USE OF METAL BELLOWS NONCONTACTING SEALS AND GUIDELINES FOR STEAM APPLICATIONS

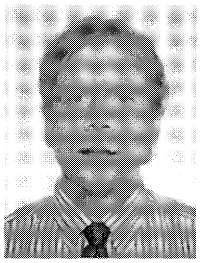
by
Lionel Young
Senior Project Engineer
Joel N. Burroughs
Senior Design Engineer
and
Michael Huebner
Manager, Product Development
Flowserve Corporation
Temecula, California

Lionel A. Young is Senior Project Engineer with Flowserve Corporation, Fluid Solutions Division, in Temecula, California. He joined Flowserve Corporation (formerly BW/IP International) in 1991 as a Project Engineer in the Research Group where he has been involved in low emissions sealing technology.

Mr. Young received his B.S. (1978) and M.S. (1980) degrees (Mechanical Engineering) from the University of New Mexico. After graduation, he continued to do research and development work at the university in mechanical seal design and testing. In 1987, he went to work at Mechanical Seal Technology, Inc., where he was involved in seal research, product development, and other engineering services.

Joel N. Burroughs is Senior Design Engineer at Flowserve Corporation, Flow Solutions Division, in Temecula, California. He joined Flowserve Corporation (formerly BW/IP) in 1996, and has worked in the area of API 682 support and steam seal development and testing. Prior to joining Flowserve, he was a co-op with BW/IP and Allied Signal Automotive.

Mr. Burroughs received his B.S. degree (Mechanical Engineering) from Cal Poly San Luis Obispo. He is a member of ASME.



Michael Huebner is the Manager of Product Development at Flowserve Corporation, Flow Solutions Division, in Temecula, California. He has more than 16 years of experience in the design of mechanical seals, centrifugal and positive displacement pumps, and fluid conditioning equipment. For Flowserve, he has served in design testing and application functions in both Europe and the U.S.

Mr. Huebner received his B.S. degree (Engineering Technology) from Texas A&M University.

ABSTRACT

Steam turbines are used throughout the process industries and provide a reliable means of driving pumps, compressors, and other rotating equipment. Carbon rings are currently the most common way of sealing these turbines. Although simple in design, the sealing capability of these devices is very low. This results in high steam losses, lower efficiency, and decreased equipment reliability.

This paper discusses the design and testing of a new noncontacting seal for operation in steam turbines. This seal was designed to improve turbine efficiency and equipment reliability. Details from three field applications are discussed. Guidelines for installation and operation of steam turbine seals are also discussed, based on experience in the laboratory and field applications.

INTRODUCTION

Steam turbines are used as drivers for pumps and other rotating equipment throughout the chemical and petroleum industries. Since steam is created as a by-product of many processes, steam turbines offer a clean and reliable method of recovering some of this energy. Steam turbines can also be easily controlled to operate at various speeds without the need for more expensive control systems. In addition, steam turbines can continue to operate in the event of electric power failures and allow for more orderly plant shutdowns. A typical steam turbine is shown in Figure 1.

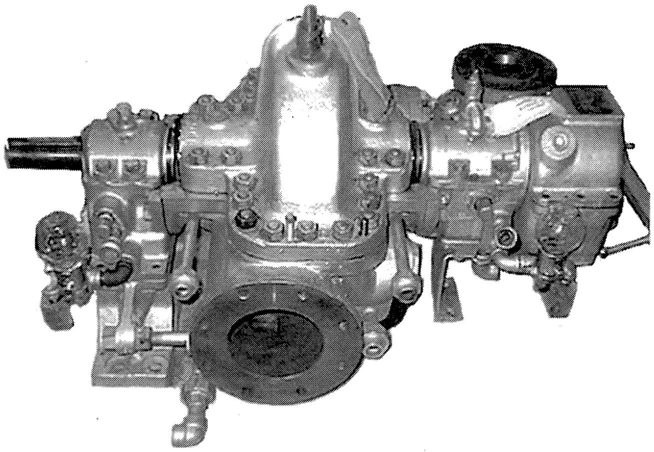


Figure 1. Typical Steam Turbine.

Although steam turbines are widely used, their method of operation can differ significantly between plants. In some cases, turbines are used as the primary drivers. In these plants, the steam turbines will run continually to support ongoing processes. In other plants, steam turbines will be used primarily in backup services in the event of a failure of an electrically driven piece of equipment. In some cases, these turbines will be left cold while on standby. More often, the backup turbines will be on hot standby or slow roll, where the turbine is maintained at near operating temperatures.

Steam turbines require a method of preventing the internal steam from escaping to atmosphere from around the rotating shaft. Due to the aggressive conditions, many of the methods used for sealing pumps or compressors have not been available for steam turbines. The most common method is the use of labyrinth or close clearance bushings. In reality, these bushings are not sealing devices; they only act as a throttling device to minimize leakage. Depending upon the bushing design and the operating conditions, substantial steam losses can be expected.

Because steam leakage is not considered an environmental problem, it has not undergone the same scrutiny as other process leakages. Controlling steam leakage, though, would be beneficial for a number of reasons. Steam released to atmosphere represents a loss in money, since the user has invested money in water, treatment chemicals, and energy to create the steam. It has been shown (Bloch and Elliott, 1985) that significant cost savings can potentially be achieved using gas seal technology in lieu of carbon rings. Second, normal steam leakage often creates clouds of steam around the turbines and adjacent areas. This makes working conditions for the operators unpleasant and potentially unsafe. This escaped steam also finds its way into other areas such as bearing lubrication systems. This can considerably reduce the lubricating properties of the oil and therefore reduce the reliability of the equipment.

DESIGN GOALS

From the above information, it is easy to see how an improved sealing device could benefit the user of steam turbines. In designing this seal, it is important to first define the design goals for the seal and then identify (or develop) the technologies to achieve these goals. This paper addresses seals designed for use in steam turbines that are covered by the API 611 specification. These turbines are generally used as drivers for pumps or other pieces of process equipment.

Steam is a poor lubricant for traditional mechanical seal designs. With very light face loading, it may be possible to use contacting faces in low pressure, low speed applications. In industry, the majority of steam turbines operate with exhaust pressures in the range of 50 psi to 300 psi (3.4 bar to 20.7 bar). Due to the construction of most turbines, the seals will only be exposed to exhaust pressure in operation. These pressures require the use of liftoff faces similar to those used in compressors and dry gas pump seals.

Liftoff type gas seals operate on a very thin gas film to both minimize leakage and to prevent face contact. While steam turbines operate on steam, they are also exposed to condensate, a variety of water treatment chemicals, and various forms of pipe scale and deposits. The presence of debris in this thin film can cause damage to the seals. In addition, a buildup of debris due to condensate flashing across the seal faces can increase the film thickness and increase seal leakage. This presents a challenge to seal designers.

Material selection is also a key consideration. Steam conditions are relatively aggressive and must withstand long exposure to high temperatures. Elastomeric materials (such as rubber gaskets) have not proven reliable in high temperature steam applications. Metallic materials also require close examination. Although most turbines are constructed from steel, the combination of steam, high temperature, and air on the atmospheric side of the seal may cause corrosion. Under high temperatures, it is also beneficial to match thermal expansion of critical surfaces to assist in piloting the rotating components and providing sleeve sealing.

Since any new seal must be adaptable to existing equipment, the seal must be installed in place of the existing carbon rings. Carbon ring boxes generally fall into two categories—detachable and integral. A detachable carbon ring box is bolted into place on the side of turbine. This allows for easier maintenance and replacement. Steam seals for these turbines are mounted externally and replace the carbon ring box (Figure 2).

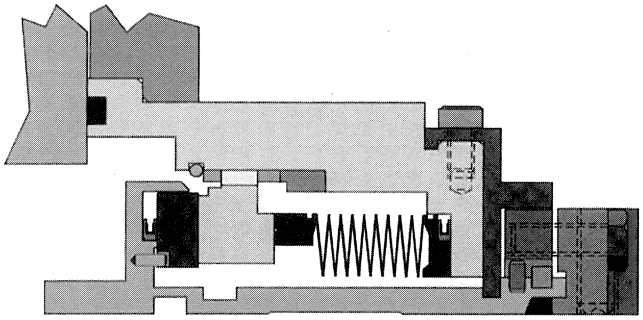


Figure 2. Externally Mounted Steam Seal.

An integral carbon ring box is part of the casting for the case and cover and cannot be removed from the turbine. A steam seal is mounted internally and must be installed within the existing box dimensions (Figure 3).

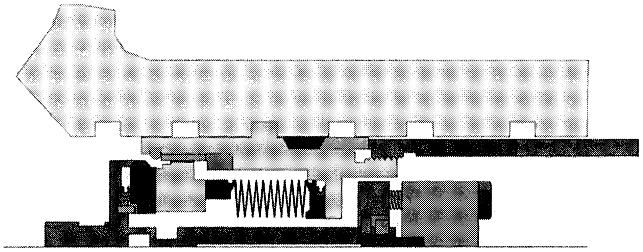


Figure 3. Internally Mounted Steam Seal.

SEAL DESIGN SPECIFICS

After analyzing all the design requirements, specific design features were selected. Since the high temperatures prevented the use of elastomeric materials, a metal bellows seal was selected. This eliminates the problem associated with hangup due to debris building up on the dynamic seal interface. Static gaskets would be flexible graphite and/or high temperature composites. Using floating faces would eliminate problems associated with shrink fits or other face clamping designs. Wavy-face technology would be used for face liftoff, since it provides the highest degree of water and debris tolerance.

In Figure 4, the main features of the final seal can be seen. The seal is based on an Alloy 718 bellows core that has been used successfully for many years in high temperature pump applications. Alloy 718 has excellent high temperature properties and good corrosion resistance to chemicals seen in steam services. In this design, the bellows core provides only an axial load to the seal faces. It does not provide any drive function. This eliminates stick slip, fatigue, and associated dynamic problems. The flange at the end of the bellows is lapped flat and seals against the carbon seal face. This lapped support surface allows free thermal expansion between the bellows and the face, which helps maintain face flatness.

Finite element analysis (FEA) was used to design stationary carbon faces to eliminate pressure distortion. Since it is not clamped into place, the face remains flat during operation. The face is driven by two drive lugs at the outer diameter (OD) and piloted to the inner diameter (ID) of the flange.

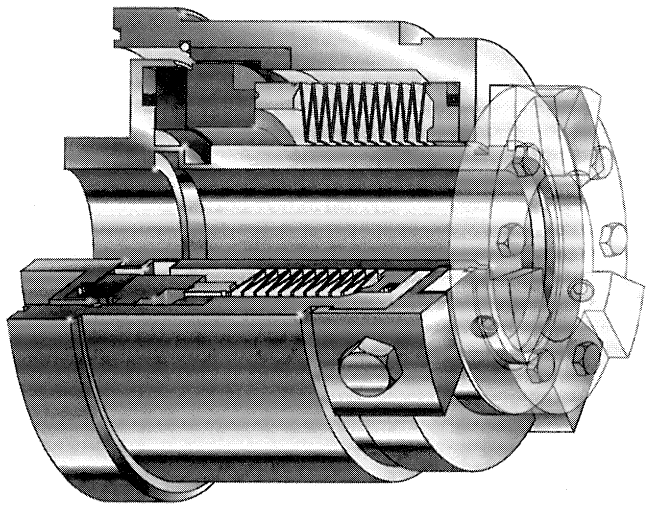


Figure 4. Cross Section of Steam Seal.

The rotating silicon carbide face is manufactured using wavy-face technology for face liftoff. Wavy-faces were first developed by Lebeck (1980) in the mid 1970s. The wavy-face is designed with a series of circumferential waves that are large at the OD and get progressively smaller toward the ID (Figure 5). Near the ID is a sealing dam that minimizes leakage past the seal faces. When the face is rotated, gas is drawn into the valleys of the waves and is compressed as the fluid film decreases at the peaks. This has two effects. First it creates a high pressure region that is capable of separating the two faces. This allows the seals to operate without face contact. A more complete description of this configuration is given in Young and Huebner (1998).

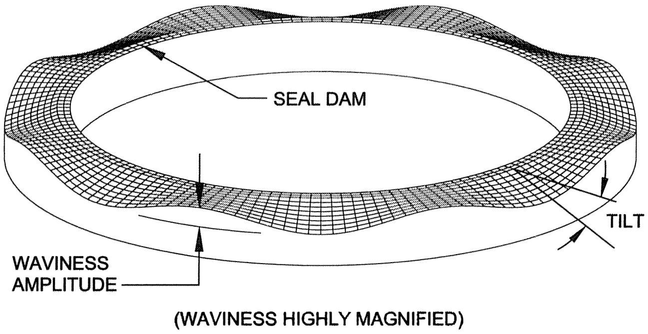


Figure 5. Wavy-face Showing Critical Design Features.

The second aspect of this design provides for a cleaning action of the faces. As the gas is compressed near the peaks of the waves, it can relieve pressure in three directions. Some will go across the seal dam as leakage. Some will go over the peak to create lift. The rest will flow toward the OD of the seal and go back into the seal chamber. This continual flow of gas across the faces creates a self-cleaning action. Since the face is free from grooves or slots, there is nowhere for the contamination to collect. This helps make the wavy-face more tolerant of contamination than grooved face designs. Figure 6 illustrates the pressure profile as steam is compressed at the wave peaks.

The rotating face, like the stationary face, is free floating and is not clamped into place. This minimizes clamping stresses and stresses imposed by differential thermal expansion between the face and sleeve. A spring energized composite seal is used to seal the rotating face to the sleeve. This seals effectively and is easy to assemble. A closeup of the faces is shown in Figure 7.

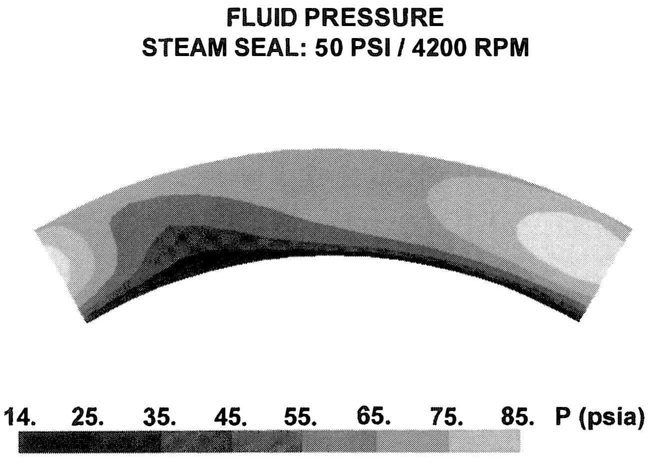


Figure 6. Pressure Profile of Steam Fluid Film on Face Section.

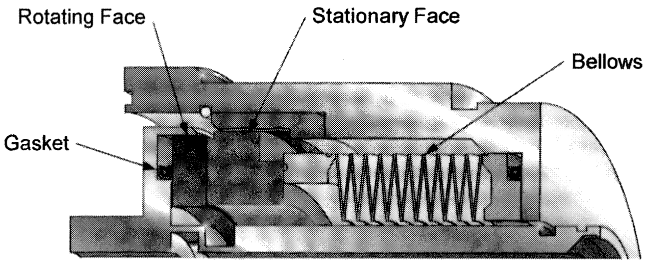


Figure 7. Detail of Seal Face Cross Section.

The sleeve is also designed to minimize distortion. Since part of the sleeve is exposed to hot steam conditions and part is exposed to cooler atmospheric conditions, the sleeve will distort due to thermal expansion. The sleeve was designed to decouple the hot and cold ends of the sleeve through a series of grooves. This allows the sleeve to be exposed to high temperature difference and still maintain a flat support surface for the face. The radial support surface for the face is kept small to minimize the effect of any residual distortion. An analysis showing this feature is seen in Figure 8.

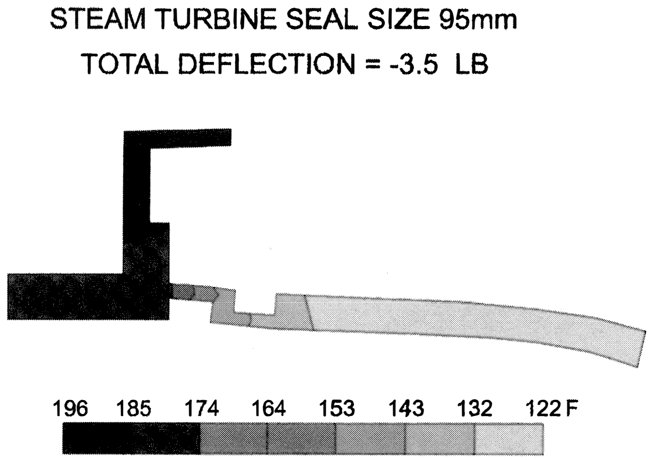


Figure 8. Sleeve Distortion Due to Temperature Gradient.

LABORATORY TESTING

To ensure proper operation in the field, seals must be tested in an environment that closely simulates actual field conditions. Testing for these seals was performed on steam under a wide variety of speeds, pressures, and steam conditions. Typical test cycles would include slow rolling at 1000 rpm during startup, followed by operation under steady-state conditions for 150 hr to 250 hr. Typical operating speeds were 3600 rpm, with some testing at 5000 rpm. In addition, starts and stops were added to simulate cyclic operation. Longer term tests under varying conditions were run up to 900 hr. All seal sizes were tested at 50 psi, 150 psi, and 300 psi (3.4 bar, 10.3 bar, and 20.7 bar) to cover the intended operating window for the seals. A steam seal tester is shown in Figure 9.

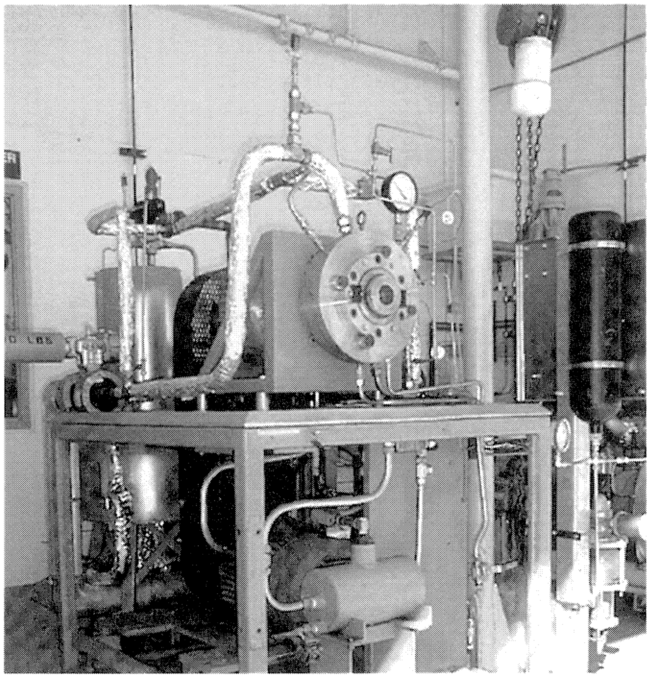


Figure 9. View of Steam Seal Tester.

Steam was created in a boiler at the test stand that was designed to create both saturated and superheated environments. Most of the testing was done with superheated steam to simulate process conditions. The condition of the water in the boiler was also monitored and varied from clean (0.4 grams/liter solids) to very dirty (128 grams/liter). On several tests, carryover from the boiler was allowed to build up solids in the tester housing. Samples of boiler water from customers' steam plants (0.4 gram/liter) were also used to provide realistic evaluation of typical treatment chemicals and contamination.

Early feedback from users indicated the need for the seals to withstand water slugs that may be present during system startups. This would be caused by condensate in the steam lines being blown through the turbine when the lines are first opened. The test seals were subjected to startup with the entire seal chamber filled with water. The seals were allowed to operate in this manner until all the water had evaporated in the tester or leaked past the seals. This was followed by the standard long term testing.

In other tests, the seals were operated on saturated steam, and condensate was allowed to build up until the seal faces were partially submerged in the water. The seals were allowed to operate under this condition for extended periods of time (several days). Because of the pressure decrease as the fluid migrates across the seal faces, the water flashed off to steam between the faces and the seal operated with a characteristic puffing. The seal was then returned to the normal long term testing. There was no damage to the seal faces during any of these tests. Operating wavy-faces in water has previously been shown to have excellent performance characteristics (Young and Lebeck, 1989).

One of the data points taken during testing was steam leakage. The task of accurately measuring steam leakage from a seal is difficult, so the method selected was to measure the amount of makeup water supplied to the seals during testing. Taking this approach gives the total leakage for the two seals, since the tester is set up in a double seal arrangement. In addition, since each seal could be of a different size, Table 1 includes this variation and shows the results for some of the combinations of seal sizes tested.

Table 1. Total Measured Steam Leakage on a Variety of Laboratory Tests.

Test #	Pressure (psi)	Outboard Seal Size (inch)	Inboard Seal Size (inch)	Total Average Steam Leakage (lb/hr)
20	150	4.125	3.750	1.3
23	300	5.000	3.750	4.7
24	50	5.000	3.750	0.06
25	50	3.250	3.750	0.08
26	150	3.250	3.750	0.10
33	300	4.125	4.125	1.5
	50	Carbon Rings		14
	50	Spiral Groove 3.500	Spiral Groove 3.500	0.27

These data show that under similar operating conditions (e.g., 50 psi), noncontacting mechanical face seals exhibit on the order of 200 times less leakage than carbon rings. It should be pointed out that although noncontacting mechanical seals have significantly less leakage, they nonetheless do leak vapor to the atmosphere. There is a common misconception that the incorporation of a mechanical seal will eliminate all steam leakage. The fact that the seal is operating in the noncontacting mode means that the leakage pathway to the environment is on the order of millionths of an inch rather than thousandths. Moreover, depending on the conditions of humidity near the turbine, steam vapor may be visible and should not necessarily be interpreted as a failed seal.

The results of the lab testing show that the seal can operate successfully under a wide variety of test conditions. The seal faces were designed with minimal pressure caused distortion and liftoff up to 300 psi (207 bar). Under running conditions, the self cleaning characteristics of the wavy-faces keep the sealing interface relatively clean of debris, even when the exposed surfaces of the seals were covered with chemical deposits. Steam leakage measurements indicated that expected leak rates are two orders of magnitude less than carbon rings.

FIELD EXPERIENCE

A number of field installations were run to evaluate the performance of the seals in operating turbines. These installations have exposed the seals to a cross section of applications that can be expected in industry. One of the conditions for selecting these field sites was that the units were operated for extended periods of time. It was thought that testing seals in standby services would not be an accurate predictor of performance. Another requirement was that the turbine be examined to ensure sealing and piloting surfaces were suitable for seal installation.

Case 1

A large petrochemical plant had reliability problems on a critical, unspared turbine-driven compressor that supplied instrument air. The turbine and compressor shared a common lubrication system. Regular oil checks showed water contamination of over 1000 ppm, with some freestanding water in the bearings.

The turbine operates with an exhaust pressure of 165 psi and an exhaust temperature well above saturation temperature. Steam quality is high and the turbine case was observed to have minimal corrosion. The turbine bore was not concentric to the bearing housings as evidenced by binding between the adaptive hardware during the initial installation. The hardware was modified to allow for the poor concentricity by increasing clearances between seal components to allow for a 0.060 inch total indicator reading (TIR) runout.

After installing steam seals, the amount of water in the oil dropped. The water concentration typically is less than 200 ppm, and usually less than 100 ppm, with no freestanding water. This improves the reliability of the equipment and has reduced time spent monitoring the water present in the oil. These seals have been running continuously for over 15 months.

Identical seals were previously installed on a similar turbine at this plant and have been running continuously for over 19 months. The operating conditions are identical.

Case 2

Not all installations are as smooth as that described above. A large petrochemical plant installed an upgraded design similar to that described in Case 1. The condition of the turbine was poor (heavy pitting and corrosion), which indicated poor steam quality and more adverse operating conditions. The turbine was reworked and seals installed. The steam leakage was excessive and the turbine was torn down and examined. The seals were reinstalled and the turbine restarted.

There was still excessive leakage on the coupling end. The turbine was examined more carefully. A crack was found in the turbine case starting inboard of the flange gasket sealing area and ending outboard of the flange gasket sealing area. Removal of the leak off port pipe showed steam erosion where the crack ended in the pipe port threads.

A tapered pin followed with a pipe plug was used to plug the through hole. A high temperature sealant was pumped into the turbine until it bubbled past the pipe plug. The leakage was substantially reduced but not eliminated. The inlet valve was opened to increase the temperature of the turbine case, which further reduced the leakage. Some of the sealant had come into contact with the sleeve and this prevented the shaft from rotating. A pipe wrench was used to break the rotor loose. The turbine was slow rolled uncoupled for one day. It was coupled to the pump and has been running continuously for over nine months.

Case 3

A large oil refinery wanted to use mechanical seals on a high pressure turbine. The exhaust pressure of 300 psi to 400 psi (20.7 bar to 27.6 bar) exceeded the 300 psi maximum pressure rating of the seal. Typically, these turbines employ a breakdown labyrinth bushing and leak off port prior to the carbon rings. The leak off port is piped to a low pressure header. This arrangement was also used with the standard seal to lower the pressure to 50 psi (3.4 bar). The turbine has been running continuously for 11 months.

Other seals installed on similar turbines at other refineries have been running for over 16 months.

GUIDELINES FOR SUCCESSFUL STEAM SEAL APPLICATIONS

From the experience gained during field trials and subsequent seal installations, a number of common topics became apparent. Installing a seal does not alone guarantee success. Some of the initial installations did not work well due to factors other than the seal. After changing some of these factors, the seal performance was improved. Some of the discoveries made during these applications are covered below. These guidelines can be used as a general reference for steam seal users.

Overview

- Understand the steam environment. Determine how the plant uses its steam and the construction and operation of the steam system. Are conditions constant or are there significant variations due to changes in plant operations?
- Learn how the turbine is operated. Check the performance with carbon rings and understand any abnormalities. Determine if the steam is saturated or superheated. It is possible that the steam may be superheated during operation and saturated during hot standby.
- Document actual operating conditions. Include pressures, temperatures, operating speeds, steam condition, and standby conditions (hot standby, slow roll, or cold standby). Share this information with the seal supplier.
- Inspect the turbine. Verify all seal cavity and first obstruction dimensions. Correct any problems with the turbine prior to installing the seal.
- Install the seal according to seal assembly drawing and procedures. The rotor should rotate freely after the turbine is fully assembled.
- Prevent water accumulation in the piping and turbine. Install steam traps and drains as required.
- Consider cold standby where possible. This eliminates many of the problems associated with hot standby or slow roll operations.

Turbine Condition

Steam turbines vary greatly in their condition. Since turbines were originally designed to use carbon rings, many noncritical surfaces may have been machined with loose tolerances or left in an "as cast" condition. After years of service, it is usual to find these surfaces pitted and corroded. When the turbine is rebuilt, these noncritical surfaces are often left in this condition. Even if all the surfaces are repaired, older turbines may have been reworked many times and may no longer have the initial original equipment manufacturer (OEM) dimensions in the carbon ring areas. When these factors are combined, it is easy to see the challenges faced with installing a steam seal. Figure 10 shows an integral carbon ring box.

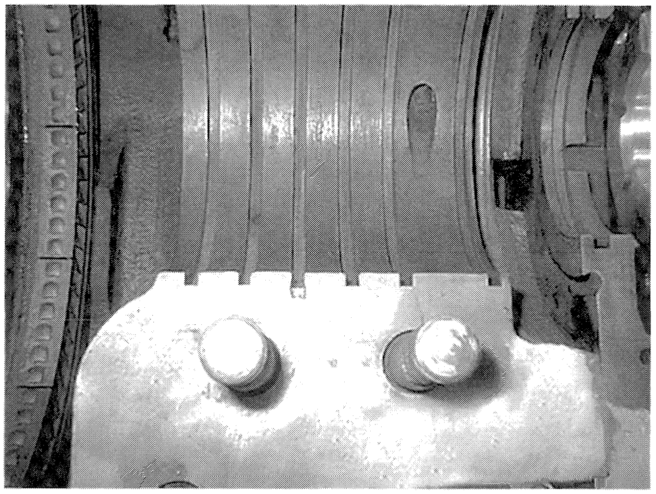


Figure 10. View of Integral Carbon Ring Box.

In addition to dimensional concerns, damage to the turbine and problems with the turbine performance need to be investigated prior to installing a new seal. Short mean time before repair (MTBR) on the turbine may indicate operation problems. If there is a hidden problem that goes undetected, the turbine and seals may fail prematurely. If possible, examine the turbine in operation prior to taking it out of service. Excessive leakage from the turbine can have several causes, and careful examination of the leakage location may indicate problem areas. Below is a list of potential leak paths.

- Worn out carbon rings/failed seal
- *Cracked turbine case*—Look around the areas where steam leakage was present for signs of corrosion or erosion.
- *Split line of turbine case*—The split line of the case or cover may be warped out of flat enough to prevent effective sealing. Examine the split line for signs of steam leakage or erosion on the joint surfaces.
- *Mismatch between the case and cover*—On detachable carbon ring boxes, a gasket will be required to seal across the split line where the carbon ring box bolts to the turbine. Examine the carbon ring box, gasket, cover, and case for signs of erosion in this area.
- *Shaft damage*—Examine the shaft in the area of the overlay. It is possible for steam to leak under an improperly applied overlay.

Talk to the operator and maintenance personnel regarding these concerns and the performance of the turbine. Find out if there are any other issues that need to be addressed regarding performance or reliability. Any problems in these areas need to be resolved prior to installation of the new steam seal. Before installing the new seal, the following areas need to be checked:

- *Dimensions*—If the seal has not been designed, provide the seal supplier with complete, accurate dimensions for the seal installation area. In addition, provide details required for mounting the seal such as distance to the bearing bracket and exclusion device. If the seal has been previously designed, compare the dimensions shown on the seal assembly drawing with the dimensions on the turbine.
- *Sealing surfaces*—Inspect all sealing surfaces to ensure that they are free from any large pits, corrosion, or steam erosion damage. Any damage in these areas must be repaired to ensure proper sealing of the static gaskets. On internal mount designs, there is often a drive pin hole located on a sealing surface. This must be filled with a suitable high temperature filler or metal plug.
- *Shaft mounting surfaces*—Check the shaft for any signs of damage in the seal area. Polish the shaft to remove any debris or burrs. Repair any damage or replace the shaft as required.
- *Check turbine alignment*—Ensure that the alignment between the shaft and the seal mounting surfaces is within specification. Misalignment, especially perpendicularity, will have a negative impact on performance. Concentricity is not as critical but must be within the seal OEM requirements (typically less than 0.030 inch TIR). Excessive misalignment may indicate problems with the bearings or shaft.

Steam Condition

The condition or quality of the steam in the turbine is a critical factor in the performance of steam seals. The ideal operating condition for gas seals in steam turbines would be superheated steam with low solids content. More often than not, this is not the case.

Many turbines are operating under saturated conditions with various levels and types of contaminate present. When steam enters the saturated condition, there can be an accumulation of water in the turbine. This will find its way to the seals and performance will be altered. Operating a gas seal in a liquid environment will increase the film thickness and cause higher leakage. It is, therefore, an advantage to minimize the accumulation of water around the steam seal.

The next area of concern is that of particulate contamination. Steam (and condensate) will contain various levels of dissolved and undissolved solids, depending on the system and piping. Analysis done from field applications has shown the presence of various metals from the piping as well as calcium arising from the general condition of the treated water. These substances can pose an abrasive condition, leading to wear of the faces and packing of any face features designed for hydrodynamic lift. Hot condensate will tend to flash as it passes across the seal faces due to the decrease in pressure. This will cause any dissolved or carried particles to be deposited in the sealing interface. Wavy-face technology has been shown to resist the effects of contamination packing, but abrasives in the steam will have long term detrimental effects.

Chemicals present in the steam can also attack metal components. Due to the high temperatures and presence of air on the atmospheric side of the seal, corrosion can sometimes be seen on the seal components. Corrosion on critical areas such as sealing surfaces can lead to additional leakage. It is, therefore, important to know what chemicals will be present in the application.

Saturated Steam, Condensate, Water Slugs

Although the steam seal has been tested successfully on water, higher leakage rates and the presence of contaminants makes operation on water undesirable. In any system running near saturation, care must be taken to ensure that freestanding water does not collect in pipes, the turbine, or other vessels. This water will corrode metal surfaces and is a large source of the contamination. In the turbine, a steam trap should be piped to the case drain to ensure that water does not collect in the turbine. The size of the steam trap must be sized for worst case conditions such as standby or startup. Eliminating water in the turbine is one of the best ways to increase seal and turbine reliability.

In some cases, large slugs of water enter the turbine when the steam lines are first opened. This may expose the turbine and the seal to large quantities of contaminants until the steam trap purges the case. Operation at saturated conditions will also expose the turbine and seals to water on a continual basis. The area around the seal should be designed to minimize collection points for water. Any water that forms near the seal must be allowed to freely drain back into the case and not form pools near the seal faces. This will help minimize seal leakage and will help prevent corrosion of the case in the vicinity of the seals.

Hot Standby, Slow Roll, Cold Standby

Many steam turbines are used as backup for other pieces of equipment. To keep the turbine ready for immediate use, the system will be kept on hot standby. In other cases, the unit will be allowed to slow roll. These conditions can cause problems for the seals if proper precautions are not taken.

When operating in hot standby, the turbine is dead-ended and will be much cooler than when operating continuously or on slow roll. Steam flows into the turbine at a much lower rate. Heat losses from the piping and turbine will reduce the temperature, and steam will start to condense. Depending on the piping arrangement, water can fill the turbine. Any debris in the system or piping can be carried into the seals.

When operating on hot standby, the case drain should be opened completely. If the drain is only partially opened, the water may not be able to drain away quickly enough to prevent the turbine from filling with water.

Because of these issues, turbines are sometimes allowed to slow roll. In slow roll, the turbine and driven equipment are allowed to operate at a fraction of the full operating speed. In practice, this is normally in the 500 rpm to 1000 rpm range and has been dictated by the minimum operating speed of the bearings. When operating in slow roll, steam flows through the turbine as it would under normal operation. This helps minimize the problems of water seen in standby conditions. Problems can occur by operating the driven equipment at these speeds and this should be investigated. In addition, steam seals also have minimum speed requirements to ensure face liftoff. The seal supplier can provide this information.

Cold standby is another option. In this case, the turbine is not exposed to steam during standby and is maintained at ambient conditions. The case drain is left completely open to allow any water to drain from the case. One major turbine manufacturer stated that 95 percent of turbines in this class could go from cold standby to full operation without any problems. The manufacturer of the specific turbine must be contacted to discuss this option. Cold standby eliminates most of the problems associated with hot standby and slow roll. It also consumes the least amount of steam.

The end user should work closely with both the seal and turbine suppliers to determine the best option for a specific application. Seals are generally installed to help improve MTBR, increase system efficiency, and increase safety. Proper operating practices, especially during standby conditions, are critical to help achieve these goals.

Seal Installation

Specific instruction for seal installations can be obtained from the seal vendor. One of the areas requiring special attention is the drive collar set screws. These set screws drive the seal and axially locate the sleeve on the shaft. Steam turbines have shafts that are often hard-surfaced under the carbon ring box. Many customers want to retain this hard-surfacing even when switching over to steam seals. This surface prevents the set screws from dimpling the shaft during installation. The steam seal described in this paper utilizes twice the number of screws normally used on typical pump seals. The drive collar is made from 416 SS to match the thermal expansion of the shaft. When properly torqued, this has worked effectively. For critical applications at higher pressures, consult the seal vendor and turbine OEM to determine if special designs are required.

Internally mounted seals require additional considerations. The seals must seat fully in the turbine case or the turbine will not properly seal at the split line. Measure the turbine bore and seal OD to ensure adequate clearance. Compare these dimensions with the installation drawing. The concentricity of the shaft and the bore must be checked. Poor concentricity can result in poor seal performance or failure.

Internally mounted seals are also designed with a lock pin between the seal flange and the turbine case (Figure 11). This is necessary to prevent the flange from spinning in the turbine when tightening the flange gasket. A small groove must be machined or ground into the turbine case for each pin so the pins do not interfere with the lowering of the cover. The location of the groove can be determined from the seal drawing and should be checked with the actual seal assembly prior to installation. The groove should be no larger than necessary to contain the pins and should not break into adjacent gasket sealing areas.

CONCLUSION

A noncontacting metal bellows steam seal has been designed for use in steam turbine applications. This seal uses wavy-face technology to create liftoff. This design provides for a higher tolerance for contamination and water exposure than other gas seal face technologies. The Alloy 718 bellows provides excellent resistance to corrosion and eliminates the problems associated with dynamic gaskets. The design of the seal face eliminates problems normally associated with clamped faces and drive mechanisms. This seal has operated successfully in both laboratory and field installations.

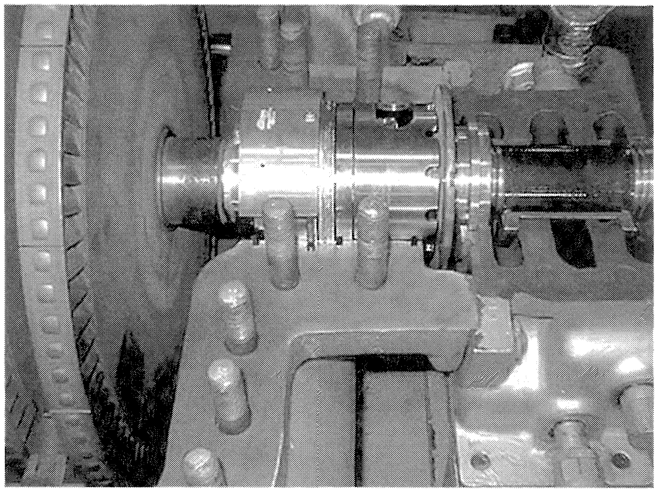


Figure 11. Internally Mounted Steam Seal Installed in Turbine Case.

Steam seals can be used successfully in the field to provide more efficient operation of steam turbines. To achieve a successful application, many factors concerning the turbine condition, operating practices, and steam condition must be examined. A steam seal, like any other seal, requires a specific environment to operate most effectively. Failure to address any of these areas can lead to unacceptable seal life or steam leakage.

The use of mechanical seals in steam turbines is relatively new compared with pumps and compressors. Because turbines have generally been designed for carbon rings, the application of seals is sometimes considered an afterthought. Many of the common practices for pumps (such as shaft to seal housing concentricity) have yet to be applied to turbines. Users are tempted to operate seals in the same manner as carbon rings. With better awareness of the seal requirements, though, the goals of higher efficiencies, increased MTBR, and improved safety can be achieved.

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