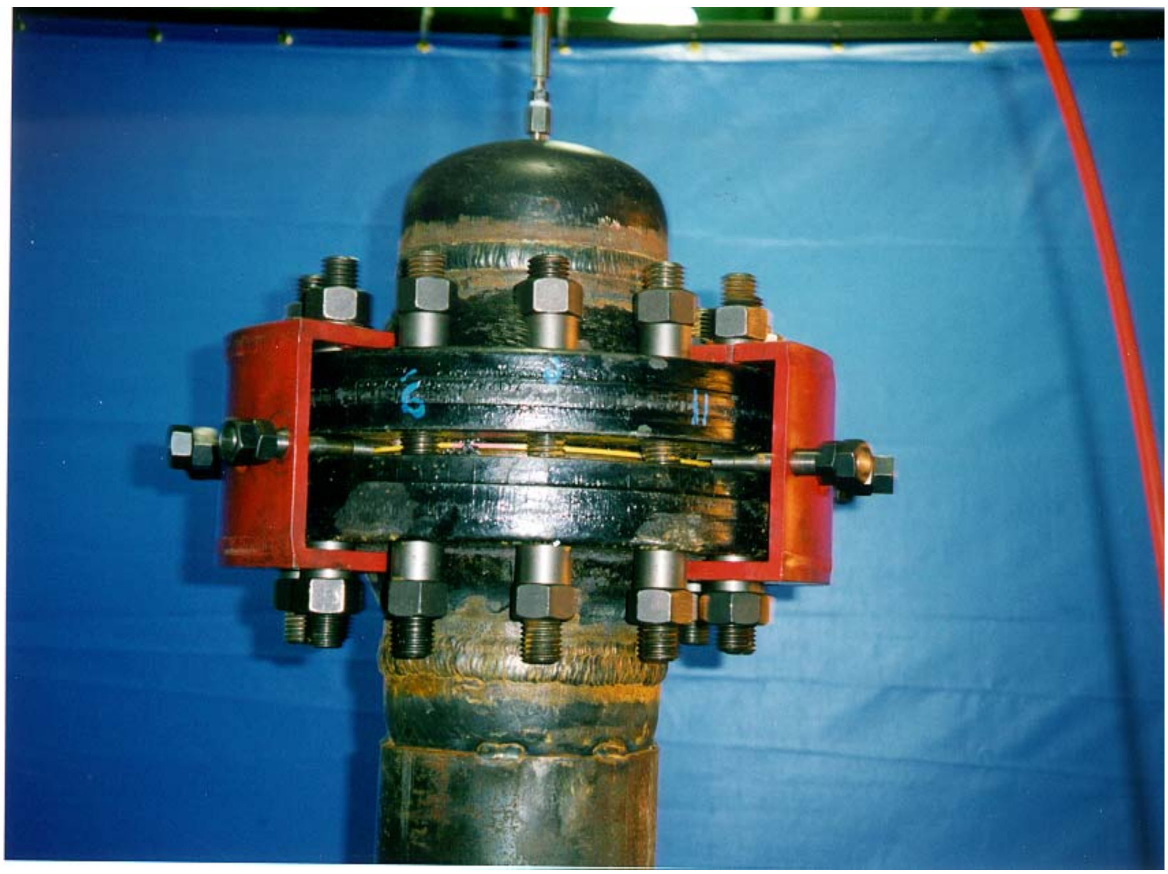
Mechanical Flange Leak Sealing

Design Modifications

1007926



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Technical Update, December 2003

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ABSTRACT

In the past, there have been basically two approaches to handling a leaking flange. First, the system could be shut down and the flange could be either repaired or replaced. Second, the leak could be mitigated by using a chemical injection around the perimeter of the flange.

Both methods work well but are time consuming and expensive. The developments made during this effort are actually second generation modifications from an earlier EPRI RRAC project. The evaluations documented in *On-Line Welded Repair for Leaking Pipe Components* (TR-108132) were the basis for developing the mechanical flange leak sealing fixture.

CONTENTS

1 INTRODUCTION

A typical leaking flange creates problems on several fronts. The lost efficiency is the most prevalent concern, but there is also increased down-time and additional personnel exposure in hot areas when making repairs or in worst cases, replacing the failed component. The Repair and Replacement Applications Center has designed and tested a new tool for use in either sealing or minimizing fluid loss from a leaking flange using a non-intrusive technique.

In the past, there have been basically two approaches to handling a leaking flange. First, the system could be shut down and the flange could be either repaired or replaced. Second, the leak could be mitigated by using a chemical injection around the perimeter of the flange.

Both methods work well but are time consuming and expensive. The developments made during this effort are actually second generation modifications from an earlier EPRI RRAC project. The evaluations documented in *On-Line Welded Repair for Leaking Pipe Components* (TR-108132) were the basis for developing the mechanical flange leak sealing fixture.

EPRI has disclosed and filed for patent protection for this development as a result of this project.

2
PROJECT SCOPE

Flange leaks are initiated by several mechanisms. The most common failures are due to degradation of the gasket while others are started from the deterioration of the flange itself.

The focus of this project is to examine methodologies to halt or minimize the leak, regardless of the root cause. The primary goal has been to offer an effective means of doing this while maintaining full flow operation.

The scope of this work was to include fixture design of a non-intrusive device, mockup testing and report documentation. While these tasks have been met, additional suggestions have been made, based on utility responses, that require more evaluation.

3
MOCKUP DESIGN

The flanges used in this testing were Class 600, 8-inch carbon steel raised face type flanges. For purposes of development work, the flanges were welded to standard schedule end caps which were in turn tack welded to another pipe at a comfortable working height.

The design of the fixture is modeled after typical clamshell devices used in various pipe working applications in that the fixture is mounted on the flange without completely disassembling the flange.

3.1 Original Design

There are several components used with this device. The pieces are identified as:

- Clamshell
- Impingement bolts or jacking bolts
- Backing bar or compression ring
- Graphite packing
- Positioning bolts
- Hardened bushings

The clamshell portion of the fixture is made from carbon steel plate. The upper and lower ‘shelf’ of the fixture was flame cut from plate material while the ‘web’ was cut and rolled. The general dimensions of the fixture are approximately 4 inches deep by 6-½ inches high. The arc length of the fixture is a 90 degree segment of the circumference of the flange.

Figure 3-1 illustrates the simplified configuration of the clamshell fixture. The three ‘sides’ of the fixture are joined together with a full penetration weld at the corners. Holes are positioned about the length of the fixture to accommodate several pieces of tooling. The top and bottom of the fixture have a series of large clearance holes spaced at 30 degree increments. This pattern allows for complete clearance of the flange studs and special hardened bushings, but does not allow the stud nuts to pass through.

Positioning bolts are located in between the larger stud holes. If the fixture is placed on a vertical run of pipe, the device will ‘lay’ on the outside surface of the flange. Since one of the keys to successful installation is ensuring that the device is properly centered, it was necessary to incorporate the positioning bolts into the fixture. By turning the bolts clockwise or counter clockwise, the fixture can be raised up or down, thus centering it over the flange and the gasket.

The web of the fixture contains a series of 'viewing' holes and tapped holes for impingement screws or jacking bolts. A typical quarter segment of the fixture will contain three or four locations for impingement bolts.

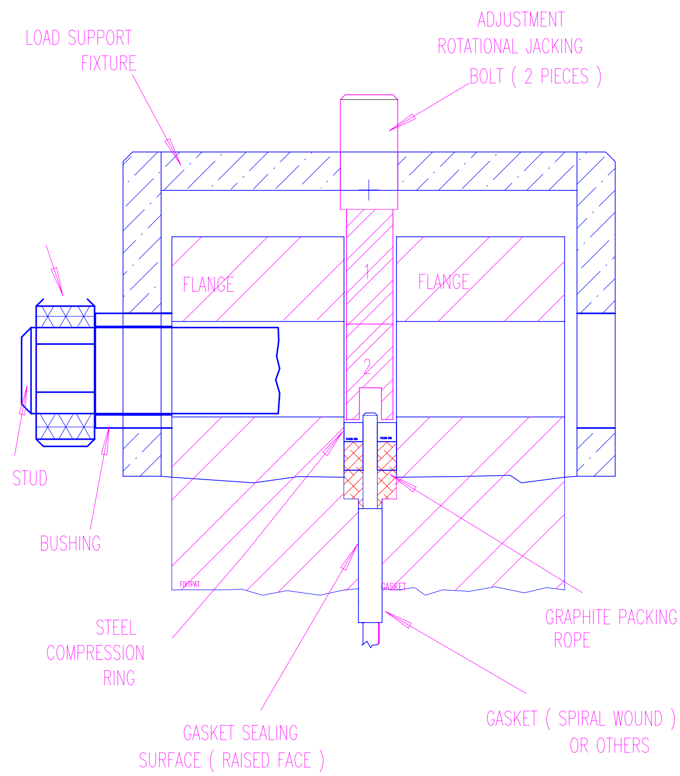

Figure 3-1
Cross-Section of Assembled Flange and Leak Sealing Fixture

The impingement bolts are comprised of three parts. The working end of the bolt is split so that it can have intimate contact with the compression ring without touching the outer edge of the gasket. The main shaft of the bolt is loosely pinned at the junction of the shaft and the fork. This will accommodate any torsion stresses that may be generated when the bolt is tightened. The third component is a nut that has been pinned to the free end of the impingement bolt. This allows the operator the ability to use standard hand tools. In this case, the nut is 1-1/16-inch across the flats.

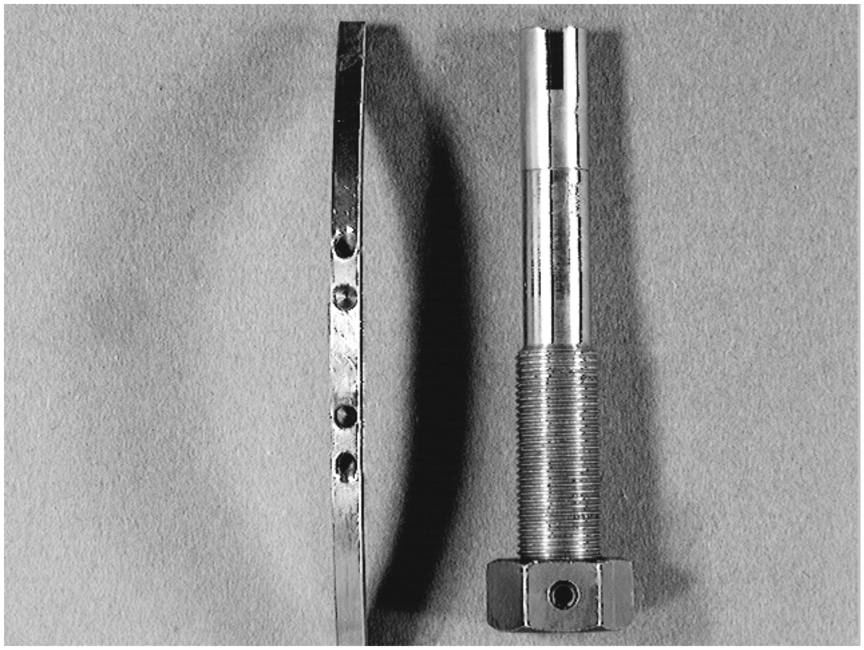

Figure 3-2
Impingement Bolt with Backing Bar Holes in Backing Bar Enable the User to “Direct” the Bar with a Rod

The modified design operates with the same principles but offers a little more flexibility in placing the impingement bolts.

One of the key changes in the design centers around the end of the impingement bolt. The contact end has been broadened and radiused to conform the curvature of the backing bar as illustrated in Figure xx.

Figure xx – Original impingement bolt on left and modified bolt on right.

Additional design changes were made to accommodate greater freedom in placing the bolts in a position conducive to stopping the leak. To do this a large slot was machined into the face of the fixture. A corresponding slot was machined into a rolled channel. This component was rolled to a radius equal to that of the face of the main fixture.

The channel was tack welded to the inside surface of the fixture. With a nut placed in the channel the bolt now has the freedom of movement.

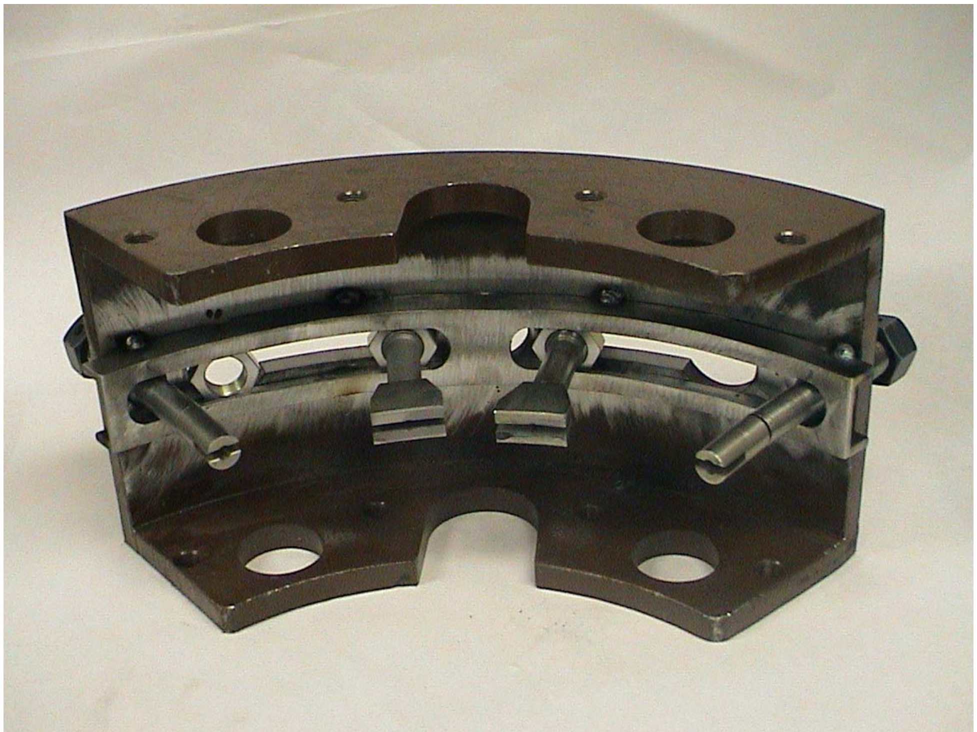

Figure xx – New slotted channel tack welded to fixture.

3.2 Loading Conditions

Under normal operation, the flange will experience two loads: 1) the bolt load induced by the torque of the nuts against the studs, and 2) the hydrostatic force created by the flow of the water.

The addition of the leak sealing fixture creates a third loading condition. As the impingement bolts are tightened, they exert a force on the graphite packing, driving the packing material into the gasket/flange face region. The reaction loads cause a shearing strain on the studs.

To counter the shear, hardened bushings were placed between the studs and the clearance holes of the fixture. This served two functions. One, as the reaction loads are applied, the overall stress on the studs is reduced since the cross-sectional area of the bushings displaces the load over a larger area. Two, the bushing acts as a hinge in allowing the fixture to swivel once the fixture is attached with a single stud. See Figure 3-3.

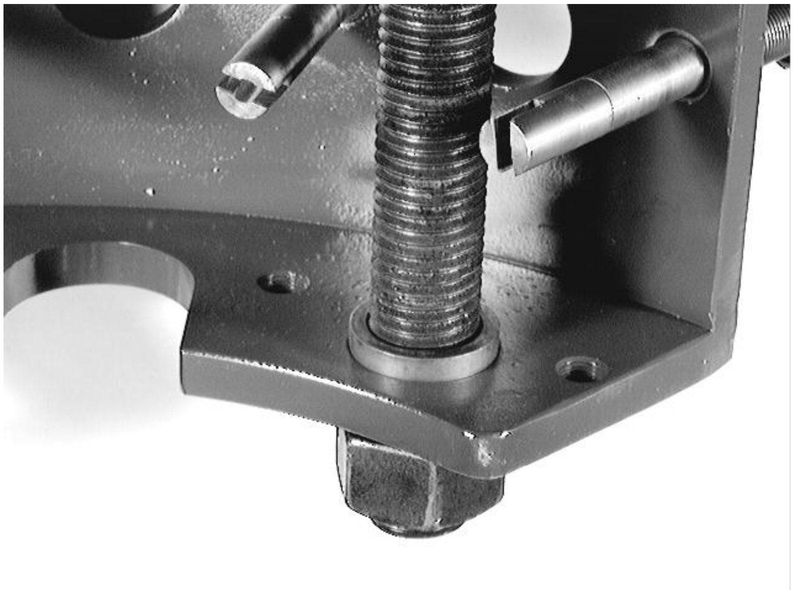

Figure 3-3
Clamshell with Stud and Hardened Bushing

Typical Loading Conditions

Total load calculations
Inside diameter of gasket = 8.75 inches
Bolt hole center diameter = 13.75 inches
Total load as designed = Pressure x Area

Flange load under normal operating conditions:

$$600\,\frac{lbs}{in^2} \times \frac{(8.75^2)\pi}{4} = 36079.2$$

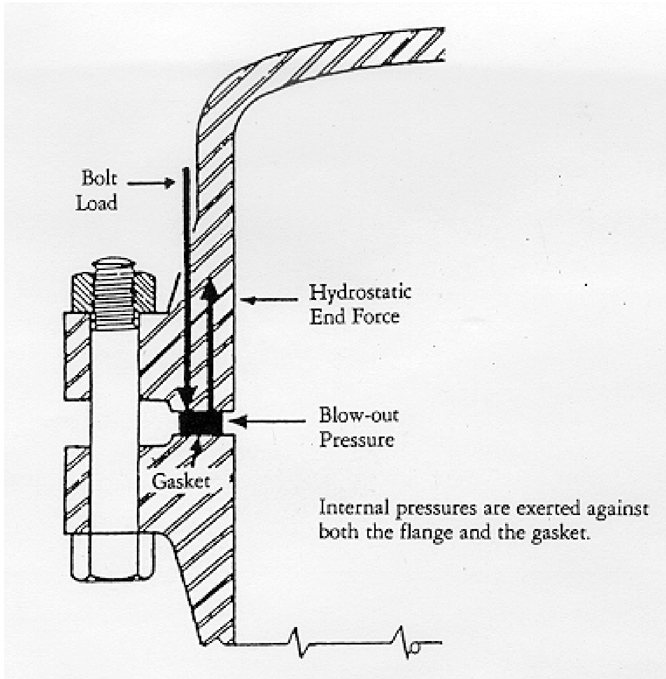

Figure 3-4
Schematic of Static and Dynamic Loads

Post installation engineering analysis is not a concern. Seismic analysis will be required due to the application of the weight of the fixture. But since this exercise is required with injection boxes, there is really no additional burden.

4
TESTING

The following provides a detailed summary of the procedures used in testing the class 600 mechanical leak sealing fixture and the results of those tests. To date, four tests have been performed with various flawed gaskets. A schematic of the setup used in each test can be found in Figure 4-1.

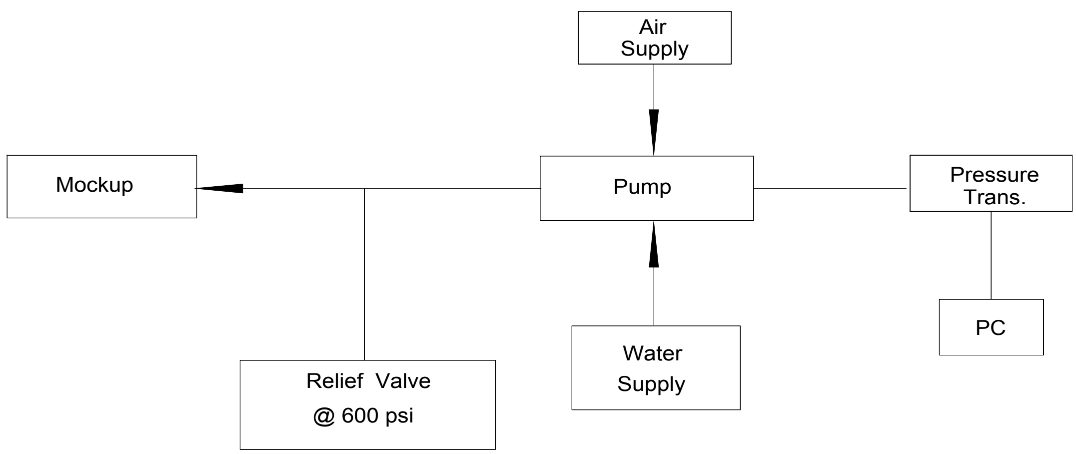

Figure 4-1
Test Setup

4.1 Installation Procedure for a Class 600 Metallic Gasket

Each of the leak tests performed on the class 600 weld neck flange followed the procedure outlined in the following paragraph for installing a class 600 metallic gasket.

The first step in the installation of the class 600 metallic gasket was to center the seating surface of the gasket on the flange. This was done by visual inspection without the aid of instrumentation to simulate conditions in the field. The mating half of the flange was then put in place and the gasket was inspected to see if it still remained centered on the flange. Bolts were then tightened according to the specified 12 bolt tightening sequence, with a series of three passes having torque values of 150 ft-lb, 300 ft-lb, and 500 ft-lb. A fourth and final pass was also made to ensure that all bolts were tightened to 500 ft-lb (maximum capacity of torque wrench).

4.2 Installation Procedure for a Class 600 Mechanical Leak Sealing Fixture

In each of the leak tests the following procedure was used to install the mechanical leak sealing fixture.

<u>Equipment List:</u>
4 quarter section mechanical leak sealing fixtures
16 slotted jackscrews
16 hardened bushings
12 1-1/8″ Dia. threaded studs and nuts
1 roll of 1/4″ graphite packing material
16 circular packing rings (carbon steel)
24 alignment bolts

4.2.1 Overview

The mechanical leak sealing fixture consists of four quarter sections that were individually mounted to the flange, as needed, and used to compress segments of graphite packing material. The graphite packing material used in the installation consisted of two 1/4″ strips that were inserted into the gaps between the flange face and centering ring on the gasket. Each section of the fixture consisted of four jackscrews and four packing rings, which were used to compress the packing material.

4.2.2 Procedure

1. To begin the installation three adjacent threaded studs in the area of the leak were selected. The two outside studs were removed while the center stud was left intact as seen in Figure 4-2.

Figure 4-2
Assemble Flange with Two Studs Removed Prior to Installation of the Fixture

2. Two strips of 1/4″ graphite packing were then inserted into the gaps above and below the gasket within the radius of the bolts in the area of the leak as seen in Figure 4-3. During this process, care was taken to make sure that the packing material properly conformed to the boss radius of the flange.

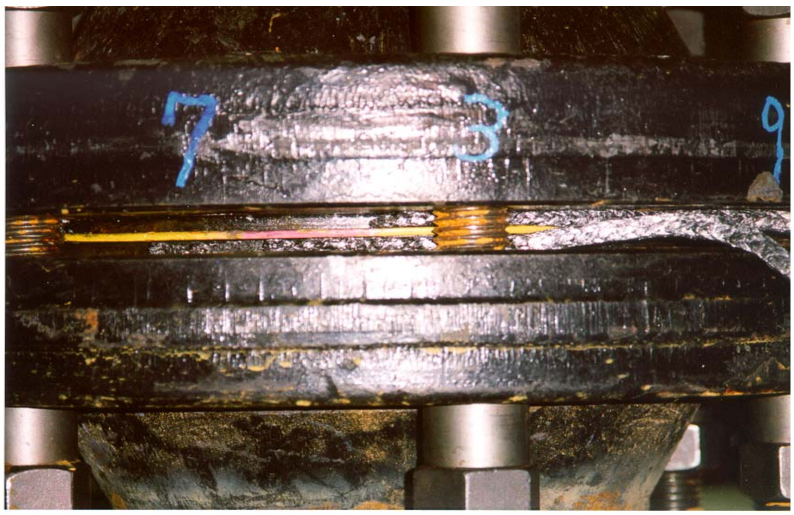

Figure 4-3
Insertion of Graphite Packing Material Above and Below the Gasket Centering Ring

3. Once the graphite packing was in place, packing rings were inserted into the gaps above and below the gasket within the radius of the bolts so that they conformed to the packing material and were in alignment with the fixture. This process can be seen in Figure 4-4. The packing rings consisted of four 1/4″ × 7/16″ circular sections. Two of the packing rings were used in the top gap and the other two were used in the lower gap.

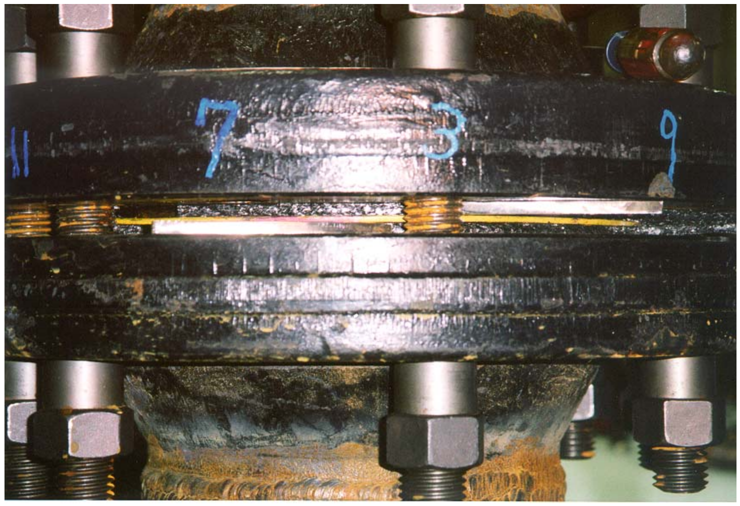

Figure 4-4
Backing Bars Being Placed Behind the Graphite Packing

4. Then one of the quarter sections of the fixture was mounted to the pipe flange as seen in Figure 4-5 using the two studs that were previously removed, in addition to the hardened bushings provided. The hardened bushing allowed the fixture to be independent of the flange, which allowed it to be moved in the vertical direction to facilitate alignment. Then each of the bolts was re-torqued to their proper specifications.

Figure 4-5
Torque Wrench Applying Full Load on Studs But Not on Fixture

5. Four of the slotted jackscrews were inserted into the fixture. Then using the alignment bolts located on the top and bottom of the fixture, the jackscrews were centered so that they would slide over the centering ring of the gasket and make contact with the packing rings.

6. Once the impingement bolts were inserted and properly aligned, they were tightened in a clockwise manner to a torque value of 50 ft-lb as seen in Figure 4-6.

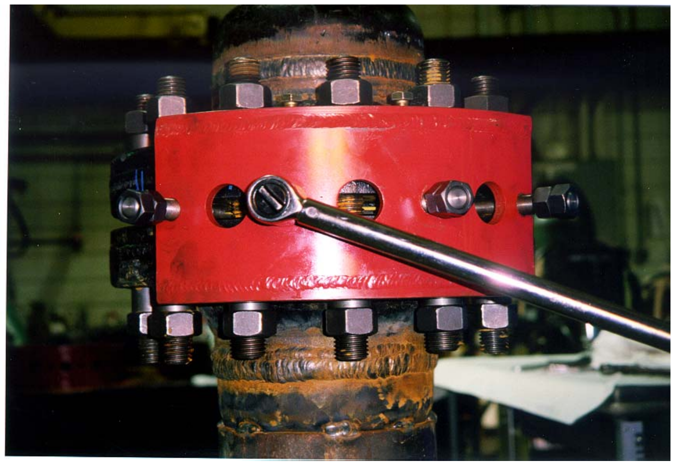

Figure 4-6
Impingement Bolts Driving Packing Material Inwards as the Bolts Are Turned

7. If necessary, additional quarter section leak sealing fixtures were installed in the same manner as seen in Figure 4-7.

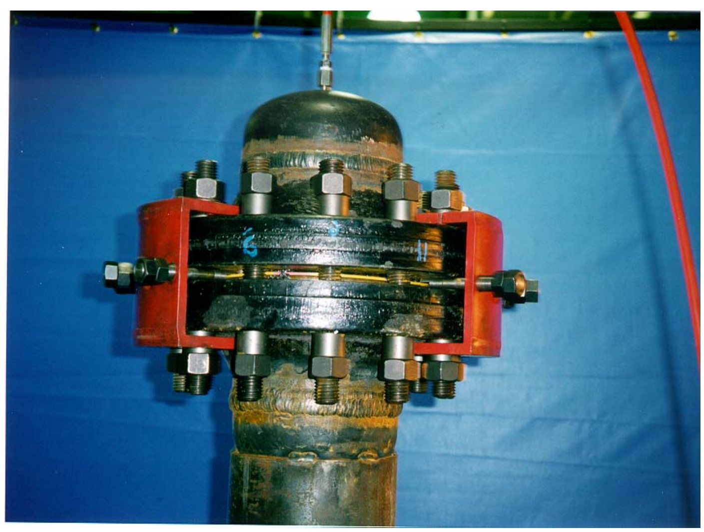

Figure 4-7
Fully Assembled Fixture After Stopping Leak

4.3 Pressurized Mockup Testing

The following test data is from the original design. As of publication the newer design modifications have not finished testing.

A series of tests were performed to simulate the effects of different flaws in gasket material. The tests outlined below were all performed at 600 psi at room temperature.

4.3.1 Leak Test # 1 for a Class 600 Weld Neck Flange

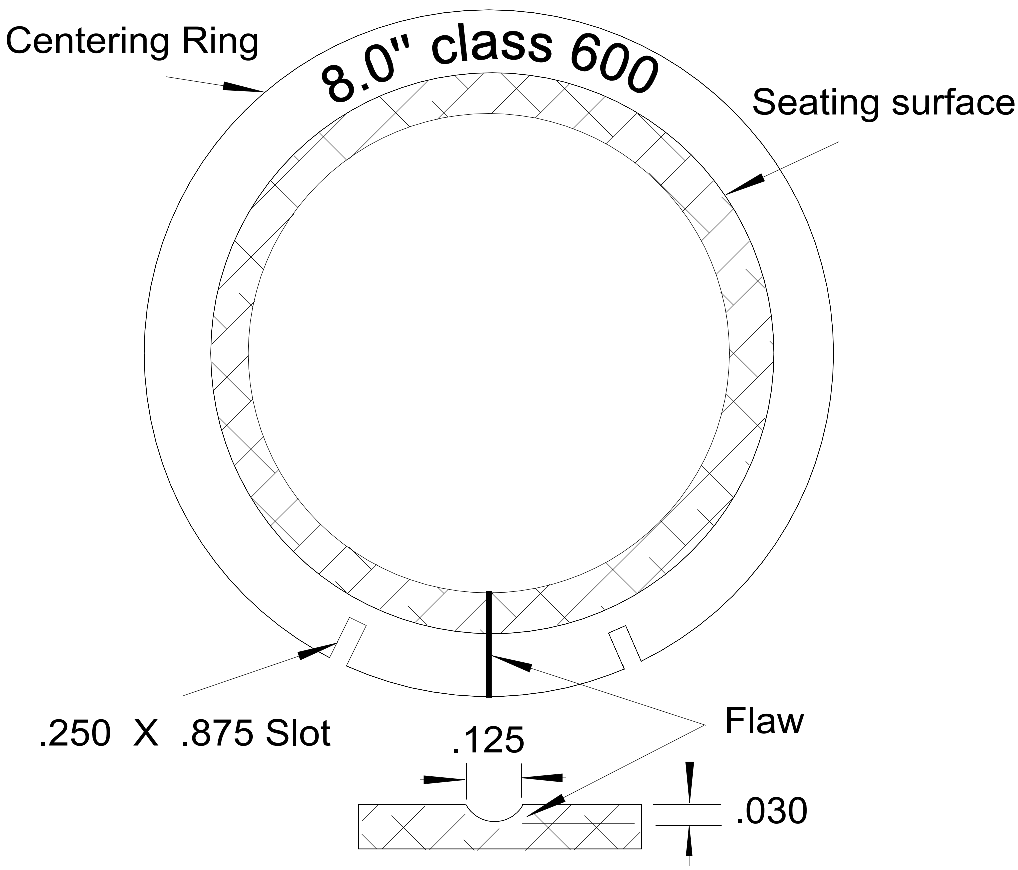

Figure 4-8
Flawed Gasket for First Test

<u>Test Description:</u>

In this test, one flaw with the dimensions shown above was inserted into a class 600 metallic gasket. The flawed gasket was then installed according to the procedures outlined above.

The flange was then pressurized and leaking began to occur at 400 psi. Visual inspection showed that the centering ring in the area of the leak was deflected downward. This prevented the installation of the graphite packing and packing rings. Attempts were made to manually correct the deflection of the centering ring; however, the centering ring was too ridged and we were unsuccessful. To solve this problem, a drill bushing (fixture) was developed and used to notch the carbon steel centering ring. This process relieved the stress on the ring and allowed it to flex. As a result, the packing and packing ring could then be installed. In this test, 1/4" graphite packing material was used. This packing was inserted into both the upper and lower gaps between the gasket and the flange.

Originally, a quarter section 1/4″ × 1/4″ packing ring was going to be inserted into the upper and lower gaps between the gasket and the flange face. However, in order to install this quarter section packing ring it would have been necessary to remove a third bolt. As a result, the packing rings were cut into half-quarter sections to prevent the removal of a third bolt. The fixture was then mounted to the flange and the slotted jackscrews were aligned with the packing rings. Then each of the four jackscrews was tightened evenly in a clockwise fashion to a final value of 50 ft-lb.

Visual inspection showed that the leak was successfully stopped. The pressure was also monitored and found to hold constant at 600-605 psi.

4.3.2 Leak Test # 2 for a Class 600 Weld Neck Flange

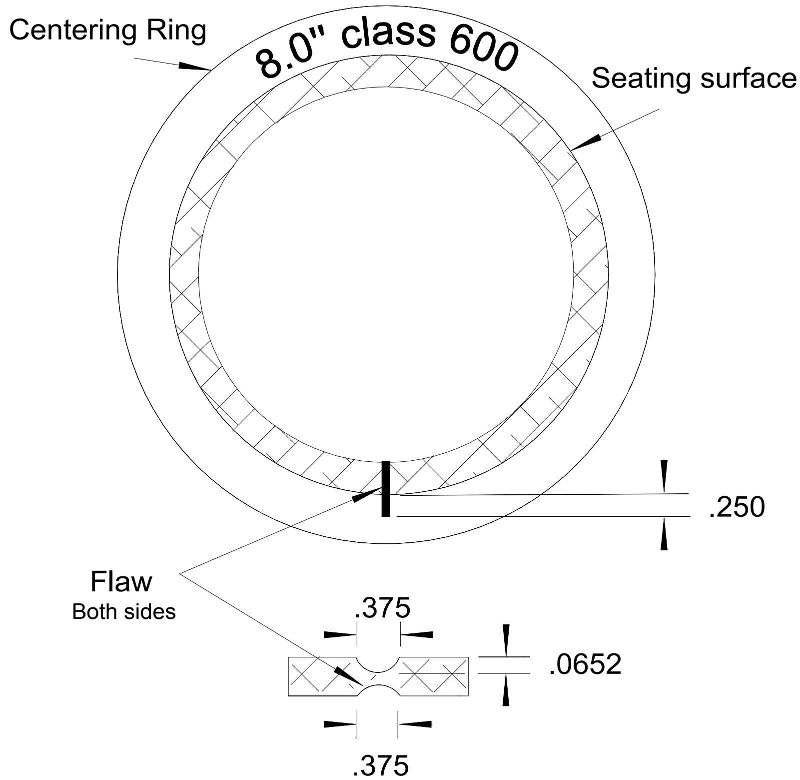

Figure 4-9
Flawed Gasket for Second Test

<u>Test Description:</u>

In this test one flaw with the dimensions shown above was inserted into a class 600 metallic gasket. The severity of the flaw caused substantial deformation in the seating surface of the gasket. This gasket was then installed following the procedure described above.

During the test substantial leaking occurred at 85 psi (water pressure). Following the installation procedures described earlier, the mechanical leak sealing fixture was then installed on the flange in the area of the leak. However, in this test 1/4″ × 7/16″ packing rings were used in place of the 1/4″ × 1/4″ used in test one. These larger packing rings were used because of their greater strength and rigidity, which allowed it to compress the packing more evenly without deforming the packing ring. As mentioned in the Test One description, four half-quarter sections packing rings were used rather than the two quarter sections. This allowed the packing rings to be installed easily without removing a third bolt from the flange.

Once the installation of the mechanical leak sealing fixture was completed, visual inspection showed that the leak was significantly slowed; however, it was not stopped. The damage to the gasket proved too great for this technique to be successful.

4.3.3 Leak Test # 3 for a Class 600 Weld Neck Flange

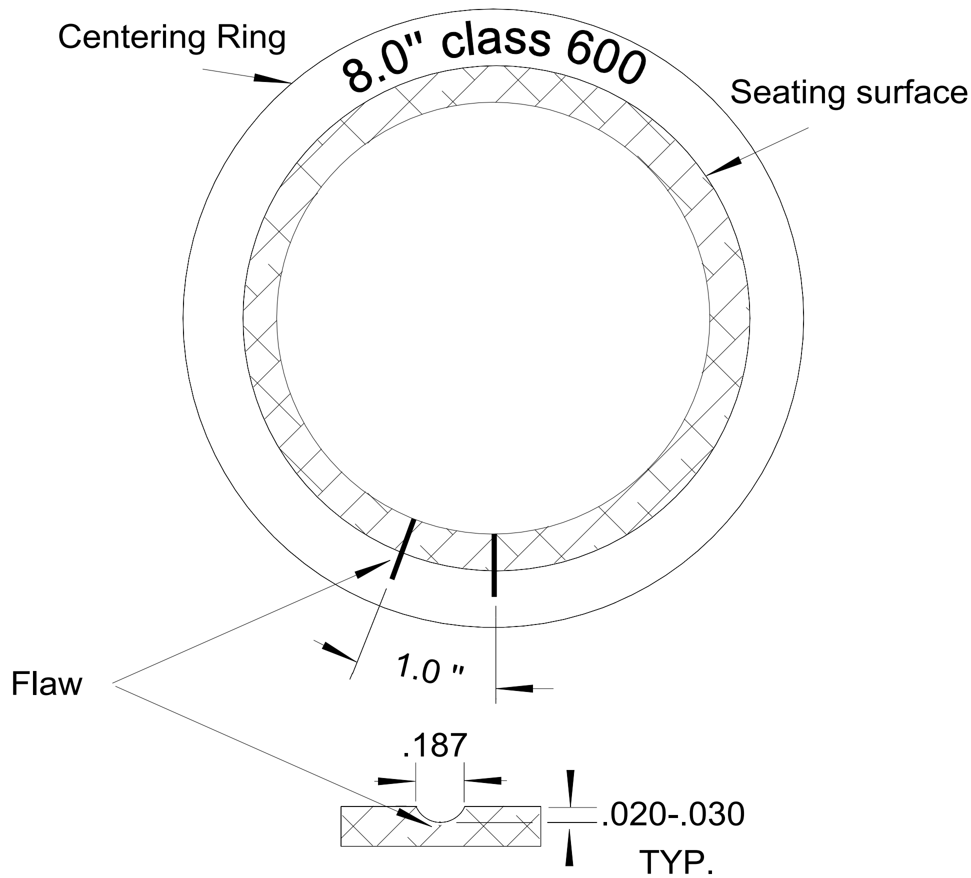

Figure 4-10
Flawed Gasket for Third Test

Test Description:

In this test, two flaws with the dimensions and orientation shown above were inserted into a class 600 metallic gasket. Initially, these flaws were only inserted into the seating surface of the gasket. However, they did not produce a leak and had to be extended into the centering ring portion of the gasket.

During the test, visual inspection showed that leaking occurred at both flaws at a pressure of 85 psi (water pressure). Due to the leaking, the maximum pressure that could be obtained with the aid of the pump was approximately 200 psi. Once the leaking area was identified, the mechanical leak sealing fixture was installed. In this test, 5/16″ packing material was used to determine if it possessed any advantage over the 1/4″ packing material used in previous test. In the installation process it was necessary to compress the 5/16″ packing to insert it into the gap. The increased thickness made it more difficult to insert the packing rings without damaging the packing. As a result no real advantage was realized by using the thicker 5/16″ packing over the 1/4″ graphite packing.

After the installation of the leak sealing fixture visual inspection showed that the leak was successfully stopped. The pressure was then monitored and found to hold at a constant pressure of 619-623 psi.

4.3.4 Leak Test # 4 for a Class 600 Weld Neck Flange

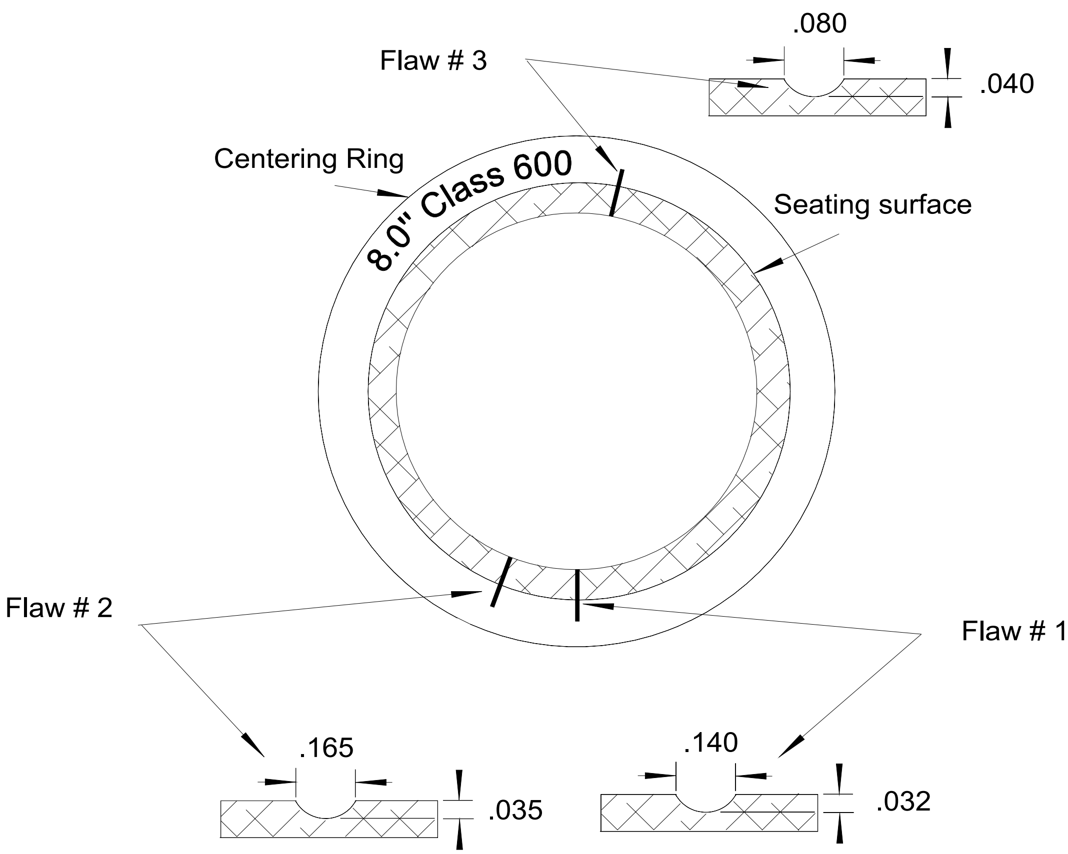

Figure 4-11
Flawed Gasket for Fourth Test

<u>Test Description:</u>

In this test, three flaws with the dimensions and orientation shown above were inserted into a class 600 metallic gasket. The flawed gasket was then installed following the procedure previously outlined.

During the pressurization of the flange, leaking occurred at 450 psi. Leaking occurred at each of the flaw locations and flaw #3 produced significant water spray. Due to the orientation of the leaks, two quarter-section leak-sealing fixtures were used. One fixture was used to seal the leaks produced by flaws #1 and #2 and a second fixture was used to seal the leak produced by flaw #3.

Once the mechanical leak sealing fixtures were installed, the flange was inspected. The inspection showed that all three leaks were stopped and the pressure could be maintained in the range of 640-655 psi.

5
CONCLUSIONS

This technique is an effective method for stopping leaks in flanges due to deterioration of the gasket's sealing surface. A mechanical device offers several advantages not available with other methods. This device is:

- Non-intrusive.
- Simple in design. Modifications are easily made.
- Temporary. Not difficult to remove during the scheduled outage.

There are some issues that still need to be addressed. As a result of live demonstrations for utility personnel, several suggestions have been made.

1. The need to make the fixture as simple as possible is of utmost importance. Several comments were made during demonstrations that this could potentially be used in a hot area. We need to make the necessary changes in the fixture design to allow the user to install the equipment as fast as possible. One key area is to make the backing bar and the graphite packing into a single piece. This has been tested under laboratory conditions with only mild success. Most adhesive compounds do not offer sufficient cohesion with graphite. While we were successful in joining the two pieces, they immediately separated as they were placed in the fixture.

2. Developing additional tooling to insert the packing while keeping personnel away from a potential steam blast was another concern. This was easily remedied by introducing a series of angled holes on the back side of the backing bars. This allowed a long 'tee' handle to hold the bar steady while inserting it into the fixture. The tool was made to be approximately 18 inches long and was fairly effective.

3. It was noted that only one stud would be allowed to be removed during a repair. Our original design called for two studs to be removed simultaneously which was unacceptable. The clamshell was modified by machining the corner edges. By removing sufficient material, the fixture could 'swivel' around a single bolt. Once the first stud was re-tightened, the hardened bushings still allowed the fixture to swivel while maintaining the 500 ft-lb torque on the flange. The second stud could then be removed and the fixture could be put into place.

Live steam line testing is the next step. The RRAC has been offered the use of a subscribing utility's test facility. This will offer a look at the feasibility of this device under realistic conditions. We anticipate this testing to occur in the first quarter of 1999.

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