bonnet bolts were retorqued at normal system pressure.
- Once access can be had to the pressure seal gasket, match mark it to the body. This will facilitate leakage investigations.
- Segmented retaining rings are removed depending on the valve design. If no knockout holes are provided, then use a brass mallet and drive the segmented ring downward. If knockout holes are provided, use a drift to drive the segment ring inward. Some valves have key segments that must be removed first. See Figure 3-2 for identification of the key segments. Larger numbers of segments are common on larger valves, but if key segments are used, they are always cut as shown. It may be necessary to first loosen them with a brass mallet prior to using the drift.

Key Human Performance Point

Measure the valve stroke. This measurement will provide a valuable reference to be used during reassembly by assuring that the valve bonnet is at the proper location for the pressure seal gasket to contact the body-sealing surface.

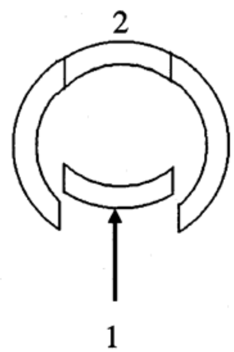

Figure 3-2
Removing Segmented Retaining Ring on Valves with Knockout Holes

- Once the gasket retaining rings or segmented keys are removed, the bonnet should be loosened using a hammer. Use a piece of wood to protect the surface of the bonnet. Care should be taken to ensure that the bonnet does not become cocked during this process.
- If the valve has not been opened for 10 years or more, disassembly can be very difficult, especially larger valves. The bonnet will not break loose easily from being wedged up on the pressure seal gasket, and corrosion will add additional friction in carbon steel bodies without a stainless steel inlay. If application of penetrating oil suggested earlier is not effective, then heat can be utilized to expand the valve body by wrapping resistance-heating coils around the outside of the body adjacent to the pressure seal area. Once the body is heated up to 300-400 degrees F, the bonnet should loosen and move easily when struck with a brass mallet.
- Removal of the bonnet and seal ring at this point should follow manufactures recommended procedure due to variability in design. It is vital that the axis of the bonnet and body remain aligned during disassembly to prevent the bonnet from jamming in the body bore. If the bonnet jams up, stop work, measure the bonnet misalignment, and correct as required. On large valves installed in vertical piping runs, special rigging fixtures may be required to safely handle the bonnet.

Key Human Performance Point

If penetrating oil has not worked, during disassembly, heat can be utilized to expand the valve body by wrapping resistance-heating coils around the outside of the body adjacent to the pressure seal area. The bonnet should loosen and move easily when struck with a brass mallet after reaching 300-400 degrees F.

3.3 Condition Assessment and Repair of Old Gasket and Body Sealing Area

A detailed inspection of the valve components during disassembly is critical to identifying the cause of the leakage. The following items should be checked:

- Inspect the old pressure seal ring for evidence of leakage either on the inside diameter (ID) or outside diameter (OD) surfaces. The outer and/or inner surface may be eroded away or steam cut. See examples in Figure 3-3. Note that vertical score marks on the OD are made during removal of the wedged gasket. Be sure to match mark the old pressure seal gasket for orientation prior to removal so that the leakage areas can be more accurately identified relative to the valve body and/or on the bonnet.
- Check the area of the bonnet where the pressure seal gasket contacts and seals against it. This area should have a very good surface finish and be free of any steam cutting or pitting. A shiny continuous ring approximately 1/16" – 1/2” (1.6-12.7 mm) wide should be seen on the bonnet. This indicates good sealing of the gasket to the bonnet.
- Inspect the valve body bore especially in the area where the pressure seal gasket contacts it. There should be a shiny continuous ring approximately 1/16" – 1/2 "(1.6-12.7 mm) wide on the bore. There should be no scratches, tool marks, nicks, pitting or porosity, and no eroded areas of damage from leakage. The surface finish of the body bore should be very smooth (32 microinch Ra (0.81 microns) finish). The use of a machine finish standard sample block to determine this finish is recommended. Comparison should be made by dragging a fingernail across the ridges of the inspected surface and comparing with the block finish.

18” Feedwater Check Valve Silver Plated Metal Pressure Seal, 350 degrees, 1150 psi. Leakage path eroded the coating as shown.

Damaged Pressure Seal Gasket, Plating Adhering to Body

Figure 3-3
Gasket Damage

Key Technical Point

A detailed inspection of the valve components during disassembly is critical.

3.4 Inspection And Measurement of New Gasket and Body Sealing Area

Inspection and measurement are critical for satisfactory performance. Below are suggested guidelines.

- The inside diameter of the valve body where the pressure seal gasket is positioned needs to be accurately measured for diameter and roundness. This measurement should be taken in at least four locations 45 degrees apart to determine the roundness of the valve body. This is critical in ensuring a leak tight bonnet assembly. Some valve manufacturers machine the valve body bore on a small taper to ease installation and removal of the pressure seal, e.g., the bodies that use gaskets as shown in Figures 2-2 (b) and (d). Personnel taking measurements of the body bore need to be aware of this taper and measure below the tapered area where the pressure seal gasket is positioned during assembly.
- The outside diameter of the new pressure seal gasket needs to be measured to determine the fit between the gasket and the valve body. This measurement should be taken in at least four locations 45 degrees apart to determine the roundness of the pressure seal ring. Sometimes pressure seal rings can become damaged during handling or warp after manufacturing.
- The following standards are recommended for all pressure seal bonnet valves that lack manufacturer's guidance:
  - Surface finish of body bore, bonnet OD and pressure seal gasket: 32 microinch Ra (0.81 microns) or better.
  - Maximum blend-out depth on body bore: 0.010" (250 microns)
  - Diametrical clearance between pressure seal and body bore ID: 0.002 inch (50 microns) plus 0.0004 (0.4) times the nominal valve size in inches (DN) to a maximum of 0.015 inch (380 microns)

    Example: For a 10 inch valve 0.002 + (0.0004 x 10) = 0.006"

    For a 36 inch valve 0.002 + (0.0004 x 36) = 0.016 > 0.015 □ Use 0.015"
  - Roundness of pressure seal gasket, body bore and bonnet OD: 0.001" per inch of diameter (1 micron per DN).

3.5 Reassembly

3.5.1 Steps

The following steps and considerations are recommended when reassembling the valve.

- Always use a new pressure seal gasket during reassembly. Wear gloves when handling the pressure seal gasket to prevent contamination of the surface finish or plating on the gasket.

- After installation of the bonnet, gasket, and retaining ring or equivalent; the valve is usually stroked open to force the gasket to seat. Use caution when utilizing the handwheel so that allowable backseat loads are not exceeded. When the gasket is seated, verify the bonnet is not in the wrong position by comparing the valve stroke used with the stroke obtained during disassembly.
- If the valve cannot be stroked, then the gasket must be seated using the bonnet studs. The bonnet nuts are torqued in a crisscross pattern to seat the gasket. The lift for each pass should not cause the bonnet to cock into the side of the body.
- On some valves, the bonnet studs may be too short to start the torquing properly. Use longer studs to provide proper alignment of the bonnet. Once the bonnet is drawn up, reinstall the permanent studs.
- Once the initial reassembly is complete, measure the valve stroke. If the bonnet is cocked or jammed in the wrong position, you should be able to detect this by comparing the valve stroke with that taken during disassembly.
- During preloading (after initial gasket seating), proper torquing of the bonnet bolting is critical to keeping the bonnet aligned properly. The bonnet nut/stud should initially be snug tight. Apply the torque in a crisscross pattern ("star") similar to that used for flanged joints. Four star passes should be adequate. Complete the preload process by performing two leveling ("circle or ring") passes. This will minimize the variation from stud to stud. It also increases the average preload. See discussion in Section 3.6.
- On check valves, some designs have cap screws extending through the bonnet retaining plate and threading into the bonnet. This makes it very difficult to monitor or measure if the bonnet is aligned properly during torquing. A good practice is to replace these cap screws with studs and nuts so that the stud can be used to measure proper alignment during bonnet torquing.

3.5.2 Large Gate and Globe Valves with Stem Not Vertical

Prior to rigging the bonnet into position, insert either a packing carbon spacer or an aluminum sleeve into the bonnet stuffing box. See Figure 3-4. This alignment sleeve will allow the full bonnet weight to be placed on the stem during installation without damaging it. Bonnet alignment is always difficult for valves with horizontal stems. If allowed, drill additional holes in the bonnet pull up plate to allow for direct measurements of the bonnet pull up to insure it remains even. At least three holes at approximately 120-degree locations on the same radius should be obtained.

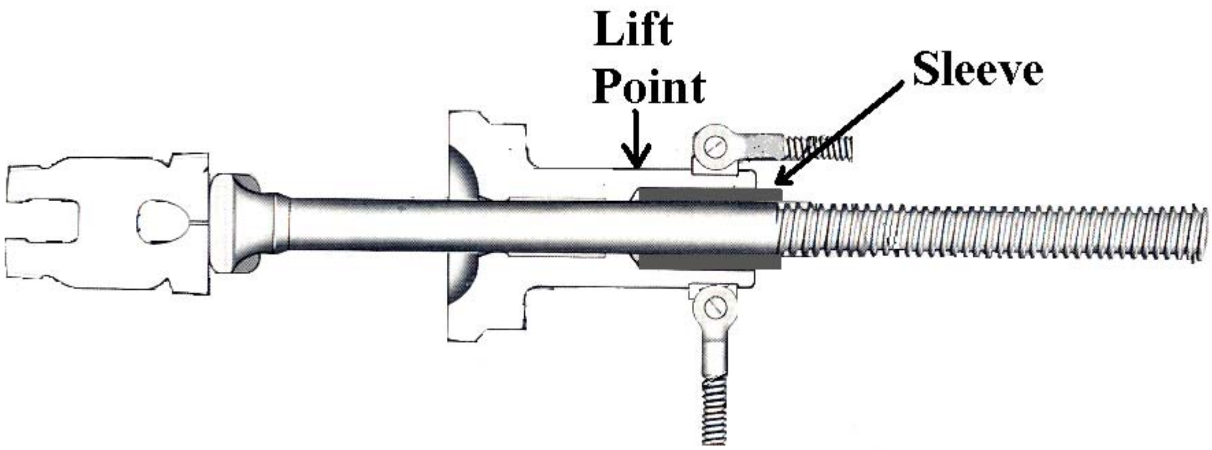

Figure 3-4
Bonnet Guiding in Large Valve with Stem Not Vertical

Once the bonnet is pushed into the valve body past the pressure seal fit-up area, the rigging can be relaxed and the pressure seal gasket, retaining ring, and the bonnet support plate installed. The rigging should then be used to aid in centering the bonnet during initial torquing of the bonnet bolting. The alignment sleeve may then be removed.

3.5.3 Large Vertical Run Check Valves

Special rigging fixtures should be used to assist in bonnet removal and installation to prevent damage to the sealing area. After the bonnet support plate is removed, a threaded guide bar can be installed in a hole used for the bonnet bolting. Add a counterweight to the outer end of the guide bar as shown in Figure 3-5.

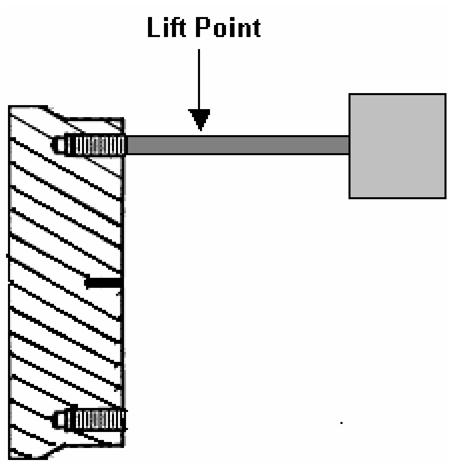

Figure 3-5
Check Valve Bonnet Special Rig for Valves in Vertical Lines

3.6 Preloading

3.6.1 Bolt Preload Torque Calculation

The basis for preloading is to minimize movement of the bonnet when the valve is pressurized.

When the valve is pressurized, the pressure force on the bonnet pushes it up. This movement can vary from microinches (microns) to as much as 1/16" (1.6 mm) on some larger valves and depend on the relationship of the preload force to the pressure force. The result is the bonnet bolting will always lose some preload stress. The most effective way to minimize this loss is to make the preload load force achieved by torquing at least equal to the pressure force pushing the bonnet up. The following is a discussion of how this torque value is calculated. A calculation sheet is provided in Section 8.

First, determine the force caused by pressure operating on the bottom of the bonnet. This is the result of the maximum operating pressure pushing against the bottom of the bonnet, and is calculated by multiplying the pressure times the bonnet area.

To calculate the torque, the amount of force required of each bonnet stud is required. This is determined by dividing the pressure force by the number of bonnet studs. The amount of torque required is calculated using the standard torque equation: T = KFD. See Section 3.3 of [5] for additional information on calculating torque.

The torque value obtained must be adjusted for uncertainty. Section 4.1.4 of [6] reports this variability with hardened washers under the nut to be ± 26%. Therefore, the torque value should be increased by at least 30% to provide additional margin. Compare the torque to that supplied by the valve vendor. If it is greater than the recommended, then consult the vendor to see if the vendor value can be raised to the calculated value. The basis of this value is the strength of the bolt, bonnet material or the bonnet support plate. See Section 3.6.3 for a discussion of bolting efficiency.

3.6.2 Torquing

When torquing for preload the following are important to proper makeup:

- Use of a crisscross pattern with 3-4 passes during torquing followed by two leveling passes (circle or ring) at the final torque value. See Section 3.8 of [5] for additional details.
- Use a calibrated torque wrench.

3.6.3 Bolting Efficiency

With the critical nature of the marginal loading of the gasket described above, closer attention is required of the bonnet nuts/studs efficiency. The variability of ± 26% discussed in Section 3.6.1

assumes certain actions with respect to "joint" must be accomplished. A great deal of attention has been given to this subject in the makeup of flanged joints. These actions are discussed in Section 3.3 and 3.8 of [5] and 4.1.4 of [6] and should form the basis of a good bolted joint program.

These actions are summarized here for convenience and emphasis.

Fastener Condition

Ensure the fastener threads are not damaged, corroded, dirty. Turn the nut up and down for the full length of the stud. Eliminate any burrs; remove any form of corrosion or foreign material.

Lubrication

A high-grade nickel-based, or equivalent, lubricant must be applied on the threads and between the nut and hardened washer.

Key Technical Point

Ensure the fastener threads are not damaged, corroded, dirty. Use a high-grade nickel-based, or equivalent, lubricant. Apply it both on the threads and between the nut and hardened washer.

Hardened Washers

Use hardened washers, e.g. ASTM F426. Typically, the valve manufacturer does not include hardened washers under the nut. The torque equation in 3.6 assumes the surface below the nut, i.e., the bonnet support plate, is in good condition. However, the support plate is always softer than the nut and over time can become damaged. This damage can result in a significant loss of the desired bolt load (values up to 25% have been reported by one plant) due to the need to overcome the resulting friction. Therefore, hardened washers are always recommended in order to assure the desired bolt load is achieved. See Sections 3.3.3, 6.11, 10.1.3, and 11.7.3 of [5] for additional information. The use of two hardened washers has been reported by [6] as improving variability by as much as 7.5 % and an increase of average bolt force as much as 15%. Use a thin film of lubricant between the washers to maximize this effect.

Key Technical Point

Typically, the valve manufacturer does not include hardened washers under the bonnet nut. The damage caused by the nut on the softer support plate material can result in a significant loss of desired bolt load. Therefore, <u>hardened washers are always recommended</u> in order to assure the desired bolt load is achieved.

Material

Use the same nut/stud material used for flanges, i.e., A194-2H, A193-B7. These quality bolts will ensure that the maximum load is obtainable.

3.7 Retightening of Bonnet Nuts after Initially Placing the Valve in Service

Bonnet bolting on pressure seal bonnet type valves should be retorqued at normal system operating pressure (hot retorque) to maintain the bonnet joint as leak tight as possible. Even though preloading is intended to minimize movement and loss of preload when the valve is pressurized, retightening after placing the valve in service is also very effective in overcoming the repeated action of depressurization and repressurization.

Key O&M Cost Point

Retightening of the bonnet nuts after placing the valve is service (hot retorque) is always recommended.

3.8 Major Repairs / Modifications

3.8.1 Body Bore Repairs

Body bore repairs are the most common repairs associated with pressure seal gaskets. It is needed when valve body bore surface finish is very poor or the body bore is excessively out-of-round. Portable machining equipment can be utilized in the field to re-bore the valve body in place. Once the body bore machining is complete, an oversize pressure seal gasket will need to be purchased to remain within the recommended diameter-difference tolerance. Minor scratches or defects in the body bore (0.010" max., 0.25 mm max) can be blended or buffed out. For deeper defects, re-boring and weld repair, in that order is recommended. Usually the body bore can be machined out to accept a larger pressure seal gasket and welding in the body is not required. Since nearly all pressure seal valves using a metal ring will have cladding in the sealing area, ensure that the existing clad is thick enough. As described in Section 2, this cladding is usually 300 series stainless steel. Consult the valve drawing for material type and thickness. Even though the weld is not pressure retaining and strength not a problem, porosity can be.

Recent experience with graphite pressure seal gaskets indicates that they should be very successful in sealing up valves with scored or out-of-round body bores. This type of pressure seal gasket may eliminate the need for valve body bore repairs. See Section 4 for a discussion of graphite gaskets.

3.8.2 Oversize Body Bores

If the problem is simply an oversize body bore, i.e., excessive clearance, then oversize pressure seal gaskets are recommended. For example, if the valve body bore is more than .015" larger than the OD of the pressure seal gasket than an oversize pressure seal gasket should be installed. The standard size of oversize pressure seal gaskets would be .015" and .030" larger than a standard pressure seal gasket. Graphite gaskets are an alternative. See Section 4 for a discussion of graphite gaskets.

3.8.3 Canopy Seal Welding

Some pressure seal bonnet valve manufacturers offer designs that incorporate a "lip seal" or "canopy seal" arrangement as part of the bonnet. This "seal" area can be welded, once the valve is assembled, and acts as a secondary leak tight seal to the pressure seal gasket.

This same "seal weld" idea can be used to repair a leaking pressure seal bonnet joint, if the valve can be depressurized. On most bonnet designs a metal "seal ring" can be seal welded between the bonnet and valve body bore to stop leakage through a leaking pressure seal bonnet joint.

3.8.4 Temporary Leak Repair Methods

A leaking pressure seal joint can be successfully injected with sealant while the valve is in service and pressurized. However, there are some difficulties in achieving an on-line seal of a leaking gasket. Only a small space is available at the tip of the pressure seal ring into which compound can be injected. See Figure 3-5. Exact dimensions need to be provided by the valve manufacturer to determine the proper spot and depth to drill for installation of the injection valves. On larger valves, multiple injection valves will be needed to ensure that the compound is injected as close to the leakage area as possible. Refer to Section 2.3.5 of [7] for information on leak sealing of pressure seal valves.

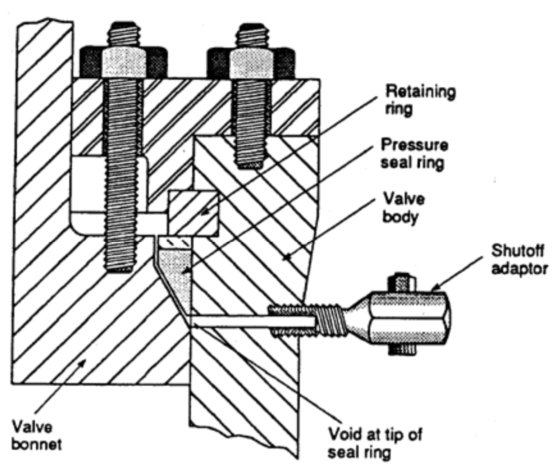

Figure 3-5
Leak Sealing Repair Injection

Once the proper spot to inject is found, the leak can usually be stopped. If the valve is later depressurized and cooled down, it will usually require re-injection if the valve is repressurized to stop the leakage that is likely to develop.

Injecting a pressure seal bonnet joint should not be considered a permanent repair due to the likelihood that the leak will redevelop after thermal and pressure cycling of the system. The valve should be disassembled and repaired correctly at the next target of opportunity.

3.9 Improvement Methods/Enhancements

3.9.1 Live Loading Pressure Seal Bonnet Bolting

Belleville washers can be installed on the bonnet studs to maintain the stretch/tension in the studs even after initial pressurization and bonnet movement. Refer to Figure 3-6. This should be considered on valves that cannot be retorqued after system pressurization. Technical information for using belleville washers to maintain load are found in Section 5 of [8].

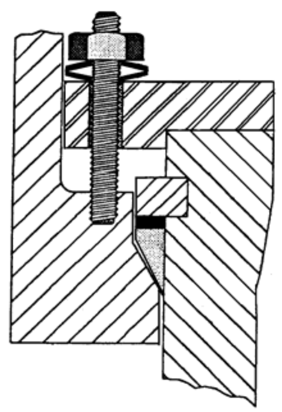

Figure 3-6
Live Loaded Pressure Seal Bonnet

3.9.2 Graphite Pressure Seal Gaskets

Graphite pressure seal gaskets have matured to the point that they are supplied as standard on some pressure seal valve. As a retrofit, much has been learned and they are very reliable, if certain precautions are observed. A complete discussion of graphite pressure seal gaskets is contained in Section 4.

3.9.3 Larger / Stronger Bonnet Bolting

On most valves, the bonnet bolting is only sized to provide enough force to initiate the seal of the pressure seal gasket. If bonnet retorques are not practical, then the size and material of the bonnet bolting can be increased and strengthened to allow a much higher wedging force to be exerted by the bonnet bolting to set the pressure seal without system pressure. It is recommended that a high strength, high temperature stud and nut material, e.g., A193-B7 and A194-2H be used. These materials are readily available in a power plant. The bonnet material should also be taken into account when increasing the torque on the bolting to ensure proper thread engagement is obtained.

3.9.4 Machining a Grove in Pressure Seal Ring OD

When using a standard metal pressure seal ring in a valve body bore which is on the large size (.015"-.030" larger than the pressure seal OD), a groove or relief can be machined into the OD of the pressure seal gasket just above the sharp edge. See Figure 3-7 for suggested dimensions. The distance from bottom of the groove to the bottom of the gasket should be approximately equal to the width of the seal line as evidenced from the old seal ring. Alternatively, the following values have been found satisfactory and may be used for comparison:

Valve Size (inches)	Distance (inches)	Valve Size (inches)	Distance (inches)
2 – 4 (DN50-100)	0.13 (3 mm)	11 – 15 (DN275-375)	0.38 (10 mm)
5 – 7 (DN125-175)	0.19 (5 mm)	16 – 24 (DN400-600)	0.50 (13 mm)
8 – 10 (DN200-250)	0.25 (6 mm)		

The groove helps the pressure seal to conform or bend out easier during the wedging of the bonnet. It also helps to initiate the seal sooner and more completely during initial torquing of the bonnet.

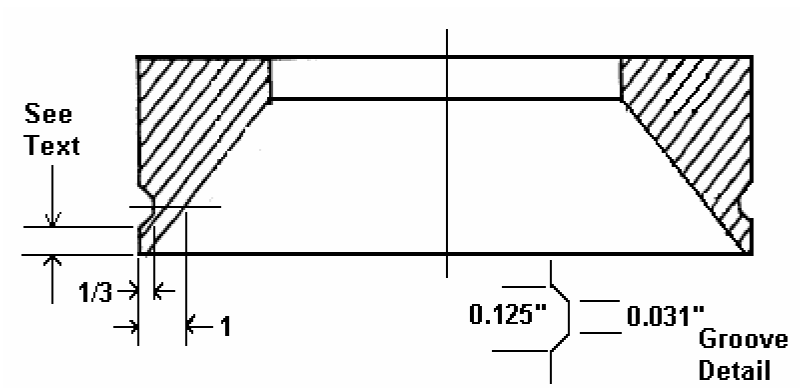

Figure 3-7
Pressure Seal Gasket Groove

3.9.5 Add/Change Thickness of Backing Ring

Some valve manufacturers do not use a backing ring above the pressure seal gasket. By adding a spacer ring or installing a thicker or thinner ring, the position of the pressure seal gasket can be changed to align the critical sealing edge with an area inside the valve body bore which is free of surface finish problems from earlier use. However repositioning of the pressure seal gasket also repositions the bonnet and, therefore can change the total available stroke of the valve.

3.9.6 Custom Size Pressure Seal Gaskets to Fit OD Needed

Oversize pressure seal gaskets are available and should be used to tighten up clearances in the bonnet joint assembly if delivery time permits. Evaluate the dimensions of the body and pressure seal gasket to be used for reassembly. If the gasket fits too loose in the body, then an oversize gasket is called for. It is cost effective to obtain extra oversize pressure seal gaskets for future use.

3.10 Other Maintainability Improvements

Listed below are some suggestion for improving maintainability. Some may involve a modification depend on individual plant process.

- Drill/tap holes in top of pressure seal gasket to ease removal and installation during maintenance.
- Drill knockout holes through valve body for segmented key removal on valves that do not have such maintenance holes.
- Machine slots in the key segmented ring(s) to allow the use of a screwdriver to pry out. Similarly, drill holes in the top of hard to access segmented rings for ease of removal.
- Machine a radius on the outer edge of the bonnet adjacent to the segmented rings. This will ease alignment during assembly, especially on valves mounted horizontally.
- Machine slots or holes in the bonnet support plate to allow the use of dial indicators, etc to monitor bonnet pull-up on reassembly to insure alignment is maintained.

4 GRAPHITE PRESSURE SEAL GASKETS

4.1 Introduction

The use of graphite pressure seal gaskets has developed since about 1990 from an application of "last resort" to the preferred practice for this troublesome valve part. No longer is it reserved for fixing problems, but rather to prevent problems. Graphite seals are more forgiving of valve conditions and provide economic savings compared to metal seals. Shorter delivery times are also available. Some utilities have committed to the wholesale conversion from metal pressure seals to graphite seals based on these facts.

However, improper application or installation of graphite seals can have serious consequences, lead to severe valve leakage, and even forced plant shutdowns. The purpose of this section is to highlight the precautions that must be taken as well as those few instances where the use of graphite is not warranted.

Much of the material contained in this section is derived from [3] which was presented at the 1st International Conference on Sealing Technology and Plant Leakage Reduction.

4.2 Manufacture of Graphite Gaskets

Flexible graphite is pure graphite that contains no binders to retain its shape. The process used to manufacture the flexible graphite is called exfoliation. A useful property of flexible graphite is its ability to conform to the surface it is pressed against. When the material (usually in a ribbon form) is placed in a die (mold) and compressed, it assumes the shape of the die. An early use of flexible graphite was as a substitute for asbestos packing. While early forms were braided, it was quickly realized that the most effective form was a solid ring manufactured using a die.

4.3 Graphite Gasket Sealing Action

To understand the use of graphite gaskets, it is important to understand how they compress compared to the metal gasket. Figure 4-1 shows a valve pressure seal area with a metal and graphite gasket. As discussed in Section 2, the metal gasket forms a virtual line of contact around the inside of the body and outside of the bonnet. The metal gasket, while deforming slightly to cause sealing, compresses less than 0.001 inch (25 microns). In the case of the graphite gasket, the material is compressed significantly into space formed by the body, bonnet and retaining ring. This compression action results in the material flowing and forming a sealing surface rather than a line-of-contact. This ability of graphite to flow and conform to the sealing surfaces is the reason for improved sealing over minor imperfections.

Key Technical Point

The ability of graphite to flow and conform to the sealing surfaces is the reason for its improved sealing over minor imperfections.

However, this ability to flow and compress is also the reason why the characteristics of extrusion and consolidation, as discussed in following paragraphs, must be understood, and provided for, if problems are to be avoided.

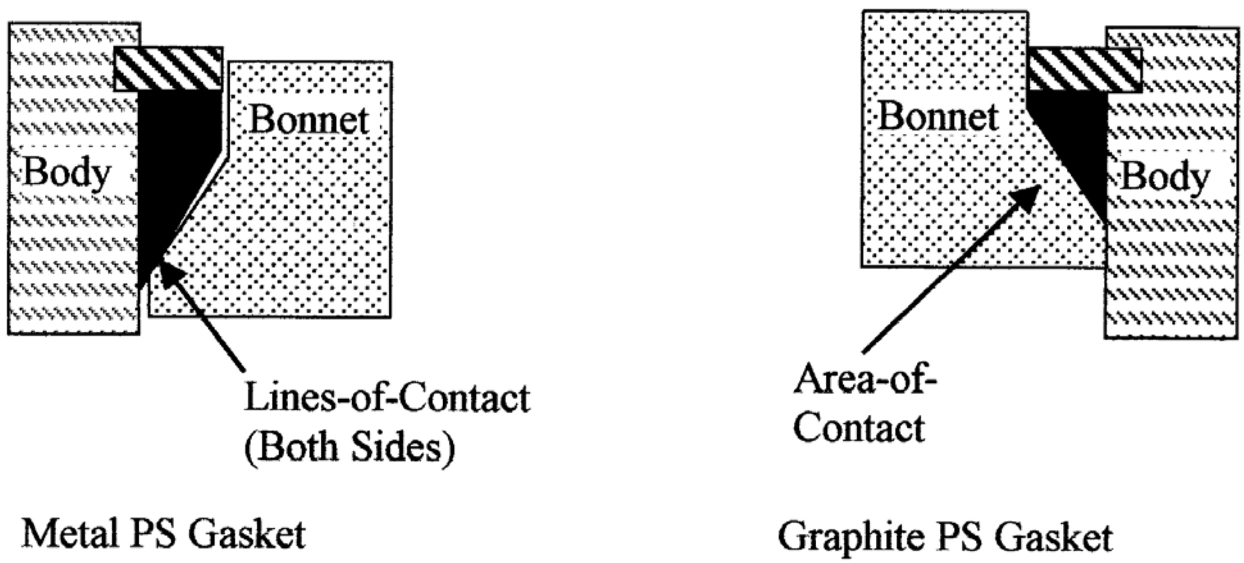

Figure 4-1
Graphite Pressure Seal Sealing Action

Key O&M Cost Point
The ability to flow is also the reason why the following characteristics must be understood, and provided for, if problems are to be avoided such as extrusion, consolidation and creep.

4.4 Extrusion

4.4.1 Problem Description

When graphite gaskets were introduced, an early problem was the *extrusion* of gasket material. Extrusion refers to the tendency for the graphite material to flow into gaps as it is loaded. (This same problem occurs in valve packing and is the reason for the wiper/composite rings at the top and bottom of the die-formed graphite rings.) Note that in Figure 4-2 the graphite gasket material is extruding between the retaining ring and bonnet (top gap) and between the body and the bonnet (bottom gap). This extrusion can take place during preloading and after preloading, i.e., while the valve is in service. In practice as the material flows out, gasket stress is lost. A loss of gasket stress means degradation in the sealing capability of the gasket. Therefore, even if the preload is correct, leakage can occur. As a result, early applications of graphite focused on controlling gap clearances to deal with extrusion.

Initially, only the top gap was usually addressed, since the bottom gap was considered adequately controlled (narrow enough) by the need to ensure sealing with the metal gasket. When the top gap was too large (as they frequently are) and/or the retaining ring was segmented (resulting in radial gaps), a backing ring with a tighter clearance was added between the gasket and the retaining ring. See Figure 4-3. This is still the practice today.

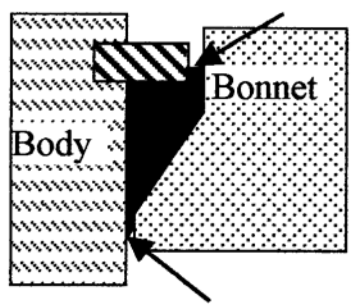

Figure 4-2
Top and Bottom Gap Extrusion

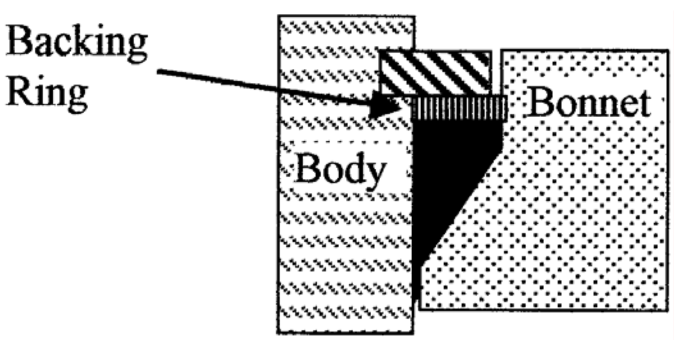

Figure 4-3
Prevention of Top Gap Extrusion

Extrusion at the bottom gap posed a more difficult problem. While bottom gaps were typically smaller, some extrusion did occur (See Figure 4-2). Even if the loss of gasket stress was minor, this extrusion resulted in the introduction of foreign material into the system. See Figure 4-4.

Figure 4-4
Bottom Gap Extrusion

Bottom gap extrusion was addressed by using a metal cap at the tip of the graphite gasket. This cap was manufactured from stainless steel and was typically 0.005 to 0.020 inches (12 – 50 microns) thick.   With experience it was found that using a metal cap on the top of the graphite ring should also be requuired even though the gap provided by the backing ring was small. Figure 4-5 shows a graphite pressure seal ring with bottom and top caps.

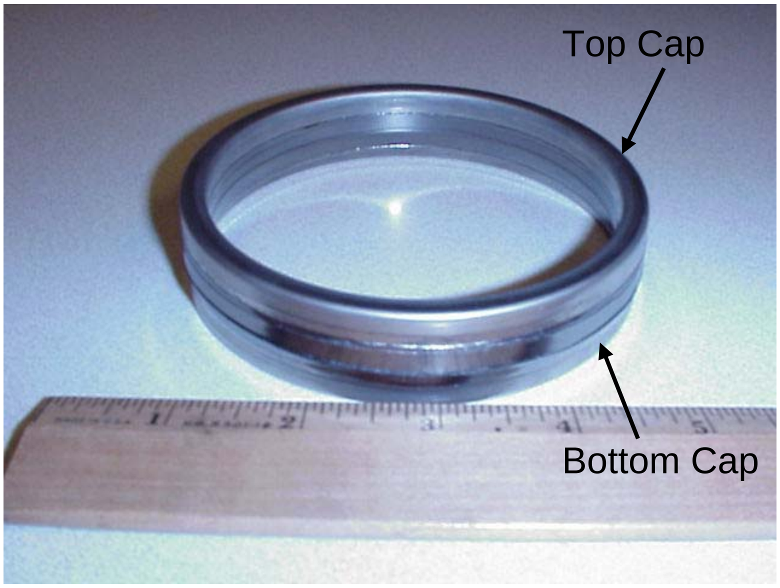

Figure 4-5
Graphite Gasket with Top and Bottom Caps

4.4.2 Controlling Extrusion

Based on the preceding discussion extrusion can controlled as follows:

- By minimizing the clearances between
  - the body and gasket
  - the bonnet and gasket
  - the retaining ring and bonnet.
  - the segmented ring pieces.

- The clearances between the retaining ring/bonnet normally require the use of a backing ring, unless the gap is very small, similar to the bottom gap. If a segmented ring is used, a backing ring is always required. Even if the retaining ring/bonnet or backing ring/bonnet gap is small, a top cap is advisable. However a top cap should never be used as a substitute for a backing ring.

- The clearances between the body/gasket and bonnet/gasket should always be controlled using a bottom cap.

Key Technical Point

Extrusion is controlled by minimizing the clearances between the body, bonnet and retaining ring. This can be done by the using of a backing ring and top cap for the top gap and a bottom cap for the bottom gap.

Key O&M Cost Point

Whenever possible, both top and bottom caps are desirable. The additional expense for using both caps is more than offset by the higher degree of confidence that the gasket will not fail in service.

Consolidation

4.5.1 Problem Description

Even though extrusion was addressed, failures still occurred initially when the graphite gasket dimensions were the same as the metal gasket dimensions. These failures were the result of gasket consolidation. Note in Figure 4-6 that the bonnet with the graphite gasket is higher up than the one with the metal gasket. This occurs because the volume containing the gasket has become smaller as the gasket is compressed. This property is called *consolidation*. The distance the bonnet travels must be accommodated.

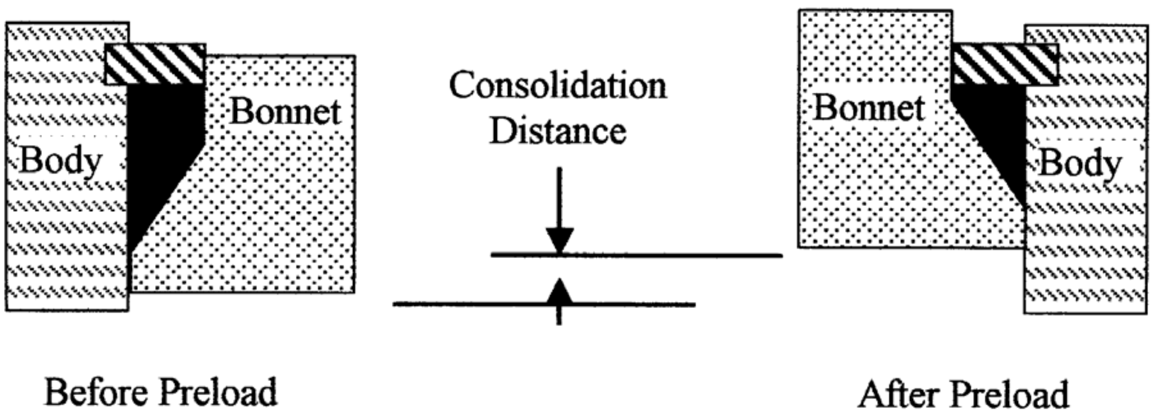

Figure 4-6
Consolidation

Consolidation occurs primarily because flexible graphite is porous and the space of all clearances must be made up. It contains micro-bubbles of gas that were captured when it was manufactured. When the gasket is compressed, these bubbles are compressed with some of the gas escaping. The amount of consolidation varies somewhat depending on material. The flake type graphite used in pressure seal gaskets consolidates about 3-3.5 times that of the typical sheet gasket material. The amount of volume change or consolidation to be expected is approximately 20 per cent.

Key Technical Point
The amount of consolidation is expected to be approximately 20%.

The result of not accommodating consolidation is shown in Figure 4-7. In both cases, the bonnet has traveled upward more than if there had been a metal gasket in place. In Figure 4-7(a) the bonnet has bottomed-out on the bonnet support plate. In Figure 4-7(b) the bonnet neck/seal area break has bottomed-out on the retaining ring. This means the gasket cannot be compressed further and preload may be inadequate since the volume was not reduced sufficiently to raise the gasket stress to the critical value. In other words, when consolidation is not accounted for or accommodated, insufficient gasket stress is likely to occur.

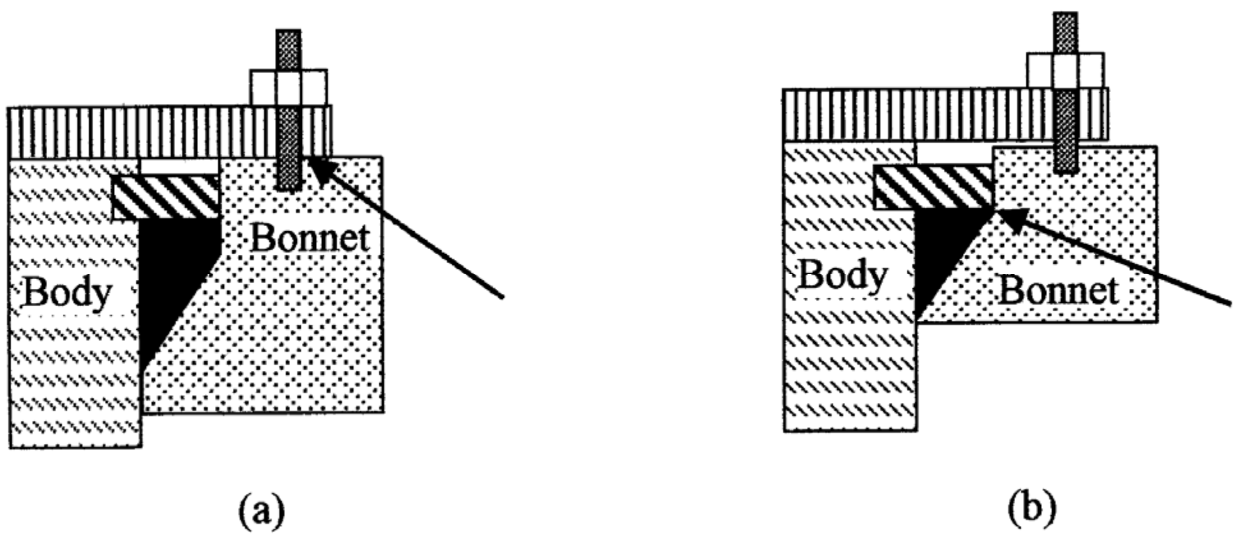

Figure 4-7
Bottoming Out Locations

Interferences as described above are commonly the result of using a graphite gasket that has been manufactured using the same basic dimensions as the metal ring, i.e. a one-for-one replacement.

4.5.2 Accommodating Consolidation

The objective in accommodating consolidation is to ensure that the bonnet position relative to the body remains the same as it was for the metal ring. Failure to do so means the bonnet moves upward, resulting in possible interferences as shown in Figure 4-7. The most straightforward approach to accommodate consolidation is to use a graphite gasket with a neck height (Figure 4-8 (a)) 20% higher than the neck height of the metal gasket.

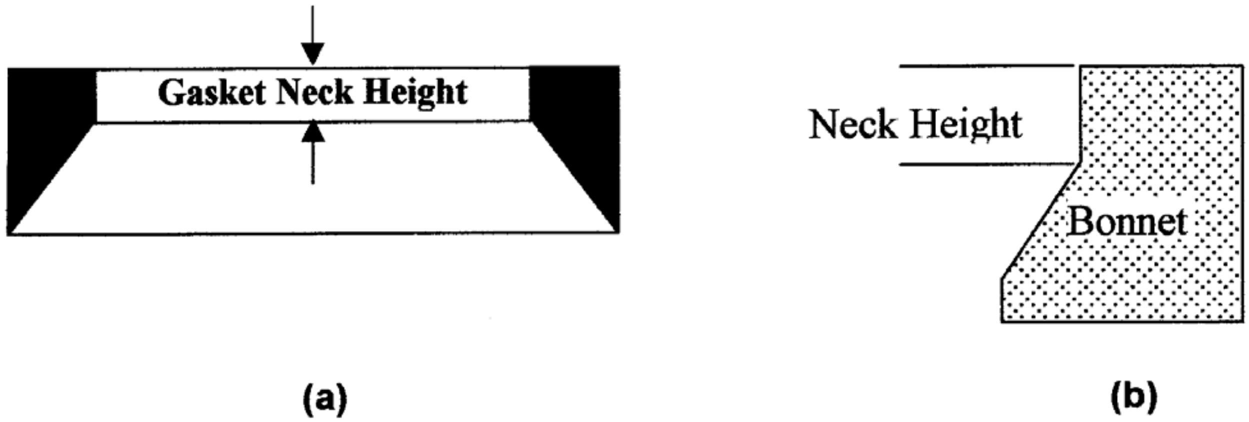

Figure 4-8
Height Requirement to Accommodate Consolidation

However, there must be sufficient height in the neck area of the bonnet (Figure 4-8 (b)) to accommodate the extra graphite needed. If there is not sufficient height, then the material at the gasket top will hang up on the bonnet top when load is applied (similar to trying to compress packing that is not completely in the stuffing box). Some of the possible solutions are as follows:

- Make sure the measurements are accurate and recheck the amount needed.
- Reduce the amount of consolidation assumed, i.e. less than 20%, and determine if interference with the bonnet or support plate will occur (Figure 4-7).
- Ensure the seal angle of the graphite gasket matches the bonnet angle and not the metal gasket angle.
- Manufacture a bonnet neck extension ring as shown in Figure 4-8. Usually the thickness of the ring is limited by the retaining ring, but the new neck length increase is on the order of 2.5 times the thickness for a 20-25° gasket angle. The extension should be secured with setscrews as shown, or tack welds on the top of the bonnet if plant procedures permit. Careful analysis of other possible interferences is required.
- Consult the vendor

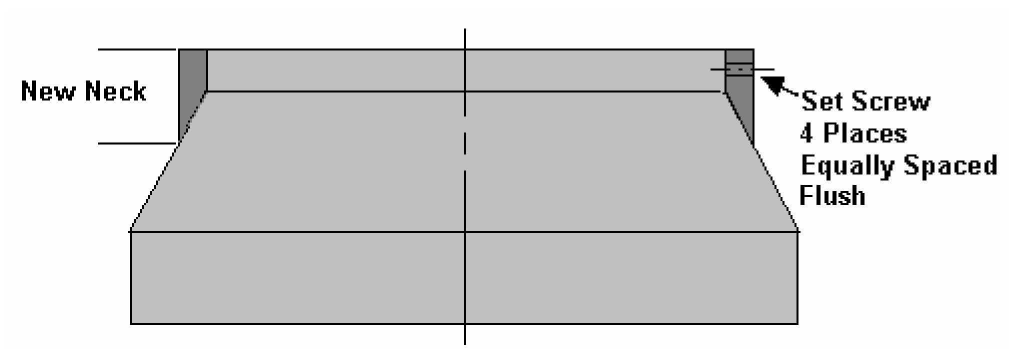

Figure 4-8
Bonnet Neck Extension Ring

Key Technical Point

Consolidation is best handled by using a graphite gasket with a neck height 20% higher than the metal gasket. There must be sufficient neck height to accommodate this increase.

4.6 Creep

While in service, some consolidation continues to occur, even though no additional load is applied. This process is called *creep*. Unlike pipe flange gaskets where it can be a serious problem, resulting in loss of gasket stress, creep does not present a challenge to maintaining pressure seal gasket stress. Loss of pressure seal gasket stress is dominated by extrusion.

4.7 Preloading

Preloading refers to the amount of stress the bonnet places on the gasket when the bonnet nuts are torqued. This torque value is based on the force required by each bonnet stud to achieve the overall load resulting in the required stress. The required stress should be in the range of 4000-8000 psi. However, as discussed in Section 4.10, the preloading should achieve a stress equal to or greater than the stress caused by the force caused by the operating pressure under the bonnet.

Key Technical Point

The required stress achieved by preloading should be in the range of 4000-8000 psi. Preloading should achive a stress equal to or greater than the gasket stress caused by system pressure operating on the bonnet.

4.7.1 Preload Calculation

The calculation of the preload torque is described below. A worksheet with formulas performing this calculation is found in Section 9.

In order to determine the preload torque it is necessary first to determine the gasket stress caused by the maximum operating pressure. This is done by dividing the horizontal cross sectional area of the gasket by the force caused by pressure operating on the bottom of the bonnet. This is the pressure stress. It is desired that it fall within a 4000-8000 psi range.

If the stress is in the 4000-8000 range, then the pressure force calculated will be the force required of the bolting during preload. If less than 4000 psi, then the equivalent pressure force for 4000 psi is calculated and used instead.

To determine the amount of force required of each bonnet stud, the pressure force is divided by the number of bonnet studs. The amount of torque required is calculated using the standard torque equation: T = KFD. See Section 3.3 of [5] for additional information on calculating torque.

The torque value obtained must be adjusted for uncertainty. Section 4.1.4 of [6] reports this variability with hardened washers under the nut to be ± 26%. Therefore, the torque value should be increased by at least 30% to provide additional margin. Compare a torque to that supplied by the valve vendor. If it is greater than the recommended, then consult the vendor to see if the vendor value can be raised to the calculated value. The basis of this value is the strength of the bolt, bonnet material or the bonnet support plate. See Section 4.10 for a discussion of bolting efficiency.

If the valve vendor torque value cannot be raised, then reverse the above procedure and determine the load used and then the total load. Compare that with the pressure load. If it less than the pressure load, then hot retorquing will be necessary before the system is fully pressurized, i.e., at 50% of final pressure. Hot retorquing is discussed in Section 4.9.

4.7.2 Fastener Length

To accommodate the extra neck height longer bonnet studs may be needed.

4.8 Bonnet Alignment

With graphite seals, there is virtually no material rigidity. This will allow the valve bonnet to easily pull up unevenly and cock. Therefore, the preloading of graphite gaskets must be done with great care using many more crisscross passes than that used for metal gaskets. The following techniques will aid bonnet misalignment prevention by ensuring the bonnet is pulled up evenly.

- Use the turn of the nut, such as a flat, in a crisscross pattern until the target torque value is obtained. This is a more accurate way of pulling the bonnet up evenly.

- If allowed, drill additional holes in the bonnet pull up plate to allow for direct measurements of the bonnet pull up to insure it remains even. At least three at approximately 120-degree locations on the same radius from bonnet axis should be obtained.

- If the valve is left unpacked, a quick check of bonnet alignment can be done with a carbon bushing use as a packing spacer. These carbon bushings have tight clearances. If the bushing is tight or does not fit on any side of the stuffing box, the bonnet is be coming misaligned.

Key Human Performance Point

Graphite seals are not rigid and the bonnet can easily pull up unevenly. They require different care and attention than metal seals.

4.9 Retorquing after Pressurization

The need for retorquing graphite gaskets after pressurization is far more critical than for the metal gasket. It should not be waived due to ALARA, schedule, etc. Pressure seal bonnets and bolting were not designed and may not be able to handle the torque required to adequately load the graphite seal. On large valves (i.e. 18- 24”) when bolting is torqued to the highest value allowed by the valve manufacturer, the graphite is usually only marginally loaded. The pressure loading, which is provided when the valve is fully pressurized, can result in significantly higher loads then the bonnet bolting. In such cases, it is advisable to retorque as system pressure is coming up, i.e. before reaching operating pressure, to insure the pressure induced graphite gasket load is captured by the bolting. This will avoid possible leakage should there be any change in plant status causing a lower pressure, hence a lower gasket stress to occur.

Key O&M Cost Point

Where the load applied to the graphite seal by the bonnet stud is significantly less than the operating pressure, it is advisable to perform an additional retorque before reaching operating pressure.

4.10 Bolting Efficiency

With the critical nature of the marginal loading of the gasket described above, closer attention is required of the bonnet nuts/studs efficiency. The variability of ± 26% discussed in Section 4.7.1 assumes certain actions with respect to “joint” must be accomplished. A great deal of attention has been given to this subject in the makeup of flanged joints. These actions are discussed in Section 3.3 and 3.8 of [5] and 4.1.4 of [6] and should form the basis of a good bolted joint program. These actions are summarized here for convenience and emphasis.

4.10.1 Fastener Condition

Ensure the fastener threads are not damaged, corroded, dirty. Turn the nut up and down for the full length of the stud. Eliminate any burrs; remove any form of corrosion or foreign material.

4.10.2 Lubrication

A high-grade nickel-based, or equivalent, lubricant must be applied on the threads and between the nut and hardened washer.

> **Key Technical Point**
>
> **Ensure the fastener threads are not damaged, corroded, dirty. Use a high-grade nickel-based, or equivalent, lubricant. Apply it both on the threads and between the nut and hardened washer.**

4.10.3 Hardened Washers

Use hardened washers, e.g. ASTM F426. Typically, the valve manufacturer does not include hardened washers under the nut. The torque equation in 4.7.1 assumes the surface below the nut, i.e., the bonnet support plate, is in good condition. However, the support plate is always softer than the nut and over time can become damaged. This damage can result in a significant loss of the desired bolt load (values up to 25% have been reported by one plant) due to the need to overcome the resulting friction. Therefore, hardened washers are always recommended in order to assure the desired bolt load is achieved. See Sections 3.3.3, 6.11, 10.1.3, and 11.7.3 of [5] for additional information. The use of two hardened washers has been reported by [6] as improving variability by as much as 7.5 % and an increase of average bolt force as much as 15%. Use a thin film of lubricant between the washers to maximize this effect.

> **Key Technical Point**
>
> **Typically, the valve manufacturer does not include hardened washers under the bonnet nut. The damage caused by the nut on the softer support plate material can result in a significant loss of desired bolt load. Therefore, <u>hardened washers are always recommended</u> in order to assure the desired bolt load is achieved.**

4.10.4 Material

Use the same nut/stud material used for flanges, i.e., A194-2H, A193-B7. These quality bolts will ensure that the maximum load is obtainable.

4.11 Improper Applications of Graphite Gaskets

There are applications in which the use of a graphite gasket is not proper. Some of the applications are discussed below.

4.11.1 Check Valve Pivot Pin Seal

The metal pressure seal gasket of the hinge pin cover of a tilting disc check valve was replaced with a graphite gasket. See Figure 4-10. The graphite gasket was in service for an 18-month cycle without leakage. A post maintenance test hydro was performed and the seals were found to leak. The seals could not be tightened since bolted hinge cover plate was found to be metal-to-metal on the body. An additional metal backing ring could not be used since the gasket cavity was triangular and the rectangular backing ring would immediately bottom out on the hinge pin.

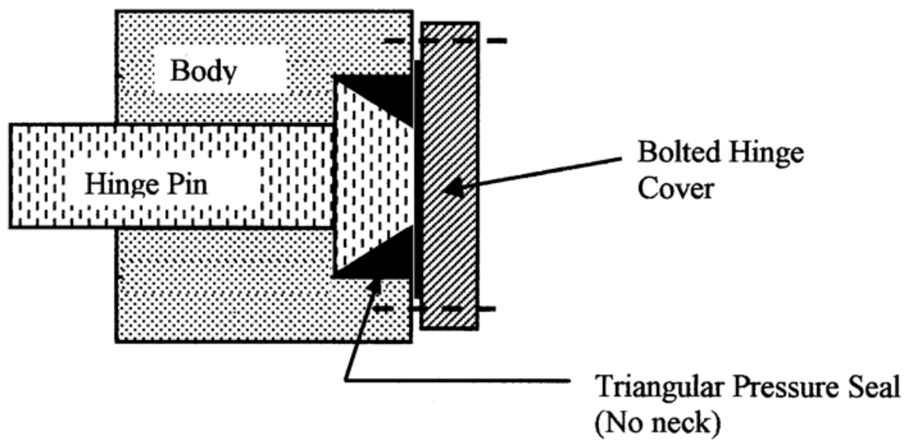

Figure 4-10
Hinge Pin Cover Using Triangular Pressure Seal

Key O&M Cost Point

Not all pressure seal applications are suitable for graphite seal replacement. A careful analysis of the seal area, including dimensional analysis, must be performed before proceeding.

4.11.2 Bonnet Hung Swing Check Valve

USNRC Information Notice 89-62 [4] was issued to alert plants of the potential malfunctioning of certain pressure seal bonnet check valves caused by the misalignment of the valve disk. The disc of these check valves is hung from the bonnet. See Figure 4-11. The final position of the bonnet establishes the location of the disc with respect to the seat ring. Manufacturers specify the critical dimension(s) to be measured, for example the distance from the top of the fully screwed-in retainer to the top of the bonnet. With a metal gasket, torquing the bonnet nuts does not alter this dimension significantly, remaining within the tolerances specified. If a graphite gasket is used, it will need be compressed sufficiently to ensure the disc/seat alignment is achieved. In [4] one plant reported problems with the amount of compression achievable for the specified pull-up torque. Insufficient compression resulted in the disc below the required position. The vendor determined that the bonnet studs were too weak to compress the gasket the needed amount.

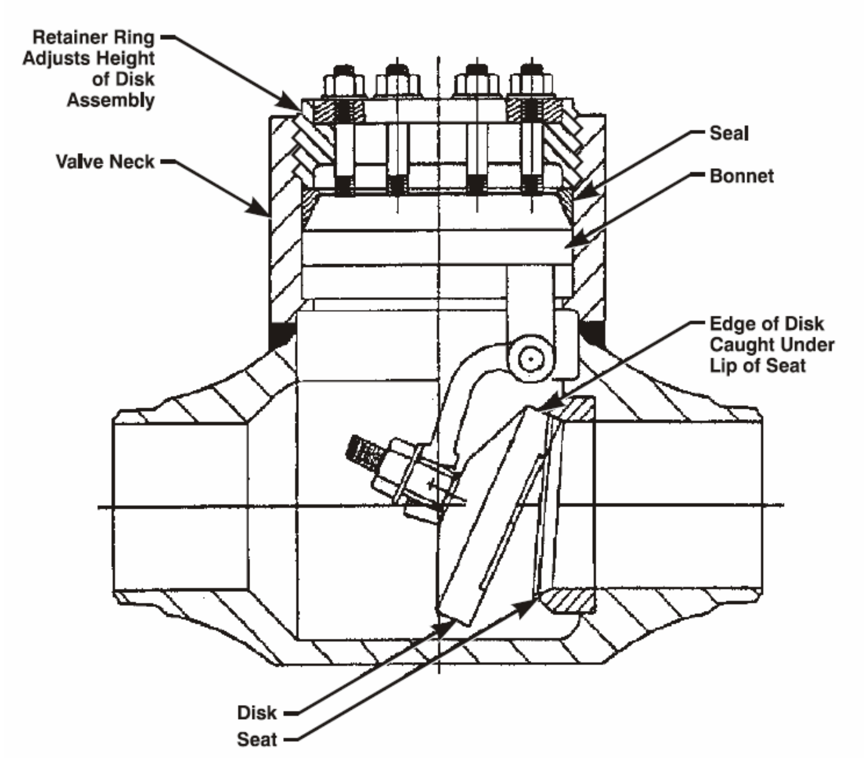

Figure 4-11
Bonnet Hung Disc Swing Check Valve

4.12 Additional Retorquing

An additional retorque is recommended after the valve has been in service for 2-4 years to ensure no additional extrusion or loss of preload has occurred.

5 TROUBLESHOOTING

5.1 Introduction

The only failure mode for pressure seal bonnet valves is leakage. This section will identify steps to be taken upon discovery as well as steps needed to prevent recurrence. In effect, this is a summary of Sections 3 and 4.

5.2 Metal Gaskets

5.2.1 Leakage during Startup

In general, for all gasket material, the longer a leak has existed by the time it has been discovered, the lower the likelihood of it being stopped. The dynamics of leak formation and growth for metal seals are complex. Fundamentally for metal gaskets, micro sized paths always exist. They may be a scratch or an imperfection in the surface. The objective of the preload is to create local stresses that are high enough to yield the material sufficiently to shut off the paths. When the stresses are not high enough, or if they are not maintained, the path (or paths) is opened and leakage begins. The micro path increases in size due primarily to flow induced erosion. This size increase is flow rate and temperature dependent. A path size is reached that cannot be shut off by additional force.

Stresses are initially not high enough due to the following:

(The numbers in parenthesis refer to the applicable section in the guide.)

- Calculated preload low (3.6.1)
- Applied preload low (3.6.2, 3.6.3)
- Excessive body/gasket gaps, scratches and other imperfections in the sealing surface (3.3, 3.4)
- Poor sealing surface finish (3.3, 3.4)
- Misaligned gaskets (slightly cocked during installation/preloading, resulting in low sealing stresses) (3.5)
- Sealing taking place in wrong location (3.5)

Actions to stop a leak once it has begun are few. The most obvious is to reapply the preload and attempt to close the micro path. Depending on conditions described above, this may be successful, particularly if done early enough. Before performing the preload, however, an attempt should be made to determine if alignment is a problem by measuring the distance from the bonnet to the bonnet support plate. If an alignment problem is found, first torquing the stud where the distance is greatest may be beneficial.

Temporary leak repair is the second option, but as explained in Section 3.9.4, there are difficulties in achieving an on-line seal. The time involved with getting the proper dimensions, etc., may make this option impractical.

5.2.2 Leakage after Startup

Leakage during operation suggests that it has been on going for a period of time. Hence, the likelihood of stopping it has become very small. Again, the stresses on the gasket are below what is necessary for sealing. Since this has occurred after startup, it usually involves some movement of the bonnet, usually because of changes in pressure and/or temperature. The most effective strategy for preventing leakage is to ensure that the preload is reapplied after placing the valve inservice as discussed in Section 3.7.

Actions to stop a leak are the same as during startup, i.e., reapply the preload or leak repair. The same precautions apply.

5.2 Graphite Gaskets

Graphite gasket leakage is almost invariably the result of low gasket stress. Even low stresses are sufficient to initially fill the micro paths described above. However, they are insufficient to resist the internal pressure that overloads these filled paths and opens up a pathway. Once the leak has formed, the magnitude of the leak increases rapidly.

Stresses for graphite gaskets are not high enough due to the following:

- Failure to control extrusion (4.4.2)
- Failure to accommodate consolidation (4.5.2)
- Incorrect preload force (4.7, 4.10)
- Poor bonnet alignment (4.8)
- Failure to retorque after pressurization (4.9)
- Incorrect application (4.11)

As mentioned above, once the leak has formed, the magnitude of the leak increases rapidly. The material erodes quickly, and there is little time to respond. Response is limited to applying the preload force and the likelihood of stopping the leak by the time it is discovered is small.

6 REFERENCES

1. *Mechanical Engineering*, ASME, Vol. 68, No 5, May, 1946

2. *Maintenance of Pressure Seal Bonnets*, G Harttraft, M Gonzales, Proceedings of the Fifth EPRI Valve Technology Symposium, June 1995

3. *Graphite Pressure Seals-Lessons Learned*, K.A. Hart, Proceedings of the 1st International Conference on Sealing Technology and Plant Leakage Reduction, EPRI, Palo Alto, CA, 1999. TR-113859

4. USNRC Notice 89-62

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6. *Performance Characterization of Bolt Torquing Techniques: Sealing Technology & Plant Leakage Reduction Series*, EPRI, Palo Alto, CA: 2002. 1003150.

7. *On-Line Leak Sealing,* EPRI, Palo Alto, CA: 1989. NP-6523-D

8. *Valve Stem Packing Improvements,* EPRI, Palo Alto, CA: 1988. NP-5697.

7 SUMMARY OF KEY POINTS

The following list provides the location of key “pop out” information in this report.

Key O&M Cost Point
Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

Referenced Section	Page Number	Key Point
3.7	3-10	Retightening of the bonnet nuts after placing the valve is service (hot retorque) is always recommended.
4.3	4-2	The ability to flow is also the reason why the following characteristics must be understood, and provided for, if problems are to be avoided such as extrusion, consolidation and creep.
4.4.2	4-5	Whenever possible, both top and bottom caps are desirable. The additional expense for using both caps is more than offset by the higher degree of confidence that the gasket will not fail in service.
4.9	4-11	Where the load applied to the graphite seal by the bonnet stud is significantly less than the operating pressure, it is advisable to retorque before reaching operating pressure.
4.11.1	4-13	Not all pressure seal applications are suitable for graphite seal replacement. A careful analysis of the seal area, including dimensional analysis, must be performed before proceeding.

Key Technical Point
Targets information that will lead to improved equipment reliability.

Referenced Section	Page Number	Key Point
3.3	3-5	A detailed inspection of the valve components during disassembly is critical.
3.6.3	3-9	Ensure the fastener threads are not damaged, corroded, dirty. Use a high-grade nickel-based, or equivalent, lubricant. Apply it both on the threads and between the nut and hardened washer.
3.6.3	3-9	Typically, the valve manufacturer does not include hardened washers under the bonnet nut. The damage caused by the nut on the softer support plate material can result in a significant loss of desired bolt load. Therefore, hardened washers are always recommended in order to assure the desired bolt load is achieved.

Referenced Section	Page Number	Key Point
4.3	4-1	The ability of graphite to flow and conform to the sealing surfaces is the reason for its improved sealing over minor imperfections.
4.4.2	4-5	Extrusion is controlled by minimizing the clearances between the body, bonnet and retaining ring. This can be done by the using of a backing ring for the top gap and a bottom cap for the bottom gap.
4.5.1	4-6	The amount of consolidation is expected to be approximately 20%.
4.5.2	4-9	Consolidation is best handled by using a graphite gasket with a neck height 20% higher than the metal gasket. There must be sufficient neck height to accommodate this increase.
4.7	4-9	The required stress achieved by preloading should be in the range of 4000-8000 psi.
4.10.2	4-12	Ensure the fastener threads are not damaged, corroded, dirty. Use a high-grade nickel-based, or equivalent, lubricant. Apply it both on the threads and between the nut and hardened washer.
4.10.3	4-12	Typically, the valve manufacturer does not include hardened washers under the bonnet nut. The damage caused by the nut on the softer support plate material can result in a significant loss of desired bolt load. Therefore, hardened washers are always recommended in order to assure the desired bolt load is achieved.

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.

Referenced Section	Page Number	Key Point
3.2	3-3	Measure the valve stroke. This measurement will provide a valuable reference to be used during reassembly by assuring that the valve bonnet is at the proper location for the pressure seal gasket to contact the body-sealing surface.
3.2	3-3	If penetrating oil has not worked, during disassembly, heat can be utilized to expand the valve body by wrapping resistance-heating coils around the outside of the body adjacent to the pressure seal area. The bonnet should loosen and move easily when struck with a brass mallet after reaching 300-400 degrees F.
4.9	4-11	Graphite seals are not rigid and the bonnet can easily pull up unevenly. They require different care and attention than metal seals.

8 APPENDIX A
CALCULATING PRELOAD FOR METAL GASKETS

A.1 Introduction

Preloading refers to the amount of stress the bonnet places on the gasket when the bonnet nuts are torqued. This torque value is based on the force required by each bonnet stud to achieve the overall load resulting in the required stress. This stress should be at least equal to the stress caused by the pressure under the bonnet. The calculation of the torque is as follows:

A.2 Calculation

Inputs required:

Di	Inside diameter of the body at the pressure seal contact area	________inches (mm)
P	Maximum operating pressure	________ psi (MPa)
N	Number of bonnet studs	________
K	Nut factor from plant torquing tables, usually 0.16 - 0.20	________ (dimensionless)
D	Diameter of the bonnet stud	________ inches (mm)

1. First, determine the force caused by pressure operating on the bottom of the bonnet. This is simply the result of the maximum operating pressure pushing against the bottom of the bonnet, and is calculated as follows:

$$Fp = [P \times \pi \times (Di)^2]/4$$

Where

Fp is the pressure force

P is from Input

Di is from Input

Fp = __________ lbs (N)

2. Divide the amount of force calculated in Step 1 by the number of bonnet studs to be used to pull up the bonnet. This is the amount of force per stud needed.

$$Fs = Fp/n$$

Where:

Fs is the required force per stud

Fp is from Step 1

n is from Inputs

Fs = _________ lbs (N)

3. Calculate the amount of torque required using the standard torque equation:

$$T = (K \times Fs \times D)/12 \text{ foot pounds}$$

$$T = (K \times Fs \times D)/1000 \text{ newton-meters}$$

Where:

T is torque

K is from Inputs

Fs is the amount of force per stud calculated in Step 2.

D is the nominal diameter of the stud.

T = _________ft-lbs (N-m)

4. Multiply T obtained in Step 3 by 1.3.

$$Tr = 1.3 \times T$$

Where:

Tr is required torque

T is torque from Step 3

Tr = ________ ft-lbs (N-m)

5. Compare this torque to that supplied by the valve vendor. If it is greater than recommended, then consult the vendor to see if it can be raised to the calculated value. The basis of this value can be the strength of the bolt, bonnet material (stud engagement length) or the bonnet support plate (deflection).

Tvendor = ________ft-lbs (N-m)

9 APPENDIX B CALCULATING PRELOAD FOR GRAPHITE GASKETS

B.1 Introduction

Preloading refers to the amount of stress the bonnet places on the gasket when the bonnet nuts are torqued. This torque value is based on the force required by each bonnet stud to achieve the overall load resulting in the required stress. This stress should be at least equal to the stress caused by the pressure under the bonnet and not less than 4000 psi (28 Mpa). The calculation of the torque is as follows:

B.2 Calculation

Inputs required:

Di	Inside diameter of the body at the pressure seal contact area	________	inches (mm)
Do	Outside diameter of the bonnet neck	________	inches (mm)
P	Operating pressure	________	psi (MPa)
K	Nut factor from plant torquing tables,usually 0.16 - 0.20	________	(dimensionless)
D	Diameter of the bonnet stud	________	inches (mm)
n	Number of bonnet studs	________	

1. Determine the cross-sectional area of the gasket when compressed. Since the gasket will be in contact with the body and bonnet, this area is equal to the body inside diameter area less the bonnet neck outside diameter.

$$Ag = \pi [(Di)^2 - (Do)^2]/4$$

Where:
Ag is the cross-sectional area of the gasket under compression
Di is from Inputs
Do is from Inputs

Ag = ________ in^2 (mm^2)

2. Obtain the operating pressure that will load the bonnet. Multiply this pressure times the area of the inside diameter of the body. This is the amount of force the operating pressure will place on the gasket.

$$Fp = [P \times \pi \times (Di)^2]/4$$

Where:
Fp = Pressure Force
P is from Inputs
Di is from Inputs

Fp = ______ lbs (N)

3. Divide the force from Step 2 by the area determined in Step 1. This is the pressure stress. It is desired that it be more than 4000 psi (28 Mpa).

$$Sp = Fp/Ag$$

Where:
Sp is the pressure stress
Fp is the pressure force calculated in Step 2
Ag is the gasket area calculated in Step 1.

Sp = ________ psi (Mpa)

4. If the stress calculated in Step 3 is 4000 psi (28 Mpa) or more, then go directly to Step 5 and use the value of Fp calculated in Step 2. If less than 4000 psi (28 Mpa), then multiply the area calculated in Step 1 by 4000 (28) and use this value for Fp in Step 5.

$$Fp = Fp \text{ of Step 2 if } Sp \geq 4000 \text{ psi (28 Mpa)}$$

$$Fp = Ag \times 4000 \text{ if } Sp < 4000 \text{ psi}$$

$$Fp = Ag \times 28 \text{ if } Sp < 28 \text{ Mpa}$$

Fp = ________ lbs (N)

Where
Ag is from Step 1

5. Divide the amount of force calculated in Step 2 or Step 4 by the number of bonnet studs to be used to pull up the bonnet. This is the amount of force per stud needed.

$$Fs = Fp/n$$

Where:
Fs is the required force per stud
Fp is from Step 4
n is from Inputs

Fs = ________ lbs (N)

6. Calculate the amount of torque required using the standard torque equation:

$$T = (K \times Fs \times D)/12 \text{ foot pounds}$$

$$T = (K \times Fs \times D)/1000 \text{ newton-meters}$$

Where:
T is torque
K is from Inputs
Fs is the amount of force per stud calculated in Step 3.
D is from Inputs.

T = ________ft-lbs (N-m)

7. Multiply T obtained in Step 6 by 1.3.

$$Tr = 1.3 \times T$$

Where:

Tr is required torque

T is torque from Step 3

Tr = ________ ft-lbs (N-m)

8. Compare this torque to that supplied by the valve vendor. If it is greater than recommended, then consult the vendor to see if it can be raised to the calculated value. The basis of this value can be the strength of the bolt, bonnet material (stud engagement length) or the bonnet support plate (deflection).

Tvendor = _______ft-lbs (N-m)

10 APPENDIX C OPERATING EXPERIENCE

C.1 Introduction

As discussed in Section 3, operational experience was reviewed to determine what issues caused reportable events involving pressure seal bonnet gasket failures. The sources of information surveyed included Operations and Maintenance Reports, Operational Experience Reports, and EPIX failure data as well as U. S. Nuclear Regulatory Commission Notices and Licensee Event Reports.

C.2 Table

Table 10-1 contains the result of the review as discussed in Section 3

Table 10-1
Analysis of Operating Events

	PLANT	EVENT NO	DATE	PROBLEM	CODE	CAUSE/DISPOSITION
1	Comanche Peak 1	867	11/20/2002	Hot torque on valve 1MS-0063. No steam was leaking from valve. The first torque pass 30 ft-lbs. Slight movement was achieved (1/2 - 1 nut flat). Second torque pass 40 Ft. Lbs. Two of the eight bonnet fasteners were torqued directly opposite of each other when loud popping noise was heard and graphite dust was observed covering the inner side of the yoke. Torquing stopped. The graphite pressure seal maintained its pressure integrity and no steam was leaking from the valve.	U	During valve disassembly, no cause identified for sound or graphite dust. Application of graphite gasket considered satisfactory. Noted that graphite pressure seal more prone to relaxation if system pressure is lost before a hot torque is applied.
2	Fermi 2	467	09/05/03	Leakage found on walkdown following scram. Attempted to control by retightening bonnet studs. Reduced, but did not stop leakage. Leakage increased forcing plant shutdown. Valve is a 4" 900 swing check.	MU	Cause not stated. Valve repaired by seal welding segment rings to body and bonnet
3	Palo Verde 2	655	12/08/03	Leak was discovered on 2PSGEV652, a check valve on the #1 Steam Generator Downcommer line in Unit 2. The Unit was in Mode 3 at the time. The crew brought the Unit to Mode 5, to facilitate repairs.	MH	The fourth segmented ring slipped/fell out of place when the bonnet was pulled into position. This resulted in the metal rolling on the 4th segmented ring, which caused a misalignment of the bonnet and prevented that quadrant of the pressure seal from seating. It is important to note that bonnet misalignment can not be ascertained visually due to the design of the component, i.e., the bonnet is completely obscured by the valve cover.

4	Nine Mile Point 2	156	05/20/98	Testable check valve failed LLRT leakage criteria.	MU	Wear on the actuator stem, degraded pressure seal, scratches on valve upper bonnet seal area and bad packing. Cause of degradation or scratching not stated.
5	Point Beach 2	134	02/13/01	Steam Generator Feedwater Check Valve Pressure Boundary Leak During Unit 2 Startup	MH	Pressure seal bonnet cocked approximately 1/4" off sealing position. Removed bonnet cover, retaining ring segments, spacer ring, gasket and bonnet. Match marked appropriate components. Found problem to be improper engagement of bonnet through retainer segments causing bonnet to cock.
6	Surry 1	66	03/28/97	Pressure seal gasket leak from valve in service since 1972. Not a check valve. Used in RCS.	U	Cause indeterminate due to part condition.
7	ANO 2	410	07/22/00	hot leg injection check valve 2SI-26A exhibited excessive leakage during seat leak test	MI	Disc is hung from bonnet. Therefore as described in NRC IN 89-62, bonnet height to valve centerline is critical. Pressure seal gasket of leaking valve was changed to graphite. Neither the bonnet bolts nor the system pressure were adequate to consolidate the gasket so that bonnet was as proper height. Follow up with Steve Smith ANO2.
8	DAEC 1	196	05/08/01	Containment Atmosphere Control valves, dampers, CV4312 internal leakage due to being improperly seated.	MH	Found pressure seal gasket not expanded to seal area of body. Leakage determined to be passing past pressure seal gasket. Reassembled valve per procedure, torqued bonnet to 67 ft-lbs. Cause not stated.
9	DAEC 1	202		Valve leaking at pressure seal gasket.	MU	Not stated. Repaired by welding.

10	Nine Mile Point 2	311	03/03/00	Leaking bonnet resulted in complete voiding of the RCIC discharge piping downstream of the injection valve. Subsequent operation of the system resulted in water hammer which resulted in pump trip due to low suction pressure. Plant shut down. Valve is a testable swing check.	MU	Not stated. Repaired while shutdown.

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