

## CASE STUDIES: SENTINEL® FBS | PROCESS STEAM TURBINES

# Guarding Against Damage And Leakage: The Sentinel® Floating Brush Seal In Action

Process steam turbines traditionally rely on four to six carbon rings per gland box to prevent steam leakage. These carbon rings are expected to withstand wet steam conditions, contaminants and cyclic duty cycles under varying pressure and temperature profiles. While carbon rings are easy to install and provide a tight clearance at the outset, they wear easily. As the carbon rings wear, steam leakage increases, operating temperatures rise, and bearing oil becomes more susceptible to contamination. Replacing one or two conventional carbon rings with Sentinel® Floating Brush Seals (FBS) from Inpro/Seal® has shown a measurable improvement in sealing effectiveness, steam loss reduction, gland box reliability and bearing life.

### CASE STUDY 1: 80% REDUCTION IN GLAND BOX LEAKAGE

A 2008 steam study at a refinery in Texas City, Texas, estimated that process steam turbine gland boxes contributed to 50% of the plant's steam leakage. Furthermore, wet steam and condensate flashing were cutting the turbines' mean time between repair (MTBR) to just 24 months.

Shortly after the study concluded, the refinery began upgrading its steam turbines with the Sentinel FBS. The Sentinel FBS combines carbon ring face sealing with densely packed bristles that form a compliant contacting seal on the shaft. This brush seal protects downstream carbon rings by filtering out steam contaminants and reducing the pressure profile.

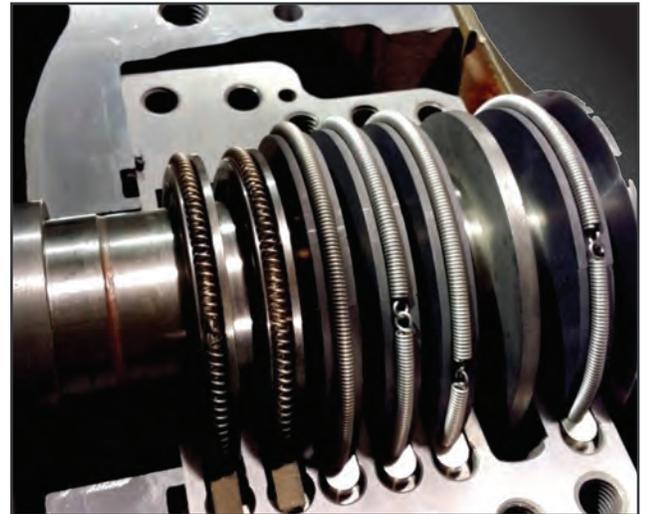
The refinery replaced two of the six carbon rings in each gland box with the Sentinel FBS. The Sentinel FBSs were installed in the seal positions furthest upstream; new carbon rings were installed in the downstream positions. Since the upgrade, the refinery has reported a reduction in gland box leakage of nearly 80%. In addition, oil lubrication temperatures are reported to have dropped by more than 42°C (75°F), and MTBR has surpassed 80 months.

### CASE STUDY 2: KEEPING STEAM OUT OF THE BEARINGS

At a refinery in Pascagoula, Mississippi, plant personnel observed excessive leakage from the gland boxes of two 825 hp steam turbines, Units 1B and 1C, operating in parallel. The leaking steam crossed over to the bearings, resulting in elevated lubrication oil temperatures and, eventually, lubrication oil contamination. A visible steam cloud from the turbines was a clear indicator of both environmental and safety hazards.

At the root of the problem was carbon ring wear. A combination of wet steam and contamination from rust and hard particles accelerated carbon ring deterioration.

The gland boxes of Unit 1C were upgraded in August 2015 with the Sentinel FBS. Two of the carbon rings in each gland box were replaced with Sentinel FBSs, while the other five carbon rings in each box were replaced with new conventional carbon rings.



Process steam turbine gland box with Sentinel Floating Brush Seal in the first and second positions (furthest left) and conventional carbon rings in the four remaining positions.

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The performance of Unit 1C with the Sentinel FBSs was compared to the performance of Unit 1B, identical to 1C except for operating on carbon rings only. Since the turbines lacked instrumentation to measure leakage, the performance comparison was based on surface temperature and bearing oil temperature measurements.

The temperature measurements showed that the lubrication oil temperature on Unit 1C was cooler than on Unit 1B by 10°C (17°F), while the gland box surface temperature at the last seal location was 39 to 61°C (70 to 110°F) hotter. The higher gland box surface temperatures on Unit 1C were likely due to lower steam flow on the unit because of the Sentinel FBSs. Lower steam flow would reduce the amount of heat pulled from the casing, as well as reducing the carryover of steam to the bearings.

The refinery is following up the Unit 1C upgrade with upgrades on other steam turbines that are bad actors.

Unit	Gland Box Seal Arrangement (per side)	Date of Seal Installation	Steam End Gland Box Temperatures				Exhaust End Gland Box Temperatures			
			Casing	Last Seal Location	Bearing Cover (top)	Bearing Oil	Casing	Last Seal Location	Bearing Cover (top)	Bearing Oil
1B	7 Carbon Rings	2011	243°C	149°C	99°C	77°C	243°C	154°C	98°C	77°C
			470°F	300°F	210°F	170°F	470°F	310°F	208°F	170°F
1C	2 Floating Brush Seals, 5 Carbon Rings	2015	249°C	210°C	88°C	67°C	248°C	193°C	76°C	67°C
			480°F	410°F	190°F	153°F	478°F	380°F	168°F	153°F

Measured temperatures of identical steam turbines with carbon rings (Unit 1B) and Sentinel Floating Brush Seals (Unit 1C).

### CASE STUDY 3: MAKING EDUCTORS REDUNDANT

At a petrochemical plant in Port Neches, Texas, poor steam quality and condensate flashing were putting turbine MTBR at 24 months. To alleviate steam crossover to the bearing lubrication oil, the plant first installed steam eductors on the unit to pull steam from the gland box.

In 2014, the plant upgraded the unit with Sentinel FBSs. The seals reduced steam leakage so effectively that the plant was able to disconnect the eductors. Bleed-off pressure from the gland boxes was reduced to 5 psig with the Sentinel FBSs, and the customer reports annual steam savings of \$58,000 from the upgrade. After two years, the units are still running without repair.

### CASE STUDY 4: OUT-PERFORMING MECHANICAL SEALS

An alternative solution for reducing gland box leakage is to switch from carbon rings to mechanical seals. A petrochemical plant in the Golden Triangle of southeast Texas had upgraded a steam turbine unit to mechanical seals to increase reliability but experienced seal failures due to condensate flashing. Mechanical seals, while offering very low leakage rates, are sensitive to wet steam and are susceptible to damage from condensate slugs. In addition, mechanical seals for steam applications can be costly to procure and install.

In 2013, the customer installed a Sentinel FBS system in place of the mechanical seals. The lower cost of the Sentinel FBS system and the ease of the system's installation both impressed the customer. While the mechanical seals required a time-consuming alignment procedure, the Sentinel FBSs could be installed as simply as the original carbon rings.

The customer reports that the Sentinel FBSs have withstood condensate slugs in the turbine, which had been problematic for carbon rings as well as mechanical seals. The combination of a high-pressure facing brush seal and a metal-encapsulated assembly make the Sentinel FBS a more robust and cost-effective solution.

#### IMPROVED RELIABILITY

The Sentinel FBS combines the simplicity of carbon rings with the effectiveness and durability of brush sealing to increase overall seal reliability. Reduced steam leakage, reduced oil temperatures and the ability to withstand steam contaminants and condensate flashing all contribute to improved MTBR and gland box reliability.



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