

## The Benefits of Maintaining & Upgrading SMART Turbine Seals

By Dan Wiechec

### Introduction

Traditional OEM style steam turbine seals have been modernized over the past several decades to improve overall turbine efficiency, reliability and availability. TurboCare leads the industry in seal modernization with SMART Turbine Seals which include: Custom Fit Labyrinth Seals, Retractable Seals, Retractable Brush Seals, Brush Tip Seals, Custom Fit Tip Seals, Articulated Inlet Pipe Seals and horizontal joint sealing solutions. With over 1000 successful SMART Turbine installations, and advanced technology brush seals installed in more than 150 units over the past decade TurboCare has the experience required to develop a solution for each operator's unique sealing requirements.

SMART Turbine Seals are designed to compensate for rotor vibration during startup and shutdown without being damaged, allowing for optimal sealing effectiveness. This allows operators with SMART Turbine Seals to achieve numerous distinct advantages over the course of a typical operating cycle. Benefits include reduced fuel consumption and greenhouse gas emissions, as well as improved efficiency, generation capability, availability, and reliability. Turbine operators can rely on SMART Turbine Seals to provide the maximum improvement in steam turbine performance and reliability throughout their next operating cycle.

To ensure that SMART Turbine Seals continue to operate at their full potential, turbine operators should inspect them during every major overhaul and perform proper maintenance. In addition, it is likely that during a typical operating cycle of 6 to 10 years TurboCare will have developed an upgraded sealing product that further improves steam turbine performance. Accordingly, when a customer contacts TurboCare about an upcoming overhaul, an evaluation of the existing seals in operation is conducted to verify that the most advanced SMART Turbine Seals are installed.

The customer in this case study has installed SMART Turbine Seal upgrades for over 25 years. They started as an early adopter of Retractable Seals, then graduated to Retractable Brush Seals and most recently installed Brush Tip Seals which have yielded significant benefits. The benefits of having the most up to date SMART Turbine Seals were recorded empirically with independent performance testing from the 2010 overhaul.

SMART Turbine Seals offer customers an edge in the increasingly competitive power market. By continually upgrading and maintaining SMART Turbine Seals turbine operators can insure that they are achieving the best performance for their steam turbine.



## 1993 Overhaul – “Upgrade from OEM Style Seals to Retractable Seals”

In 1993, TurboCare was contacted to evaluate and recommend upgrades to a customer’s 1972 vintage 330 MW GE type steam turbine (Figure 1) to improve efficiency and reliability.

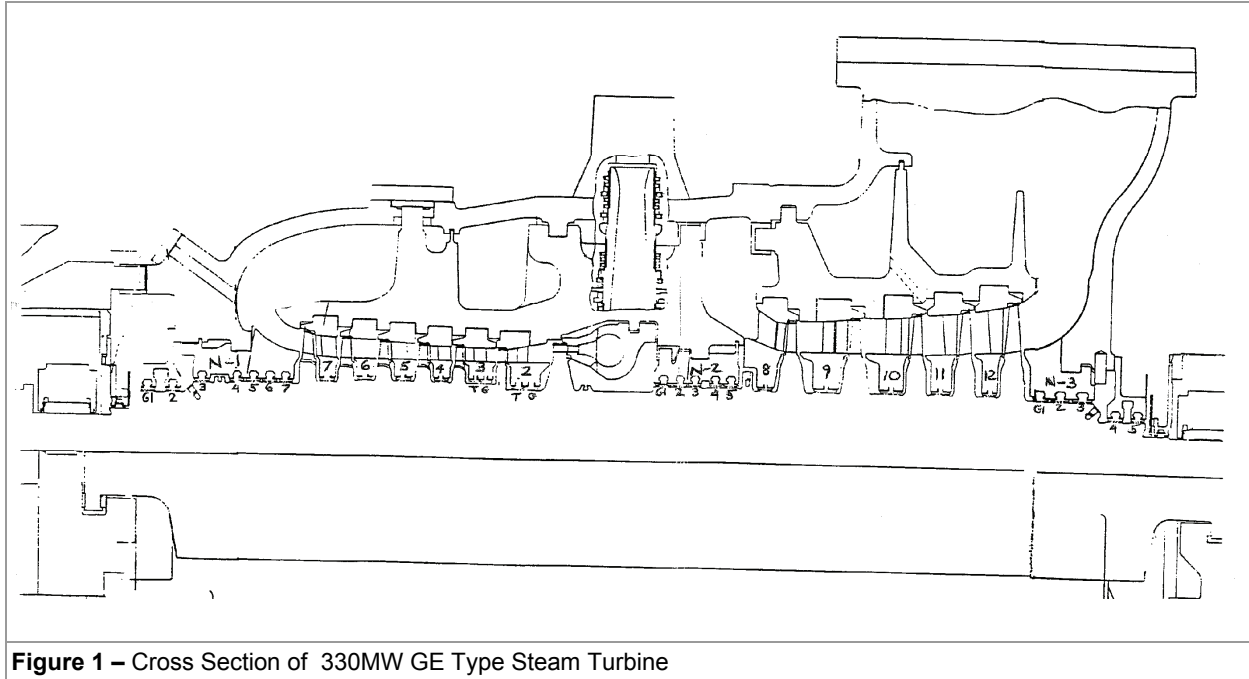
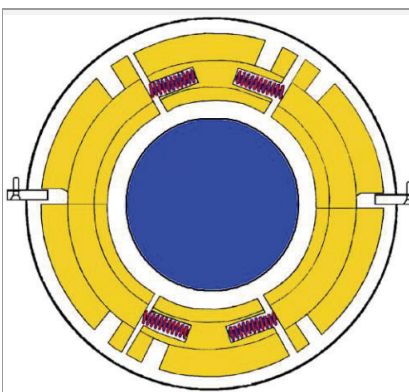


Figure 1 – Cross Section of 330MW GE Type Steam Turbine

After an in-depth engineering review, it was concluded that replacing the turbine’s OEM style labyrinth shaft seals with TurboCare’s Retractable Seals would be the most efficient and cost effective way to improve the performance of their steam turbine.



**Retractable Seals** – Retractable Seals by maintaining OEM or better seal clearances throughout the operating cycle, allow operators to realize significant performance and operational benefits.

The seals are retracted from the rotor during startup, mitigating the possibility of a rub. The seal rings then close as the pressure ramps up to operating condition, closing the rings to effectively operate between .015” and .025” (0.38 - 0.64mm) clearance.





Figure 2 – Portable CNC Mill

To achieve the desired clearance control with SMART Turbine Seals, TurboCare custom fits all of their seals. During the overhaul, TurboCare's field service technicians measured the rotor and seal holders at disassembly of the unit. Using these measurements, SMART Turbine Seals were custom manufactured. Then the seals were sent to the site for installation with TurboCare's portable machinery to ensure the desired final clearances were achieved. TurboCare's portable unit includes a CNC mill and all the tooling necessary for installation (Figure 2).

Retractable Seals were installed in 1993 and by not rubbing the shaft seals as the unit cycled, the customer was able to operate at a superior performance level throughout their 10 year operating period.

### 1998 TurboCare Development – “Introduction of Patented Retractable Brush Seals”

In 1998, an advancement was made in Retractable Seal Technology. A brush element with proven application in jet engines as well as gas turbines was added to the Retractable Seal which provides an even tighter clearance to the rotor. Utilizing these seals results in a performance improvement.



**Retractable Brush Seal** – A “zero clearance” flexible metal brush element is incorporated into the Retractable Seal which achieves a 0.002” (0.05 mm) effective radial clearance.

When the flexible seal comes in contact with the rotor, steam leakage is greatly reduced, allowing for improved performance.



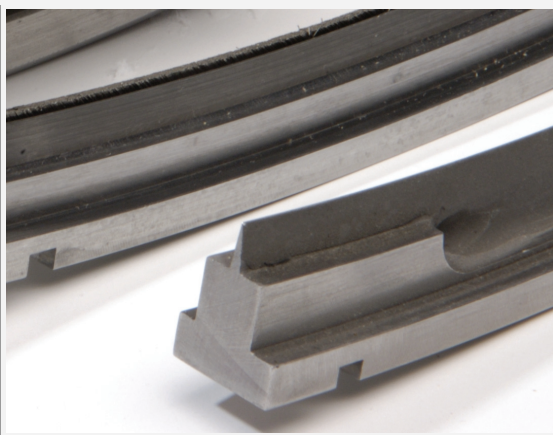
## 2003 Overhaul – “Retractable Brush Seal Upgrade”

In early 2003, TurboCare was contacted to plan for the next overhaul. The customer requested that the Retractable Seals in their unit be reviewed for the latest TurboCare sealing technology. The re-evaluation concluded that upgrading their Retractable Shaft Seals to Patented Retractable Brush Seals, would provide significant performance and reliability improvements. The customer accepted the recommendation and installed Retractable Brush Seals. The customer once again ensured that their turbine was operating at the best possible performance level.

## 2003 TurboCare Development – “Brush Tip Seals with HELP’R® Segments”

In late 2003, TurboCare leveraged the success of the Retractable Brush Seal and applied it to clearance at the blade tip. Typically, blade tip seals (also referred to as spill strips) are installed with a 60 mil (1.524 mm) clearance to avoid rubs caused by rotor excursions during start up or shut down at the shaft which is amplified at the blade tip. Since both Retractable Seals and Retractable Brush Seals virtually eliminate this problem blade tips seal clearance typically can be reduced to 20 mils (0.508 mm). In addition, if any excursions do occur, the flexibility of the brush allows the clearance to be kept throughout the operating cycle.

Due to the reduced tip seal clearances, particles that enter the turbine need a path to easily pass through the turbine without causing damage to components. Therefore, each row of Brush Tip Seals contains a HELP’R® Seal segment which has a small passageway that facilitates the exit of harmful particles from the steam turbine.



**Brush Tip Seals & HELP’R® Segments** - A large amount of efficiency is lost through excessive seal clearances at the rotating blade tips. Brush Tip Seals, like Retractable Brush Seals, reduce clearances and improve overall performance.

HELP’R® Segments mitigate the risk of particle damage by allowing damaging particles to exit the steam path.



Due to the reduced clearance at the blade tips and the shaft TurboCare recommends completing a rotor stability analysis to evaluate the potential vibration effects on a turbine.



**Anti-Swirl Vanes** – These vanes are added to the higher pressure seal areas to improve the stability of the unit. Maintaining stability is an important consideration when reducing seal clearances with Retractable Brush Seals.

In addition anti-swirl vanes can be applied to improve a unit's stability beyond OEM conditions.

## 2010 Overhaul – “Upgrading Again with Brush Tip Seals”

To plan for this unit's 2010 overhaul, the customer contacted TurboCare for a third seal evaluation. Having operated since 1993 with TurboCare's SMART Turbine Seals, the customer chose again to install all of the latest upgrades for their upcoming 8 year operating cycle. During this overhaul, Brush Tip Seals, HELP'R® seals, and anti-swirl features were added to expand on the benefits from the previously installed patented Retractable Brush Seals.

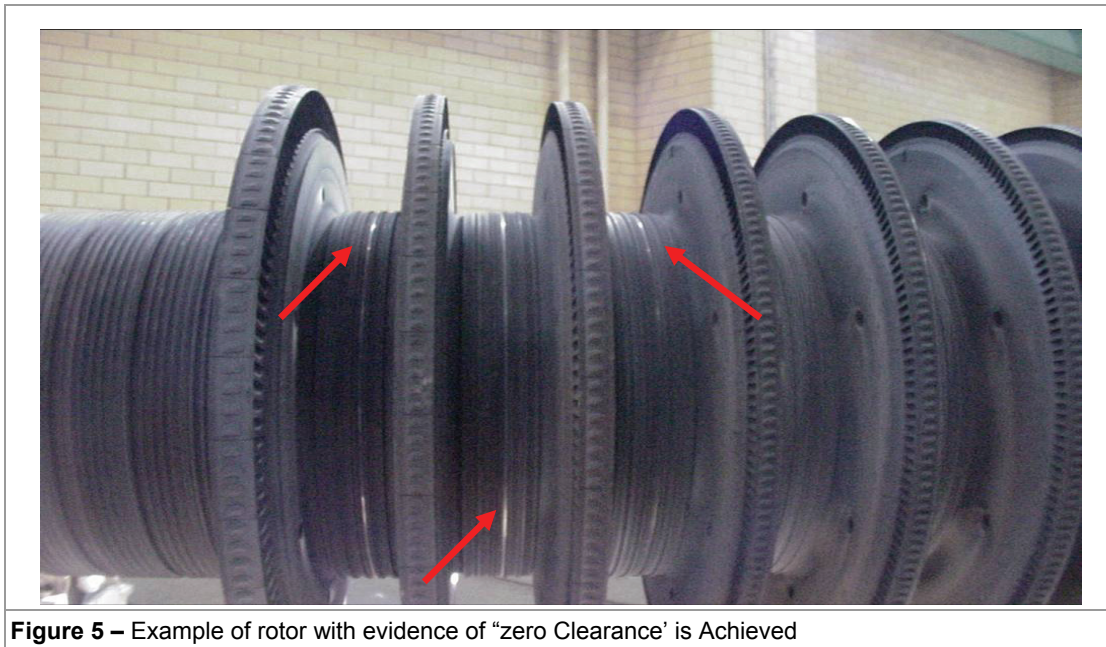


Figure 4 – Retractable Brush Seals after 7 Years of Operation



As part of TurboCare's maintenance program, a detailed inspection was performed on the SMART Turbine Seals during the 2010 overhaul. The 2003 vintage Retractable Brush Seals were found to be in excellent condition after their 7 year operating period (Figure 4). There was minimal to no wear on the seal teeth and brush. It is estimated that the Retractable Brush Seals were still providing an effective 0.004"-0.005" (0.10 – 0.13mm) radial clearance. The steam seal faces of the Retractable Brush Seal segments were found to be in good condition as well and showed evidence of effective closure during operation.

During a SMART Turbine Seal Inspection it is also important to inspect the condition of the rotor. A noticeable attribute of an effective zero clearance seal is a polished surface beneath the brush seal on the rotor (Figure 5).



**Figure 5** – Example of rotor with evidence of “zero Clearance” is Achieved

This occurs when the brush “blows down” to “zero clearance” during operation. When this condition is observed there is typically no damage to the rotor. The brush, however, does rub very slowly over time. The blow down effect keeps the tight clearance but the length of the brush is reduced. Due to this wear TurboCare recommends renewing the brush at each overhaul to take the opportunity to re-establish optimum sealing performance for the next operating cycle.



## 2010 Test Results – “Pre and Post Overhaul Performance”

To quantify the value of the overhaul the customer conducted performance tests and steam path audits (SPA). A performance test was completed prior to the unit coming down for the 2010 overhaul so that the condition of the machine was known before the repairs were made. Upon opening the machine, a steam path audit was completed to understand where the performance losses were and how much could be regained from specific repairs.

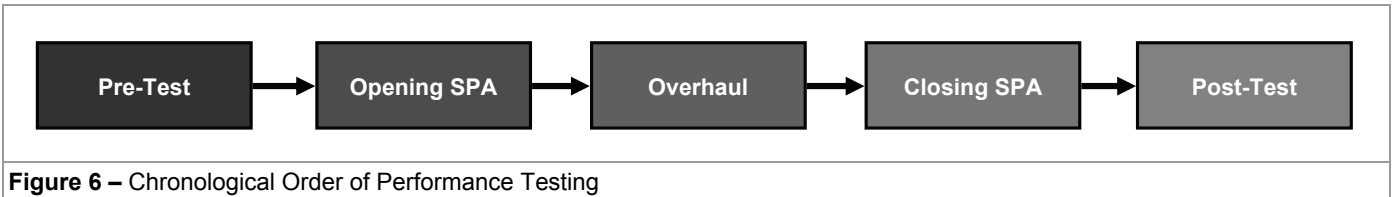


Figure 6 – Chronological Order of Performance Testing

After completion of the repairs, a closing steam path audit was performed to measure the impact of the various repairs. By comparing the opening and closing steam path audit the performance improvements of the SMART Turbine Seals could be isolated from the other repairs performed on the unit. A final performance test was completed after the unit was closed to determine the impact that SMART Turbine Seals had on performance.

The testing determined that the HP turbine efficiency increased by 2% while IP efficiency increased by 0.7%. In addition, a 55 btu/kWh (58 KJ/kWh) heat rate improvement and over 7 MW of additional generating capacity were achieved. Using the information from the steam path audit, **4 MW** and **44 btu/ kWh** (46 KJ/kWh) of the performance improvement can be attributed to the SMART Turbine Seals.

By putting these figures into a financial perspective, this turbine now has the potential to generate an additional **\$890,000** in generation revenue annually while reducing fuel cost by **\$325,000** annually. Over the 7 year operating period the improved performance could equate to over **\$8.5 million**. Also, over **80,000 tons** of carbon dioxide emissions can be avoided.

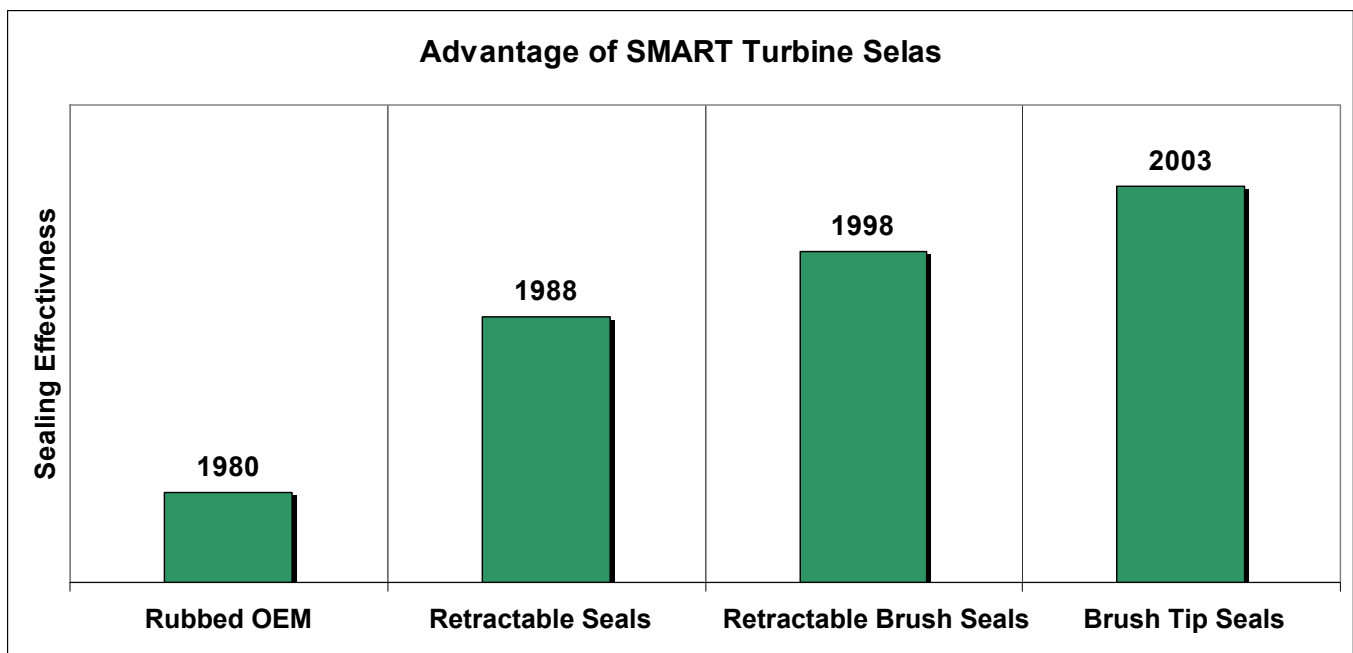
Value of SMART Turbine Seals	Benefits	Year 1	Over 7 Years
<b>Generation</b>	4 MW	\$890,000	\$6.2 Million
<b>Heat Rate</b>	44 Btu/kWh	\$325,000	\$2.3 million
<b>Emissions</b>	80,000 Tons/Year	11,000 Tons	80,000 Tons
<b>Total</b>		\$1.2 Million	\$8.5 Million

\* Assumptions for Calculations: 85% Capacity factor, \$3/btu, power rate \$30/Mwh, sub bituminous coal, heat rate of 8870 Btu/kWh, Carbon Tax = 0 \$/ Ton



## Conclusion

Before 1988, operators had limited to no options for advanced steam turbine seals. Then TurboCare introduced the revolutionary Retractable Seals which were retracted from the rotor during start up and shut down to prevent rubs and increase performance. In 1998, TurboCare continued to advance sealing technology with Retractable Brush Seals, which improved on the Retractable Seal by adding a flexible metallic brush element to create a zero clearance seal and further increase performance. The advances continued in 2003, when TurboCare developed Brush Tip Seals to improve Tip Seal performance. When combined with inlet pipe seals, SMART Turbine Seals, the culmination of these advances, can provide up to a **5% increase in power generation and a 5% reduction in turbine heat rate.**



*\*Note each value reflects the best possible combination of SMART Turbine Seals*

TurboCare has continued to advance and upgrade steam turbine seal technology over the past thirty years. Customers who incorporate these advances and upgrades into their steam turbine maintenance programs can be confident that their steam turbines operate at optimal performance levels through the next outage cycle.

**Contact TurboCare today for a free SMART Turbine Seal Evaluation!**

