Water Turbine Driven Pump (RTS Pump™)

Background

Westinghouse has designed and patented a Long-Term Containment Cooling (LTCC) System to support the Severe Accident Management (SAM) at VVER-440/V-213 nuclear power plant reactors with implemented In-Vessel Melt Retention (IVMR) strategy. The LTCC System ensures stable heat removal and effective containment depressurization in case of a severe accident, without the need of contaminated water leaving the containment and without the need of filtered venting.

Crucial component of the system is a Water Turbine Driven Pump (WTDP) able to operate for prolonged periods of time under harsh conditions during Severe Accident (SA).

Westinghouse assigned KSB to design, manufacture, and test an adequate, high-end customized and engineered WTDP based on common KSB pump/turbine hydraulics and well proven components (with lubricated bearings, double mechanical seal, etc.), with materials resistant to temperature, pressure, radiation, and chemical properties of the pumped sump water, with considerable amounts of dispersed solid debris particles.

The KSB Reactor-Turbine-Sump Pump **(RTS Pump)**[1] was developed to be used for such emergency cooling of a nuclear reactor containment.

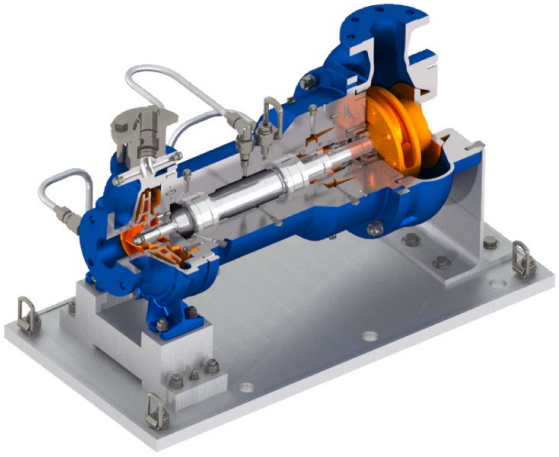
Description

Design Features

- The **RTS Pump** has been designed for dry or wet installation, to be possibly partially or fully submerged in hot contaminated sump water. It withstands a radiation dose of up to 3.65 MGy during an emergency operating time of at least six months. Its design (maximum ambient und pumping fluid) temperature is 150 °C.
- The **RTS Pump** consists of a pump stage featuring a waste-water hydraulic capable of pumping aggressive, abrasive water with large amounts of solid debris particles, sized well more than 10 mm, as caused by the severe accident. The turbine stage consists of a pump hydraulic used as a turbine. A double mechanical seal separates the pump stage from the turbine stage.
- The double mechanical seal prevents contaminated pump water to flow into the clean turbine water stage. During standstill, the mechanical seal is leak tight up to a specified pump to turbine stages differential pressure (e.g., 5 bar). During operation, the pressure levels inside the turbine and pump stages are chosen to force any mechanical seal leakage into the pump side.
- Turbine and pump impellers are connected to a common shaft which is supported by radial and axial plain bearings. Turbine impeller, bearings, and mechanical seal are located inside the turbine housing, whereas the pump impeller is located inside its own pump casing. Thus, the bearings and the driven end side of the mechanical seal are always in contact with clean turbine water. Only the non-driven end side of the mechanical seal and the pump impeller are in contact with contaminated fluid.

RTS Pump

Below are shown/listed a 3D-sketch of an **RTS Pump** and some of its design characteristics.



*3D-Sketch of a KSB **RTS Pump***

[1] **RTS Pump** is a Trademark of KSB.

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KSB

Type	RTS Pump
Safety Class	2N / 3N[1]
Seismic Category	I / II[1]
Min. operating time	6 months

[1] Depending on requirements of the plant

	Pump Side	Turbine Side
Nominal fluid flow	approx. 67 m³/h	approx. 57 m³/h
Nominal head	20 m	68 m
Fluid flow range	17–126 m³/h	30–75 m³/h
Head range	3.8–48 m	19.5–113 m
Max. inlet pressure (abs)	6 bar	13.6 bar
Max. outlet pressure (abs):		
Not submerged	6 bar	6.6 bar
Submerged	10 bar	6.6 bar
Fluid temperature range	5–150 °C	5–55 °C
Max. operating ambient temperature	150 °C	
Housing:		
Design pressure (abs)	10 bar	15.5 bar
Design temperature	150 °C	
Fluid	boric acid solution spray solution industrial water	clean filtered water drinking water industrial water
Max. solid particle size in fluid	well more than 10 mm	–

Main design characteristics of a KSB **RTS Pump**

Note the **RTS Pump** can be scaled up/down to adapt its hydraulic parameters (e.g., volume flow and pressure head ranges) to a particular application.

Qualification Tests

The implemented test program for qualification of equipment under severe accident conditions was defined and developed based on IAEA recommendations (e.g., TECDOC-1818), available international standards and guides (e.g., ISO 9906), and Westinghouse and KSB experience in development of new and innovative equipment.

Besides leak tightness tests of the mechanical seal, hydrostatic pressure tests of the turbine and pump housings, and visual tests, **RTS Pump** qualification requires **Hydraulic Performance Tests** and **Harsh Environment Tests**. All tests were performed at KSB premises in Frankenthal, Germany.

Benefits

- The **RTS Pump** is not driven by electricity but by a pressurized water flow from a mobile pump station.
- It can be used inside containment in case of severe accident with a persisting station blackout with non-availability of all nominal cooling systems.
- It can be coupled with an in-containment heat exchanger to remove heat from the containment, and with an in-containment spray system to ensure effective containment depressurization in case of severe accident, without need of filtered venting. Application is particularly important in case of damage of containment hermetic isolation or for containments with relatively large leakage rates.
- The double mechanical seal prevents contaminated pump water to flow into the clean turbine water stage, thus enhancing the plant safety by impeding any radioactive release from the containment via the **RTS Pump**.
- Due to its turbine water lubricating bearing design, the **RTS Pump** operation is free of maintenance.
- The **RTS Pump** allows for control of its performance from outside containment.
- The **RTS Pump** has been designed and tested to be qualified for operation under VVER-440 severe accident conditions. KSB robust and well proven components' design and materials allow the **RTS Pump** for normal operation well beyond six months under expected radiation dose and prevailing sump water conditions (for temperature, pressure, amounts of debris particles, and chemical composition).

Deliverables

- Fully qualified **RTS Pump**, fit to a contractual operational point with fixed values for the volume flow rates and differential pressure heads of pump and turbine, and a minimum required net positive suction head, scaled for reliable operation within specified ranges
- Basic and detailed design of an LTCC System that applies an **RTS Pump**: system description, equipment components, P&ID, mass and heat balances, materials, stress and seismic calculations, etc.
- Quality plan, quality control procedures, qualification documentation, welding procedures, risk analyses of equipment, etc.

Experience

Westinghouse has performed similar projects for application of alternative cooling systems under severe accident conditions, for example at Krško NPP (Slovenia), for design and implementation of 1) a closed spent fuel pool cooling system that applies a mobile station with a Diesel motor driven pump and a heat exchanger, and 2) a spent fuel assemblies cooling system that applies a spray system fed with river water.

KSB has been developing high performance pumps and valves for primary, secondary, and auxiliary systems of nuclear power stations for more than 40 years.

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