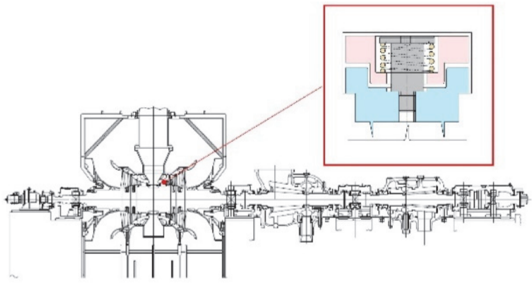
# Development of High-performance Seals for Steam Turbines



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*As awareness in environmental load reduction and energy savings increases, further improvement in power generation efficiency is required.*

*To improve power generation efficiency, reducing leakage in steam turbines is needed. Mitsubishi Heavy Industries, Ltd. has been developing sealing mechanisms to prevent leakage for many years, and has recently developed a new high-performance seal for low-pressure turbines that significantly contributes to the improvement of the overall efficiency of steam turbines. This report presents the features of the developed high-performance ACC seal for low-pressure turbines and the results of performance verification conducted at MHI's demonstration power generation facility.*

## 1. Introduction

To improve the performance of steam turbines, reducing leakage at the turbine blade tips is important. The sealing mechanism on the tips of turbine blades is shown in **Figure 1**. Mitsubishi Heavy Industries, Ltd. (hereinafter referred to as MHI) has reduced the leakage from the blade tip by improving the sealing mechanism. The Active Clearance Control (hereinafter referred to as ACC) seal, developed by MHI, can actively control clearance during operations, and is characterized by the ability to maintain an extremely small amount of leakage during operations. As shown in **Figure 2**, the clearance between the rotor and the labyrinth seal is kept large during start/stop operation. However, during constant load operation, the seal segment is moved to a predetermined position using the differential pressure of the seal and the clearance is kept small, and the leakage during operation is suppressed extremely.

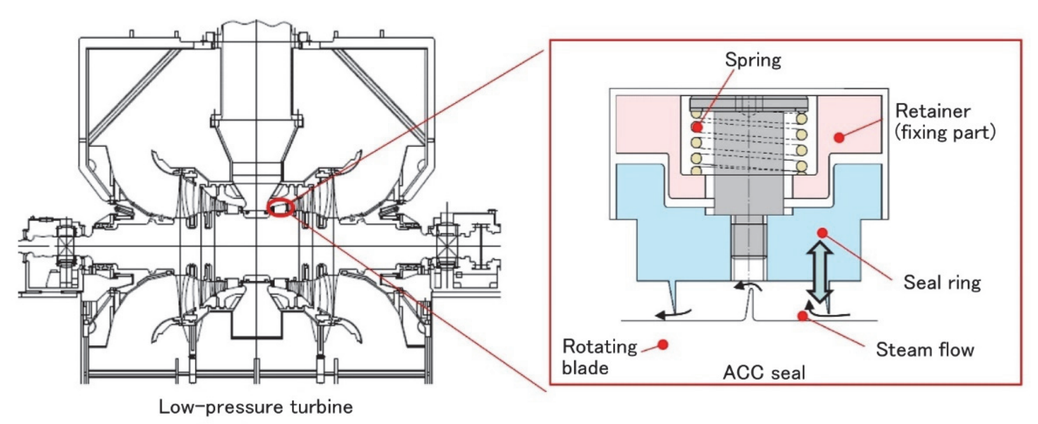


**Figure 1 Low-pressure turbine seal**

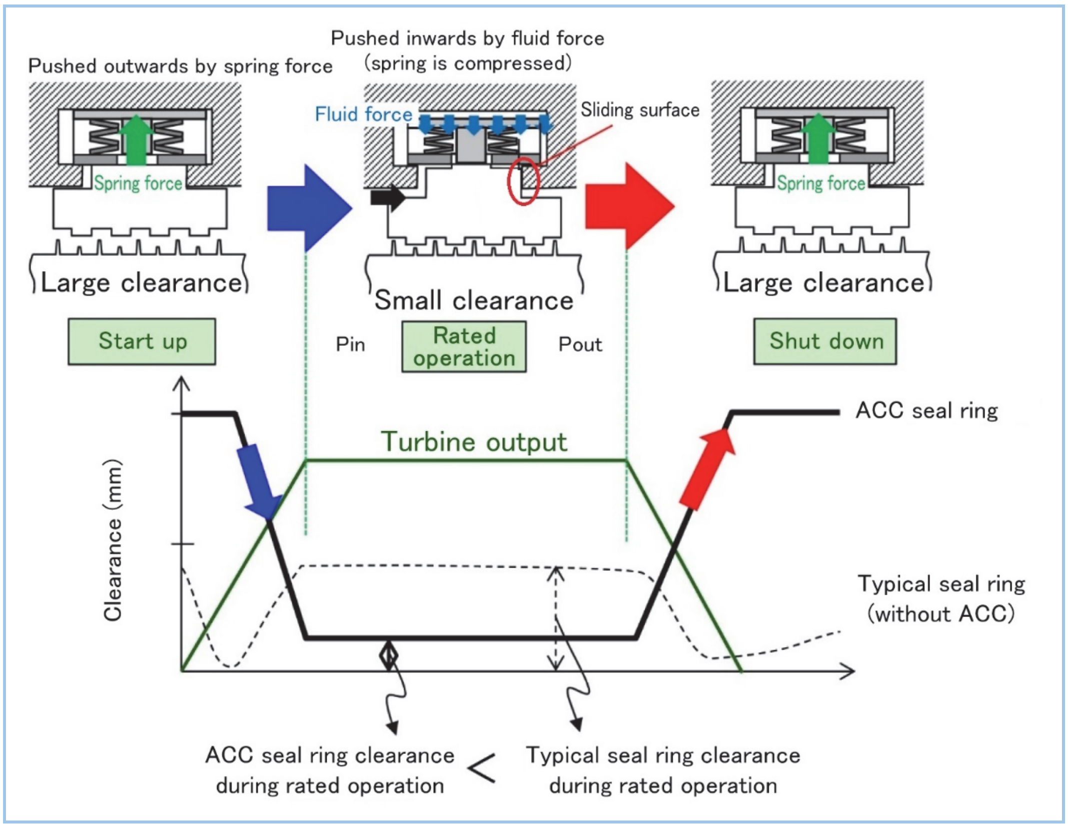


**Figure 2 Working principle of ACC seal**

Low-pressure turbines are two to three times larger in diameter than high- and intermediate-pressure turbines, so optimal control of seal clearance over the entire circumference is not possible. Consequently, applying ACC seals to them is considered difficult. For this reason, ACC seals have been applied only to high- and intermediate-pressure turbines. However, MHI has developed another ACC seal that can optimally control clearance even for large-diameter, low-pressure turbines, by reviewing the method for dividing seal ring in circumferential direction and method for moving seal ring.

## 2. Features of newly developed high-performance seal

A comparison of the structure of a conventional ACC seal for high- and intermediate-pressure turbines and that of the newly developed high-performance ACC seal for low-pressure turbines is shown in **Figure 3**. The conventional ACC seal consists of four fixed segments and two movable segments, and clearance is controlled only by the vertical movement of the movable segments. In contrast, the newly developed ACC seal has no fixed segments but eight evenly divided movable segments all around the circumference, and all segments can move independently. This allows for optimal clearance control over the entire circumference, even in low-pressure turbines with large diameters. Furthermore, another advantage of this seal is that it can flexibly handle various changes in frame design, such as those due to an increase in clearance variation in the left-right direction as seen in new turbines with side exhausts to reduce turbine building height instead of conventional lower exhausts, as shown in **Figure 4**.

The developed seal has a segmented structure consisting of attachment parts (retainers) on the outside of the movable seal ring, and springs placed evenly in the circumferential direction between the retainers to hold the seal ring in place. The guide in the center of each segment is shown in Figure 3. The seal ring contacts the retainer on its upper end surface by gravity, and moves along this surface. The gap at the ends is designed to allow for the minimum necessary gap after moving, in consideration of the movement allowance of the guide to prevent the seal ring from protruding from the retainer. By arranging these segments equally around the entire circumference, each segment moves in a circumferential balance so that contact with adjacent segments does not impede movement.

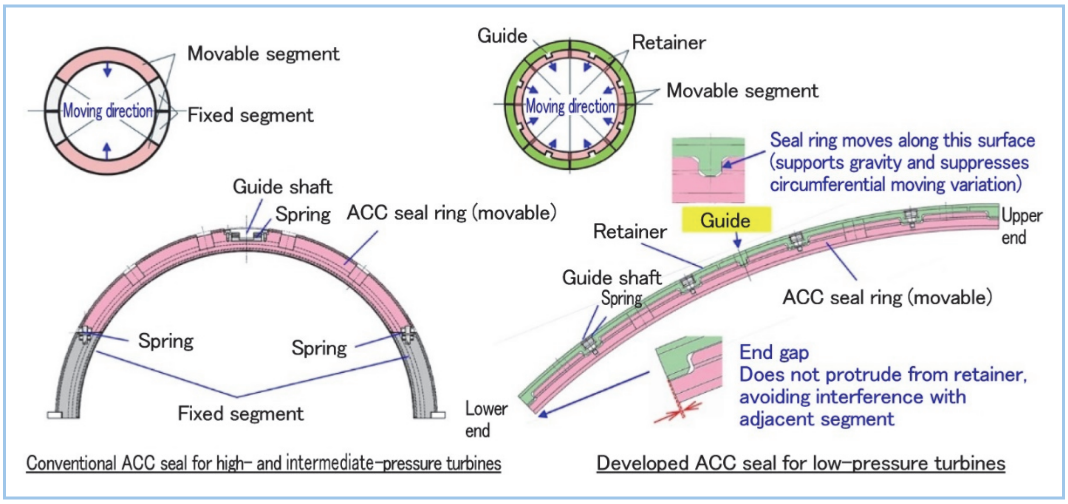


**Figure 3 Structure of ACC seal**

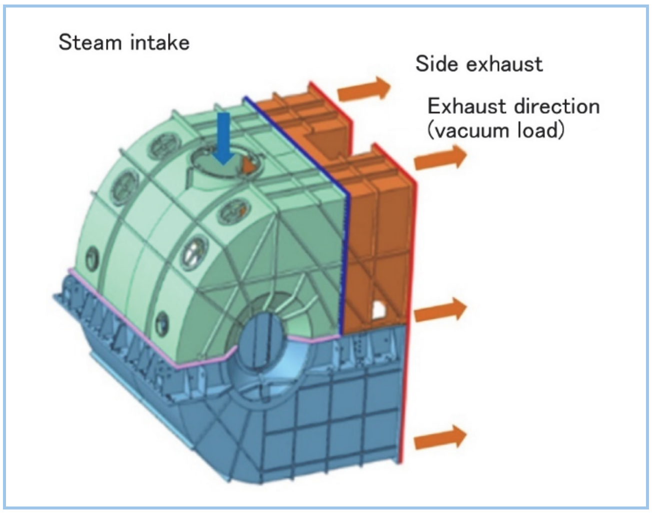


**Figure 4 Side exhaust structure**

## 3. Verification test

To confirm operability of the developed ACC seal, a one-year verification of operability was carried out by applying the seal ring to the upstream stage of an LP turbine at our demonstration facility, T-Point 2. The structure of the verified seal is shown **Figure 5**. The working state of the ACC seal during operations was monitored by attaching eddy-current GAP sensors on the back of the seal ring. In this verification, the amount of movement at several points on the upper, lower, left, and right segments was measured.

The annual trend of ACC seal movement as measured by the sensors is shown in **Figure 6**. The data shown in this figure was obtained under load operation. The results of the verification for one-year of operation indicate that the seal ring had a large clearance when the turbine was stopped and a small clearance when the turbine was operating, and demonstrated stable work over the full stroke under the rated condition.

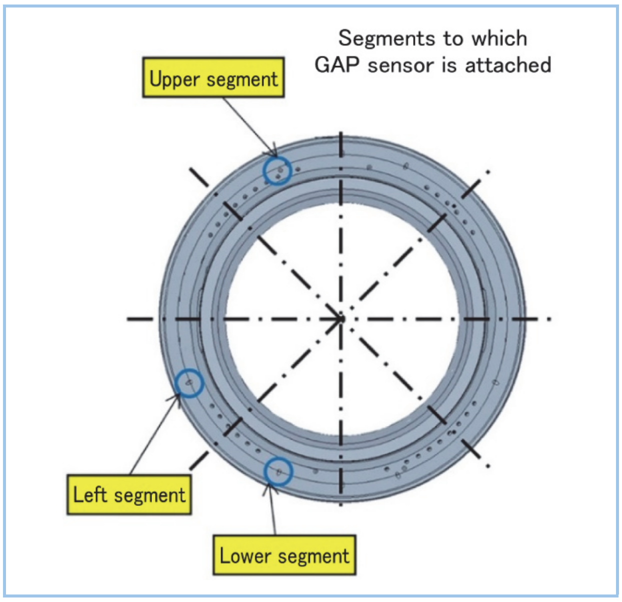


**Figure 5　Structure of ACC seal applied to T-Point 2**

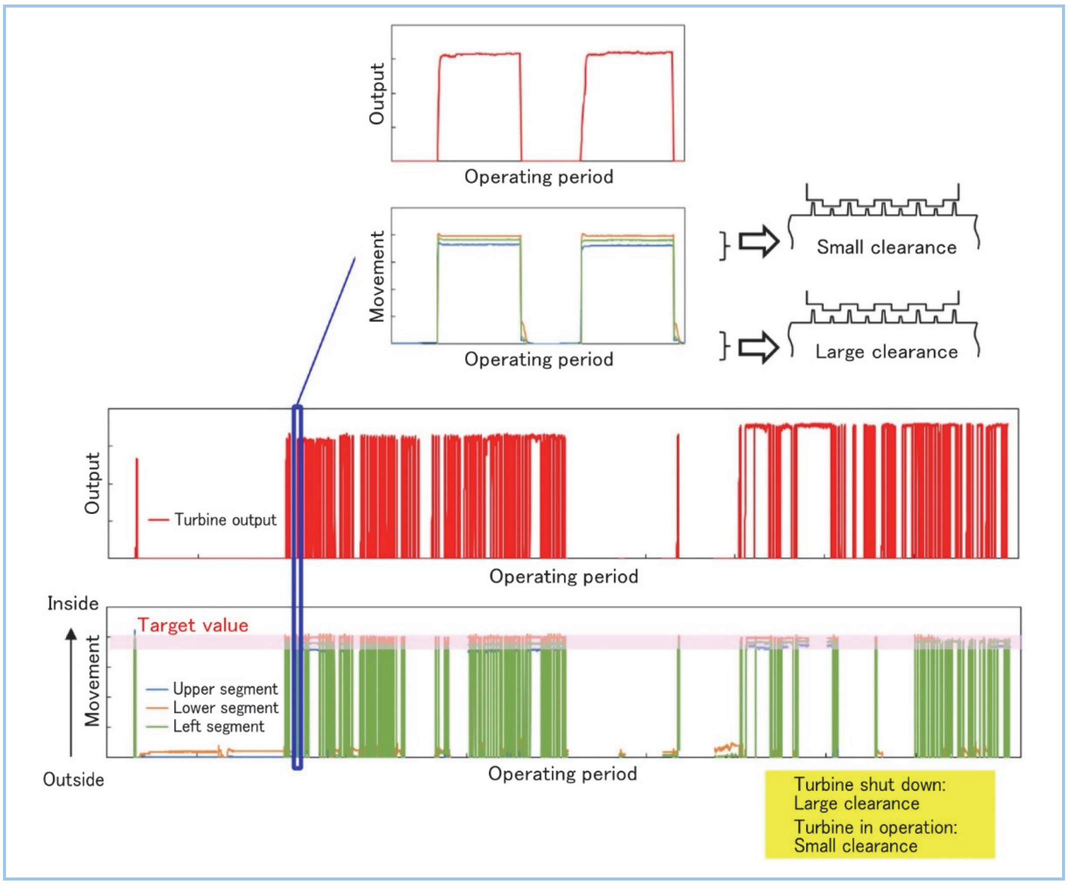


**Figure 6　Workability verification results of ACC seal applied to T-Point 2**

## 4. Future prospects

MHI will continue to develop new technologies for seals and in other fields, contributing to further improvements in efficiency and reduction in the environmental load of steam turbines.