RETROFIT OF AECL CAN6 SEALS INTO THE PICKERING SHUTDOWN COOLING PUMPS

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Abstract

The existing mechanical seals in the shutdown cooling (SDC) pumps at the eight-unit Pickering Nuclear Generating Station have caused at least seven forced outages in the last fifteen years. The SDC pumps were originally intended to run only during shutdowns, mostly at low pressure, except for short periods during routine testing of SDC isolation valves while the plant is operating at full pressure to verify that the emergency core injection system is available. Unfortunately, in practice, some SDC pumps must be run much more frequently than this to prevent overheating or freezing of components in the system while the plant is at power. This more severe service has decreased seal lifetime from about 8000 running hours to about 3000 running hours. Rather than tackling the difficult task of eliminating on-power running of the pumps, Pickering decided to install a more robust seal design that could withstand this.

Through the process of competitive tender, AECL's CAN6 seal was chosen. This seal has a successful history in similarly demanding conditions in boiling water reactors in the USA. To supplement this and demonstrate there would be no "surprises," a 2000-hour test program was conducted. Testing consisted of simulating all the expected conditions, plus some special tests under abnormal conditions. This has given assurance that the seal will operate reliably in the Pickering shutdown cooling pumps.

Seal Operating Conditions

The normal operating condition for the SDC pumps occurs when the unit is shut down. The pumps rotate at 1200 rpm. Pressure is quite low—about 0.2 MPa. Temperature is 30 to 50°C. The pumps are required to operate in this state for the duration of the outage, which may last a month or two, although they must be capable of operating at these conditions for much longer times in unusual circumstances. Low pressure shutdown operation has caused relatively fewer problems than has high pressure operation while the unit is at power.

There is an isolation valve on the suction and discharge sides of each of the four SDC loops in each unit to separate the loop from the heat transport system. If, as frequently happens, either of these valves leaks while the unit is operating, then hot 8.9 MPa water from the heat transport system circulates in the SDC loop and gradually heats it up. While stopped, SDC pumps are not well cooled, because they rely on the pumping head to circulate water through a cooler. Therefore, to prevent overheating of the seals, station procedure has been to operate the SDC pumps intermittently during reactor operation, whenever seal temperature rises above the 77°C alarm. This may occur once or twice a shift. (The four newer Pickering B units also have seal injection and a cooling jacket, but these are sometimes insufficient to prevent overheating in this situation.) Occasionally a damaged isolation valve will have to be backseated, in which case that SDC pump must be operated continuously.

Excessive cooling can also be a problem. During the winter, a leaking high pressure service water valve can cause the D_2O in the tube side of the SDC heat exchanger to be exposed to H_2O colder than 4°C, which is the freezing temperature of D_2O. To avoid the risk of freezing, it is then necessary to run the particular SDC pump to circulate warm water in the loop.

A special requirement is that the seal must be capable of operating during an emergency crash cooldown of the plant and then be capable of normal shutdown operation afterwards. In this duty, the pump is started while the SDC loop is cool, and the seal is heated suddenly to 218°C as heat transport system water enters the loop. The pump continues operating and cools to 100°C within 8 minutes and to about 34°C within an hour and half. Pressure is 8.9 MPa throughout.

CAN6 Pump Seal

The CAN6 seal was developed in the late 1980s for similar-sized "reactor water cleanup pumps" in US boiling water reactors. Table 1 summarizes the operating conditions of the CAN6 seal in the Pickering and US applications. The higher shaft speed of the US reactor water cleanup pumps indicates that the normal operating conditions are actually more severe in these pumps than in the Pickering application, although the off-normal conditions are somewhat different.

The CAN6 seal addresses the problems encountered in Pickering by controlling the gap between the seal faces so that there is always a thin lubricating film of water separating the stationary face from the rotating face. This separation is only about 50 micro-inches, but is sufficient to prevent rubbing. As shown in Figure 1, the seal is designed so that the high pressure heat transport system water, which is on the outside of the seal, bleeds across the gap between the faces to the atmospheric side.

Table 1. CAN6 Seal Operating Conditions.

	Pickering Shutdown Cooling Pumps	US Reactor Water Cleanup Pumps
Shaft Diameter	2.250"	1.875"
Seal Balance Diameter	2.875"	2.600"
Shaft Speed	1200 rpm intermittent	3600 rpm continuous
Temperature	Normal 30-50°C, Alarm at 77°C, Sometimes rises to 146°C Emergency to 218°C	Normal 40 to 100°C, Sometimes 100–120°C continuous
High Pressure	8.9 MPa	7.2 MPa
Low Pressure	0.2–0.3 MPa during shutdown	1.0 MPa during shutdown

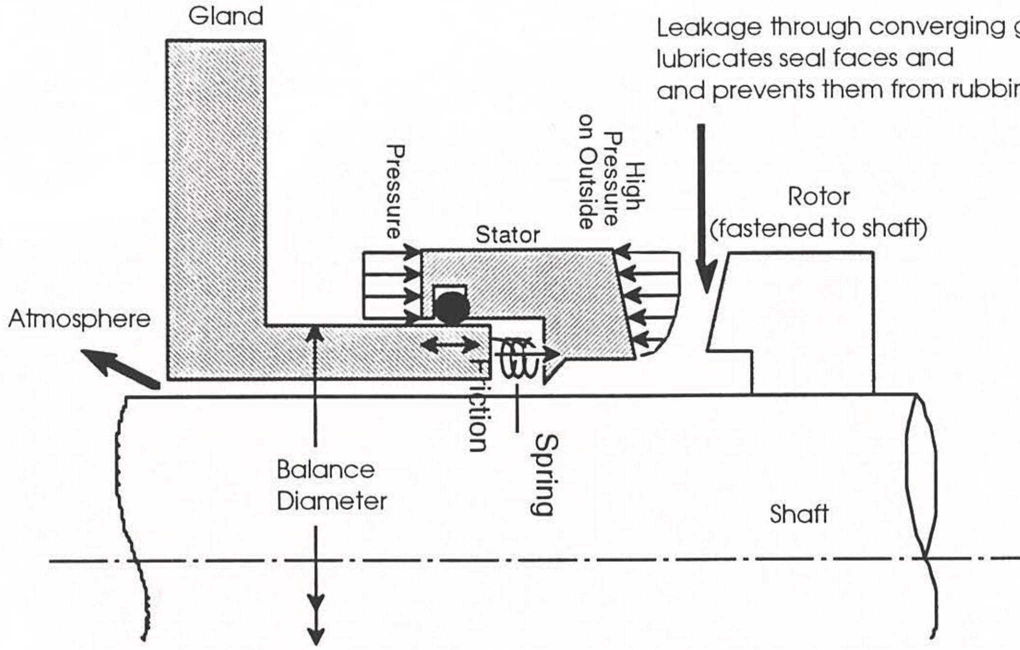

Figure 1. Schematic of a stationary balance mechanical seal such as the CAN6 shutdown cooling pump seal. Note that the convergence angle and separation between the seal faces is greatly exaggerated.

To maintain this film, it is essential that the seal be designed to deflect the seal faces in such a way that the gap between the faces is wider at the outside than at the inside, so that the water can "squeeze" in, forming a lubricating film that is wider at the outside than the inside. (If the gap is wider on the inside than the outside, then the faces contact at the outside edge, no water is forced between the faces to keep them apart, and they rub hard and wear.)

Elastomer problems were addressed by using high-temperature qualified O-rings. Potential dirt problems were addressed by creating good circulation and using hard carbide materials for the stationary and rotating seal face rings, so that any dirt that does make its way between the faces will not cause undue wear. The stationary seal ring is supported on springs to take up possible axial motion of the shaft. The seal was designed to fit into the existing gland without requiring any modification.

Test Results

The CAN6 seal was tested in the double-ended test rig shown in Figure 2. This is pressurized in the middle and has a horizontal shaft running all the way through, with a test seal in each end. Shaft speed, water pressure and water temperature were computer-controlled to match predicted transient conditions in the plant. The seal faces were inspected periodically to determine the individual effect of various tests. One end of the rig was used to test the reference design for the Pickering application while the other was used for other studies.

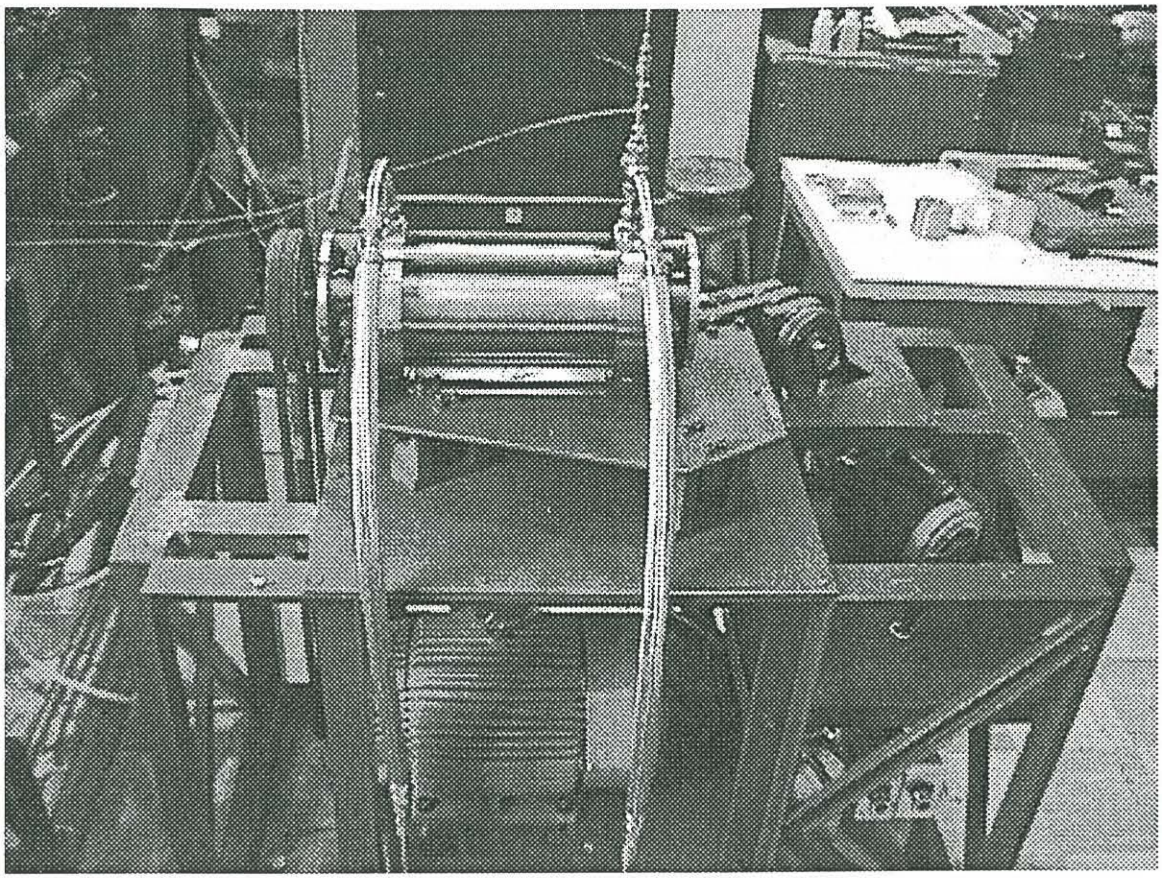

Figure 2. CAN6 seal test rig.

The first test was a 1000-hour run at low pressure to simulate normal running conditions of the seal while the plant is shut down (0.2 MPa, 30°C, 1200 rpm). Wear was insignificant (0.0001" or less), which extrapolates to a seal lifetime under normal operating conditions exceeding the lifetime of the plant.

The remaining testing subjected the seal to abnormal conditions that could pose more of a challenge.

- Dry Starts and Seal Wear-In. First, the rig was started without any water inside and stopped after a few seconds to simulate an electrician "bumping" the pump to see if the motor leads were connected the right way around. This was repeated twice and had no effect on the seal. Next the rig was run for 24 hours at 8.9 MPa, 80°C.

- Hot Stationary Operation. This test simulated the seal sitting stationary at high temperature and pressure (370 hours at 0 rpm, 8.9 MPa, 140°C, with short running periods every 100 hours while the temperature dropped to 34°C).

- Normal Cool-Down Transient. This two-hour test simulated the SDC pumps being turned on at the beginning of a plant shutdown. It was repeated 25 times. For this transient, the rig was started at 8.9 MPa, temperature slowly rose to 146°C and was cooled back to 71°C over the first hour. For the second hour, the rig was run at 0.2 MPa and slowly cooled to 34°C.

- Cold Test (Leaking Service Water Valve). This test simulated the conditions in the seal when the pump must be turned on to prevent freezing of the D_2O because of cold lake water used for cooling. Test pressure was 8.9 MPa. Each cycle consisted of a 30-minute cool-down period with the rig stationary, followed by a 30-minute warm-up period (back to normal operating temperature) with the test rig rotating. Fifty cycles were performed. These are relatively benign test conditions—cool temperatures are less damaging to the seal than hot temperatures because the water is less likely to vaporize between the faces when cool.

- Hot Test (Leaking Isolation Valve). This one-hour test (repeated 300 times) simulated hot water leaking into the shutdown cooling system while the plant is at power, then the pump being run to cool the seal back to normal temperature. It consisted of a 40-minute stationary period at 8.9 MPa with temperature slowly rising from 34°C to 110°C, then a 20-minute running period with the rig cooling back to 34°C.

- Emergency Crash Cool-Down. This test simulated the emergency situation of the SDC pumps being used to cool the primary heat transport system from 265°C rather than from 177°C, as occurs during a normal shutdown. This is an extremely rare event. The seals were inspected before and after the first test, then after two more repetitions.

The stationary seal face wore 0.0003" from the start of all this abnormal testing until the end of the first crash cool-down. The rotating seal face wore less than one tenth of this. (The height of the raised seal faces available to wear away is about 0.060".) After the third crash cool-down, the stationary face was worn 0.005" and the rotating face was worn 0.0004", with very fine heat checks. Both faces were still in serviceable condition. (Heat checks are shallow surface cracks across the seal face caused by hard rubbing.) The testing has given assurance that the CAN6 seal is suitable for use in Pickering shutdown cooling pumps, and is capable of handling abnormal events such as the emergency crash cool-down without failing.

Installation Plans

Installation of a pair of CAN6 seals into one of the Pickering B shutdown cooling pumps is scheduled for the fall of 1997.