EagleBurgmann
a member of EKK and FREUDENBERG

RELY ON EXCELLENCE

DF-SA DiamondFace mechanical seal for CANDU reactor

Innovative material pairing enables low-friction operation and extends the service life five times

In countries like Canada, South Korea and Argentina, CANDU reactors ("Canada deuterium uranium reactors") use nuclear fuel to generate electric power. Unlike the pressurized water reactors and boiling water reactors mainly used in Europe, CANDU reactors can be refueled during operation to increase availability. However, sealing the hydraulic machines used in this process represents a technical challenge.

The Canadian CANDU Owners Group (COG*) regularly struggled with failing seals which led to costly shutdowns. To develop a reliable solution, material scientists from EagleBurgmann set out on a research mission which led them to observe material behavior on an atomic scale.

The RAM machines are critical for trouble-free reactor operation. An essential part of these highly complex hydraulic systems is a mechanical seal which seals the pressurized tube of the RAM machine against its drive gears. As the seals in place did not reliably withstand the operating stresses and failed frequently, the COG tendered new mechanical seals for the RAM machines.

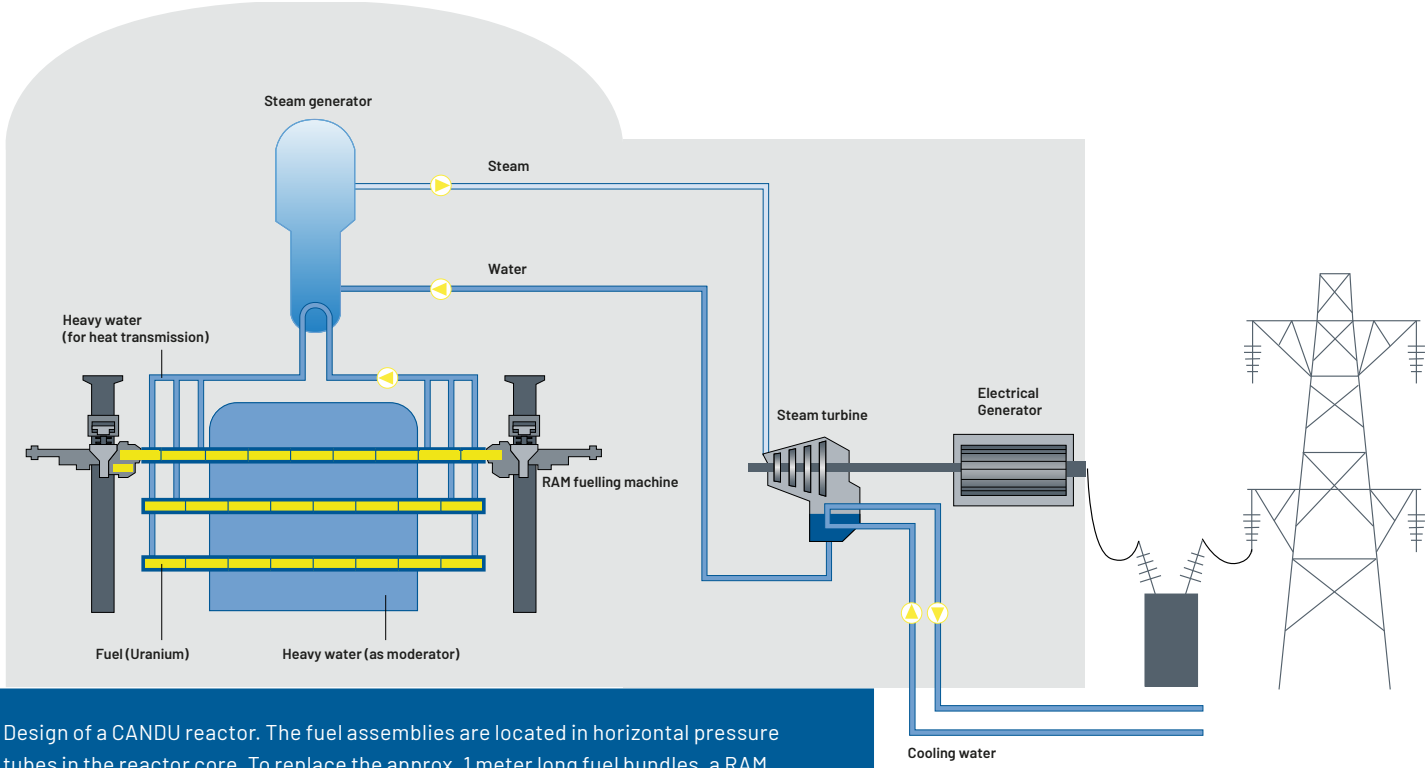
Best-of-breed solution required

The new seal had to meet high requirements: torque and leakage had to be kept at a minimum even at pressures of 120 bar and rotational speeds of up to 261 rpm. It also had to be designed to work independent of the direction of rotation, since the RAM machine rotates in opposite directions to open and close the reactor tube. Finally, the new seal had to work reliably as this was the weak point of the previous products. When a mechanical seal fails, it costs the operator between 500,000 up to one million dollars per day in maintenance and lost revenue. In addition, service technicians are exposed to increased radiation levels when working on the RAM machine.

In CANDU reactors, heavy water (D_2O) functions as both a moderator and a coolant. It absorbs the heat generated by the nuclear fission and transfers it to a secondary loop with normal water (H_2O) which drives a steam turbine. Since it contains the hydrogen isotope deuterium, heavy water absorbs fewer neutrons than normal water. CANDU reactors can therefore be fueled with natural uranium. This is a decisive advantage for operators, as natural uranium is more easily available than enriched uranium.

CASE STUDY

- **Reference:** CANDU-Reaktor
- **Client:** CANDU Owners Group (COG), Canada
- **Industry:** Nuclear power
- **Challenge:** Bad actor solution | Development of a new mechanical seal for the hydraulic loading machine
- **EagleBurgmann services:** Consulting, engineering, atomistic simulation
- **Technical solution:** DF-SA DiamondFace engineered seal for power plant technology



Design of a CANDU reactor. The fuel assemblies are located in horizontal pressure tubes in the reactor core. To replace the approx. 1 meter long fuel bundles, a RAM fuelling machine docks onto the reactor tube. After sealing the tube, it opens the tube plug and pushes a new fuel bundle inside. This automatically pushes the used fuel bundle into a second RAM machine on the other side of the reactor tube.

Unexpected problems call for a scientific approach

During the development of the mechanical seal, EagleBurgmann's engineers encountered an unexpected problem: under certain conditions, the torque of the seal increased significantly after a few turning cycles, a behavior that no one had anticipated. To determine the cause of the rapid increase in friction, the material specialists at EagleBurgmann had to take a closer look at the atomic bonding forces between the sliding faces. Working with their colleagues at their parent company, the Freudenberg group, they conducted an atomic simulation that proved to be the key to understanding the effect.

In leak-free operation without media, it was found that cold welding occurred between individual carbon atoms on the sliding faces. In effect, the sliding faces were interlocked on a molecular level. Based on these findings, the specialists used further simulations to gradually approach the perfect material pairing.

In the end, a combination of crystalline diamond coating and silicon carbide sliding surfaces turned out to be the ideal solution.

This combination reduces cold welding to a minimum and keeps frictional resistance permanently low. Wear on the faces is also reduced. This increases the service life of the seal to four years – almost five times longer than the previous one.

DiamondFace® – an innovative sliding surface technology for maximum operational performance – was developed in 2007 in collaboration with EagleBurgmann und the Fraunhofer Institute for Surface Engineering and Thin Films (IST). A unique microcrystalline diamond surface is created by chemical vapor deposition in a vacuum at a temperature of 2,000 °C (3,362 °F).

What is an atomistic simulation?

An atomistic simulation calculates how atoms and molecules behave and interact with each other. These interactions on an atomic level include binding forces which we can feel as static or sliding friction. This makes atomic simulations especially useful in the scientific field of tribology, which studies friction, wear and lubrication. This approach offers scientists a new perspective on materials and creates a deeper understanding of why material pairings behave the way they do. Atomistic simulations are mainly used in scientific settings but can also be applied to problems in industrial applications. They help engineers develop contact surfaces with less friction thereby paving the way for more energy-efficient and wear-resistant products.

„We support many customers in the nuclear industry. Our experience and expertise enables us not only to develop technical solutions that meet all specifications, but also to take into account the specific requirements and standards of the industry at every step of the process."

Bernd Wunderlich,
Senior Project Development Manager
Nuclear Power

Special challenge: safety-critical application

As the mechanical seals will be used in proximity to the reactor, the client had particularly high demands for quality, diligence and transparency. Prior to delivery, each mechanical seal was extensively tested on a special test rig that simulates the operating conditions in the RAM machine. In addition, all materials and components used have been selected for their long shelf life to enable operators to manage their own spare parts. For example, only freshly manufactured O-rings are used in the RAM seals. Such measures ensure a long service life; the customer only needs to check seals that have been stored for years.
Finally, industry-specific packaging requirements had to be met. The seals were shrink-wrapped in a special film that is free of chlorides and other corrosive components and approved for use in the nuclear industry.

Certified to N299

For this project, EagleBurgmann was certified to the Canadian Nuclear Power Standard „N299 - Quality Assurance Program Requirements for the Supply of Items and Services for Nuclear Power Plants". From an audit of the entire company and its manufacturing processes to the selection of appropriate materials and the approval of suppliers, EagleBurgmann set the stage in every part of the process to ensure that the COG receives the best possible manufactured and documented product.

* The CANDU Owners Group is a private, not-for-profit corporation that is a leader in the field of nuclear technology. Together with its members, it drives innovation in power plant equipment and processes to achieve the highest standards of safety, efficiency and environmental performance. For more information, visit: www.candu.org

Advantage of the DF-SA DiamondFace

The DF-SA DiamondFace mechanical seal from EagleBurgmann was specially developed as a functional element for critical applications in power plant technology. The innovative material pairing, standardized components and high flexibility in adapting the connection parts to the pump seal chamber make it the technically ideal and cost-effective sealing solution for use in pumps for boiler feed water and ultrapure water.

- Resistant to electrochemical corrosion.
- No dosing system, no cooling circuit conditioning required.
- Extremely long service life (>40,000 h).
- Very low friction and reduced power consumption due to DamondFace technlogy.
- Deformation-optimized for high sliding velocities and medium pressures.

Result

The new mechanical seal developed for the CANDU reactor not only met all the customer's specifications but also performed impressively in the field. The expected service life of all installed seals was significantly exceeded. EagleBurgmann's DF-SA DiamondFace mechanical seal has now established itself as a standard component for power plant operators. To date, more than 300 units have been successfully installed worldwide.

EagleBurgmann – Leading Innovation in Sustainable Sealing Solutions

We are your leading international specialist in industrial sealing technology. We combine innovative technologies, digital solutions and our passion and enthusiasm to create sophisticated and reliable sealing systems. Our products help make entire industries safer and more sustainable. 6,000 employees create added value for our customers around the world with their enthusiasm and competence. EagleBurgmann is a joint venture between the German Freudenberg Group and the Japanese Eagle Industry Group.

Rely on excellence.

eagleburgmann.com
info@eagleburgmann.com