

## RELY ON EXCELLENCE

# Watching atoms at work to unravel friction

## EagleBurgmann develops low-friction mechanical seals for nuclear power plants

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.



In CANDU reactors, heavy water (D<sub>2</sub>O) 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<sub>2</sub>O) 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 fuelled with natural uranium. This is a decisive advantage for operators, as natural uranium is more easily available than enriched uranium.

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.

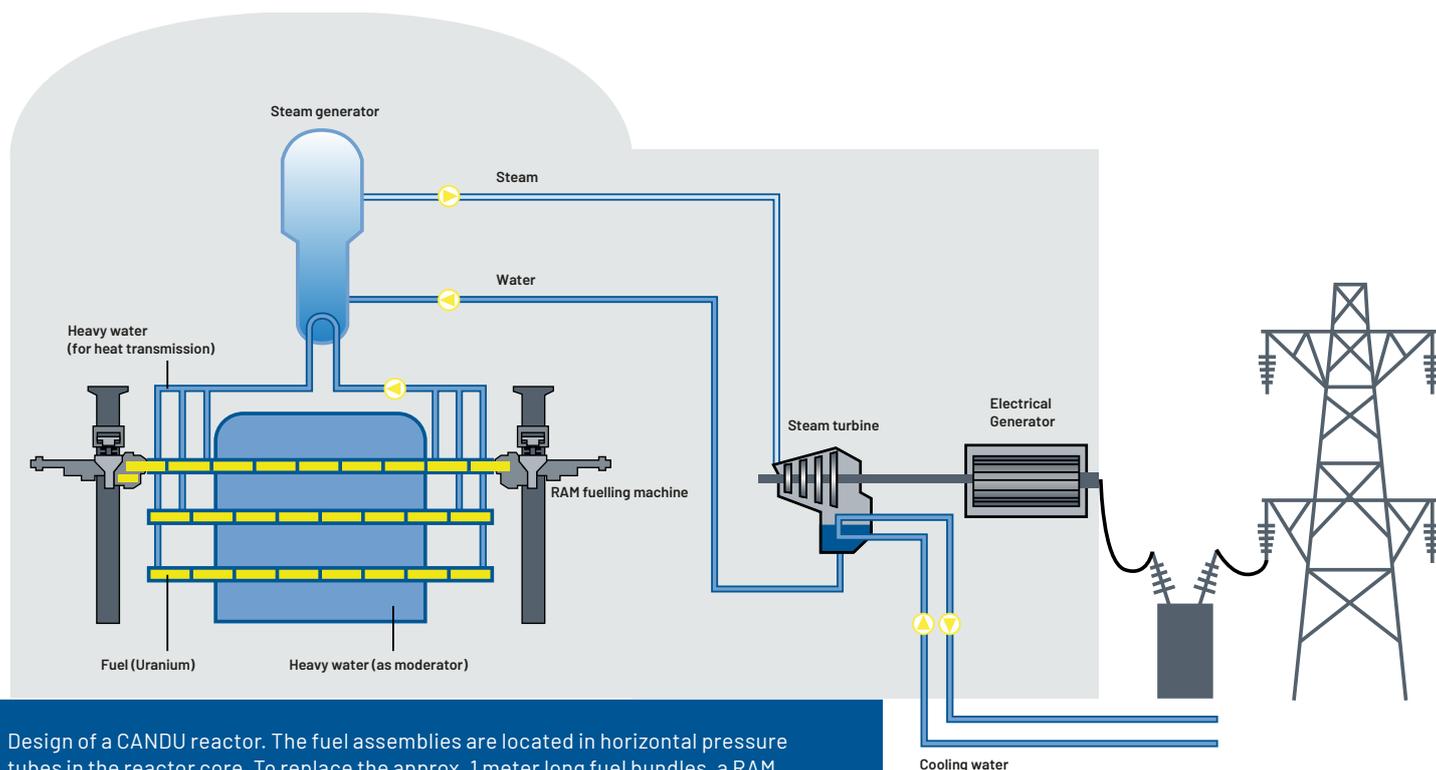
### Reliable seals protect personnel and prevent downtime costs

The new seals 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. Furthermore, they had to be designed to work independent of the direction of rotation since the RAM machine frequently turns in different directions to open and close the reactor tube. Last but not least, the new seals had to work reliably as this was the weak point

of the previous products. In case a mechanical seal fails, costs for the operator resulting from lost revenue and maintenance expenses can range somewhere between 500,000 up to one million dollars per day. Seal failure also exposes the service technicians working on the RAM machine to higher radiation doses.

### Advantages of the new mechanical seal:

- Very low friction due to optimized material pairing
- Low leakage
- Fits into the existing machine: 1:1 replacement
- High reliability and long service life



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

When developing the new mechanical seals, EagleBurgmann's engineers were confronted with an unexpected problem. "Under certain circumstances, the seal's torque increased significantly after a few turning cycles. A behavior we had not anticipated", explains Jens Hofmann, head of technical sales support pump seals power, mining, pulp & paper, water at EagleBurgmann. To get to the bottom of what caused the rapid increase in friction, the material specialists at EagleBurgmann had to take a closer look at the atomic binding forces between the sliding faces. In cooperation with colleagues from their parent company, the Freudenberg group, they carried out an atomic simulation which turned out to be the key to understanding the effect.

"During leakage-free operation without media between the sliding faces, we observed cold welding between the carbon atoms. The sliding faces were intermeshed on a molecular level", explains Hofmann. On the grounds of these findings, the scientists used further simulations to gradually approach the perfect material pairing. Eventually, a combination of crystalline diamond coating and silicon-carbide slide

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", Hofmann elaborates.

### 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.

### **Safety-critical application requires high standards**

Since the mechanical seals are to be used in close proximity to the reactor, the client had specific requirements regarding quality, diligence and transparency. Before delivery, every mechanical seal is mounted to a test rig where the operating conditions of the RAM machine are simulated and the product is extensively tested. To ensure self-sufficient spare parts management for operators, all used materials and components were also chosen to allow for a long storage time.

"For example, all O-rings were produced shortly before being installed in the seal", explains Hofmann. "These measures serve to ensure a long shelf life. The seals can be stored for years at the client's facilities before an inspection is needed." Even when it comes to packaging, the nuclear industry has special requirements, as Hofmann explains: "The seals may only be wrapped in special foil, free of chlorides and other corrosive elements and thus approved for nuclear equipment."

For this project, EagleBurgmann was certified according to the Canadian nuclear power plant standard. At every step of the process, EagleBurgmann made sure that COG was supplied with a product manufactured to the highest standards and extensively documented. This included procedures from auditing the entire company as well as individual manufacturing processes to selecting suitable materials and certifying suppliers.

### **An innovation becomes a reliable standard component**

Decades-long experience in nuclear projects around the world and a high level of sophistication in material science make EagleBurgmann a trusted partner when it comes to developing effective and reliable solutions for even the most challenging applications. Furthermore, EagleBurgmann is able to flexibly adapt processes according to the client's standards and requirements.

"Many of our clients are from the nuclear sector, therefore we know the special demands of the industry", explains Hofmann. "Our experience and expertise put us in a position in which we can develop effective technical solutions while also taking into account the respective standards of the industry at every step." EagleBurgmann's newly developed seal has quickly become a standard component for operators.

## **EagleBurgmann – at the leading edge of industrial sealing technology**

Our products are used wherever safety and reliability count: in the industries of oil & gas, refineries, petrochemicals, chemicals, pharmaceuticals, food, power, water and many more. About 6,000 employees contribute their ideas, solutions and dedication every day to ensure that customers around the globe can rely on our seals. With our modular TotalSealCare Service, we emphasize our strong customer orientation and offer custom-tailored services for every need. [Rely on excellence.](#)

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