

DVSS Primary Pumps for Pressurized Water and Pressurized Heavy Water Reactors (PWR's and PHWR's)



Purpose

This brief paper describes the main components and features of Flowserve DVSS primary pumps used in PWR and PHWR reactors.

Application/Terminology

One of the key components in the primary loop of every Pressurized Water Reactor (PWR) and Pressurized Heavy Water Reactor (PHWR) is the primary pumps which circulate reactor coolant from the reactor core to the steam generators where the heat generated in the reactor is used to produce steam to drive the steam turbine-generator sets.

Primary pump is a generic term. In PWR's a primary pump is typically called a Reactor Coolant Pump and in PHWR's it is called a Primary Heat Transport Pump or a Primary Coolant Pump. The generic term also applies to Reactor Recirculation Pumps which are used in Boiling Water Reactors (BWR).

Many large PWR's and PHWR's have four primary pumps per reactor all of which are required to operate continuously. The typical configuration in PWR's consists of four primary pumps with each providing circulation from the reactor to one of four steam generators. PHWR's also have four pumps per reactor but the arrangement is quite different. The PHWR primary circuit is divided into two independent loops with two pumps and two steam generators arranged in series in each loop.

It should be noted that, unlike most pumping systems, there are no valves in the primary loops of either PWR's or PHWR's. This provides some unique challenges in the primary pump application.

Experience

Approximately 400 Flowserve DVSS pumps have seen service in nearly 100 PWR, PHWR and BWR reactors installed in 10 countries. Over 80% of these pumps are in PWR's and PHWR's. The first DVSS pumps went into service in the 1960's and approximately 225 of them continue in operation today.

Flowserve DVSS Pumps

The Flowserve DVSS is a vertical shaft single stage cast casing dual volute mechanically sealed pump which is directly connected to a drive motor through a rigid spacer coupling. The DVSS has a bottom suction and either a single tangential discharge or two tangential discharges. The latter is frequently specified in PHWR service. An alternate design (DFSS) with a diffuser insert and collector has been applied in some PWR's.

The pumps are designed to meet the requirements of ASME Section III Class 1. DVSS pumps are available for operating parameters in the following range:

- Flows to 24500 m³/h (108000 usgpm)
- Heads to 250 m (820 ft)
- Pressures to 170 bar (2500 psig)
- Temperature to 300°C (580°F)
- Speeds to 1800 rpm
- Power to 9400 kW (12600 hp)

Pump Features

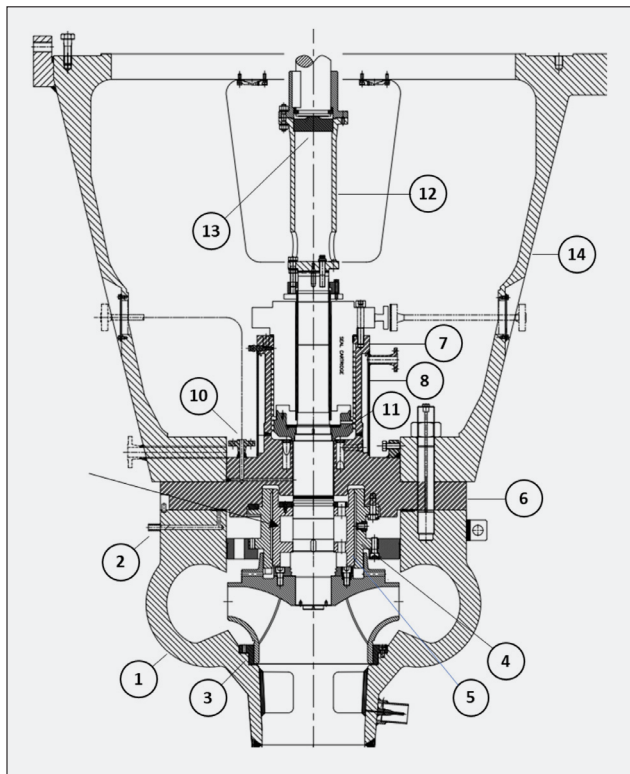


Figure 3: DVSS Pump Sectional Showing Major Components

Figure 3 is a sectional drawing of a typical DVSS pump as used in a PWR or PHWR.

The main components are the pump casing assembly, hydrostatic bearing, pump cover assembly, rotating element, and driver mount.

Pump Casing Assembly

The DVSS pump has a cast dual volute casing (1) that is designed to meet the requirements of ASME Section III Subsection NB. Casings for PWR pumps are commonly cast in ASME SA 351 CF8 or CF8M austenitic stainless steel. Casings for PHWR pumps are usually cast in carbon steel including ASME SA-216 Grade WCC. In the latter case a 300 series stainless steel overlay is applied at the gasketed carbon steel surfaces between the casing and casing cover.

The casing assembly frequently features inner and outer spiral wound gaskets between the casing and casing cover with a leak off connection (2) between the two gaskets.

Suction and discharge connections are prepared for butt welding into the primary loop piping. In PHWR's the pump vendor is required to provide 90-degree long radius elbows welded to the single suction and two discharge nozzles.

A casing wear ring (3) is provided. There is no wear ring on the impeller.

The casing is provided with studs that secure the casing cover and driver mount to the casing. The studs can be hydraulically tensioned for ease of assembly and disassembly.

Hydrostatic Bearing

There are no oil lubricated bearings in the DVSS pump. The pump uses a rigid spacer coupling so pump radial loads are taken by the two radial bearings in the motor and by a water lubricated self-aligning hydrostatic pump bearing which requires virtually no maintenance and is extremely forgiving of system upsets. Some earlier DVSS pumps used a hydrodynamic bearing but the hydrostatic bearing has proven to provide much higher reliability.

The stationary portion of the hydrostatic bearing consists of the bearing and external plate assembly (4) which is bolted to the underside of the pump cover. The rotating hydrostatic bearing journal (5) is keyed to the shaft and restrained axially by a split ring.

Radial holes on the back of the impeller act as an auxiliary impeller to provide a pressurizing flow of reactor coolant to the bearing. A hub on the back of the impeller fits over the OD of the bearing providing a flow return path to the auxiliary impeller.

The hydraulic thrust of the pump is absorbed by an oil lubricated water cooled thrust bearing at the top of the motor.

Casing Cover Assembly

The casing cover assembly is a welded fabrication that includes the following forged components: cover (6), seal housing or stuffing box (7) and cooling water jacket (8). The cover assembly is also designed to ASME Section III Subsection NB. Materials typically match the casing and, once again, stainless overlay is provided at gasketed surfaces where carbon steel is utilized.

Figure 3 illustrates the seal gland injection connection flange (10) and associated rifle drilling in the cover assembly. Also illustrated are the axial interconnected cooling passages arranged annularly around the shaft just below the bottom of the seal housing. More details on the working of the injection and cooling features are provided below under Mechanical Seal Injection and Cooling.

Rotating Assembly

The rotating assembly consists of the following main components: impeller, shaft, hydrostatic bearing journal, recirculation impeller (11) and coupling spacer (12).

The fully closed ringless impeller is fitted on the shaft and is secured with bolts. Typical impeller material used in a PHWR is ASTM A-487 Grade CA6NM. PWR impellers are austenitic stainless steel. While the impeller is not a pressure boundary component some users specify the equivalent ASME material. Shafts are typically ASTM A-479 Type 410.

The shaft can be connected to the rigid spacer coupling using various methods. The preferred solution uses curvic teeth on the spacer and shaft ends eliminating the pump half coupling and associated keys and keyways. Alignment is more precise and more reliable reducing maintenance and exposure time.

Another feature is the domed spacer plug (13). Unlike most other pumps, primary pumps operate with a high continuous upthrust. The spacer plug ensures concentric thrust transmission to the motor shaft end.



Figure 1: Curvic coupling

Driver Mount

The driver mount (14) is generally cast although fabricated mounts have also been used on some installations. The driver mount is often designed to the requirements of ASME Section III Subsection NF.

The driver mount is sized and provided with large access openings to facilitate easy access to the mechanical seal for maintenance.

The mechanical seal is installed and removed as a complete pre-assembled cartridge reducing maintenance and exposure time. This is facilitated by special tooling that can be installed in the driver mount during maintenance

Mechanical Seal Injection and Cooling Flow Paths

Sealing Configuration

Flowserve DVSS pumps are supplied with Flowserve's exclusive N-Seal. The N-Seal uses full cartridge construction and hydrodynamic seal face technology. The typical configuration used in a PWR or PHWR consists of three identical seal stages which are each designed to handle full system pressure differential. Pressure breakdown devices in each stage bypass flow around the seal faces and ensure that each seal stage carries the same differential pressure even if one of the stages fails. The gland return flow is directed to the volume control tank in a PWR or the D2O tank in a PHWR. Figure 2 provides a schematic representation of this seal staging.

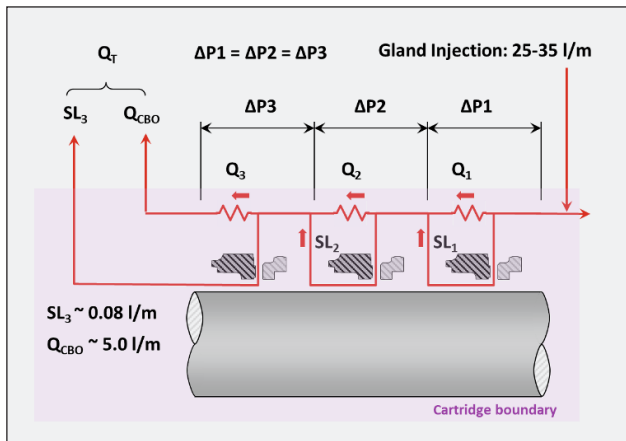


Figure 2: N-Seal staging

The seal package also includes an abeyance seal which is a flow activated passive device located above the last seal stage. The abeyance seal is designed to provide a near leak-tight seal when (and only when) activated by the complete failure of all three seal stages thus permitting the plant to respond to a wide range of extended loss of cooling accidents.

While a station black out test on a full size reactor coolant pump in the 1990's demonstrated that the N-Seal was able to cope with a loss of power and cooling for eight hours with minimal leakage, tests have since been conducted

under simulated conditions showing that the abeyance seal is capable of withstanding full temperature and pressure for more than 250 hours with virtually zero leakage.

Finally, a segmental carbon ring back up seal is provided above the abeyance seal and can be arranged for air purging.

Gland Injection and Cooling Water Flows

It is critical that the proper operating environment be maintained for the seals to function reliably. The objective is to control the temperature within the cartridge to 60°C (140°F) during normal operation.

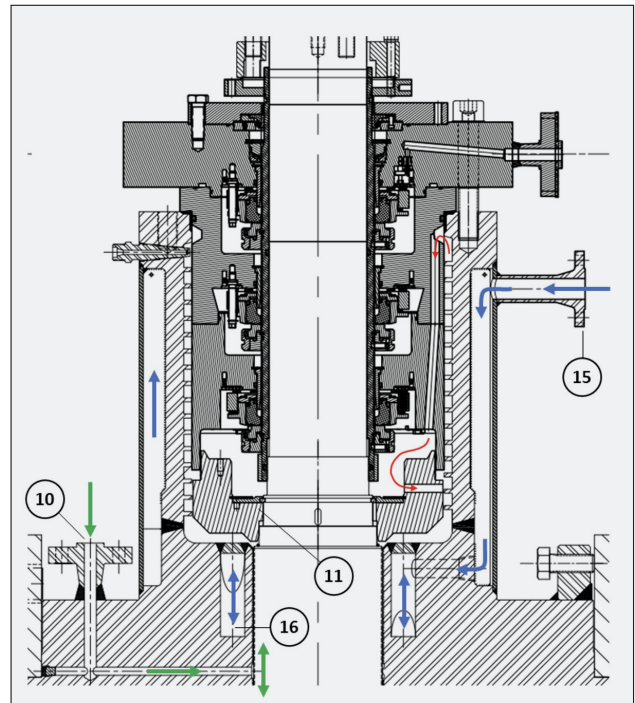


Figure 4: Gland Injection, Cooling Water and Recirculation Flows

Figure 4 illustrates the gland injection and cooling water flow paths as well as the recirculation flow within the seal housing and seal cartridge.

The gland injection flow is shown in green in Figure 4. The fluid is cooled reactor coolant provided from the Chemical & Volume Control System Pump (PWR's) or the Primary Pressuring Pump (PHWR's). The gland injection flow is in the order of 25-35 l/m (7-9 usgpm) with about 70-80% flowing downwards into the pump casing.



The pump is provided with a water cooling jacket around the outside of the seal housing. Cooling passages are also machined into the casing cover in a close annular pattern around the shaft just below the seal housing. The cooling water flow path is shown in blue in Figure 4.

The cooling water enters the inlet nozzle (15) and is channeled downwards by ribs in the jacket to the passages in the casing cover (16). It then returns to the jacket providing cooling to the outside of the seal housing before exiting the cooling water outlet. The outlet is located on the cooling jacket at the same axial position and adjacent to the inlet but is not shown on the drawing for the sake of clarity.

Heat transfer between the seal housing and the seal cartridge is promoted by a recirculation flow established by the recirculation impeller (11). This flow is shown in red in Figure 4. A circuitous flow path is created between the seal

housing ID and seal cartridge OD by machining a helical channel in the ID of the seal housing. The coolant returns to the recirculation impeller via passages in the seal cartridge.

The pump must be able to continue operating with the loss of either the gland injection or the cooling water. Plant operators specify the minimum time needed for each scenario. Loss of both the cooling water and gland injection at the same time requires the rapid shutdown of the pump.

Conclusion

The Flowserve DVSS primary pump incorporates advanced design features that were developed to satisfy the demanding needs of the industry and extensive operating experience has demonstrated its outstanding reliability, maintainability and performance.

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