OPERATIONAL EXPERIENCE OF COOLING WATER SYSTEMS FOR ACCELERATOR COMPONENTS AT PLS*

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Abstract

The PLS cooling water system has been utilized for absorbing thermal load generated by a multitude of electromagnetic rf power delivering networks at PLS. The low conductivity cooling water for heat removal from the accelerator components is deionised and filtered to more than 2 MΩ·cm of specific resistance. The operation temperature of dedicated components in the accelerator is sustained as tight as ±0.1°C to minimize the influence of temperature fluctuation on the beam energy and stability. Although the PLS cooling systems were initially installed with a high degree of flexibility to allow for the conditioned operations for high beam gain, the system improvements and repairs have been employed to enhance the operational performance and reliability, and to incorporate the newly developed operating interfaces such as EPICS accelerator control systems.

INTRODUCTION

The cooling water system for the 2.5 GeV Pohang Light Source (PLS) has been operated successfully since the beam energy ramping on October 2002 [1]. The separate cooling water distribution systems for the storage ring, beam transport line and linear accelerator have been made according to their different operating temperatures, pressures, and machine construction schedules. For linac cooling system, the precise temperature control of 45±0.1°C for the accelerating structures, and normal cooling of klystrons and magnets were conducted with low conductivity water from the localized pumping station. The low conductivity cooling water pumping station for SR components as of magnets, power supplies, etc., was at the separate building, with more than 1000 meters of piping routed into SR building. Especially, a stand alone SR rf cavity cooling system has been recently reconstructed for suppressing higher order mode frequency and delivering more rf power into the storage ring [2].

The PLS cooling water system has a practice to perform the temperature stability and accuracy, low vibration source and reliable operation with safety. Especially, for maintaining the stable rf phase with electron beam in linac and SR rf cavity, the temperature control is driven by localized (modularized) temperature control system. Thus some temperature stability faults are confined into modular unit without affecting peripheral devices, and great flexibility is achieved at time consuming maintenance. The follow-up test and timely repairs of the degraded cooling devices are also carried out for obtaining the required system availability and the reduced downtime. The ten year's operation results including design characterization are described with the emphasis on temperature stability devoting to a tangible contribution to stable beam operation of accelerator components.

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COOLING SYSTEM LAYOUT

Linac Cooling System

The linac cooling water systems are divided in two subsystems by operation temperature and pressure level. It consists of the accelerator structure cooling subsystem for accelerating structures and waveguide networks, rf pulse compressors (SLED), and also the klystron cooling subsystem for klystron collectors, solenoid coils, and magnets. Each subsystem having the closed loop primary and secondary circuits removes the thermal load in the secondary side of plate-type heat exchangers. Finally, the thermal load is dissipated in evaporative cooling towers which cool the primary side of the heat exchangers. Figure 1 illustrates the flow diagram of accelerator structure cooling subsystem for precise temperature control of linac accelerator components.

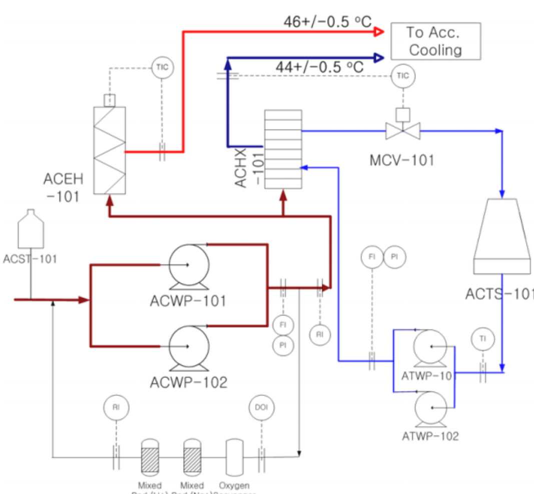

Figure 1: Schematic flow diagram of linac accelerator structure cooling system (linac main pump station).

The operating water pressure of 5.5 kgf/cm^2 and the flow rate of 220 m^3/hr are maintained for secondary loop of accelerator components. The flow with reverse return piping network is adopted to overcome unequal pressure loss paths and thus to make balancing of constant volume flow. For heat removal, the heat exchanger of 160 Mcal/hr is positioned at interface between the primary

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and the secondary loops, regulating the flow rate of cooling tower water with the cold circuit temperature of 44±0.5°C. The electric heater of 120 kW has a function of heating the water when the linac has no rf power and initial operation, maintaining the hot circuit temperature of 46±0.5°C during normal rf operation. In essence, the PLS linac primary and secondary loops operate as co-dependent, and an automatic control and interlock of process parameters are functioned to have a reliable and safe operation. In recent five years by 2004, the average operation availability and operation time is more than 99.5% and about 8,100 hours per year, respectively.

Storage Ring/BTL Cooling System

The SR/BTL cooling water system is also divided in two subsystems by pressure levels, as shown in Fig. 2. It consists of relatively high pressurized magnet cooling subsystem for bending magnets and quadrupoles, and the depressurized cooling subsystem from high pressure water subsystem for power supplies and beamline optical components of front end zone in SR tunnel. The SR cooling system having closed loop primary circuit removes the thermal load in the side of heat exchanger. Finally, the thermal load is dissipated in evaporative cooling towers which cool the condensing units in the refrigerator.

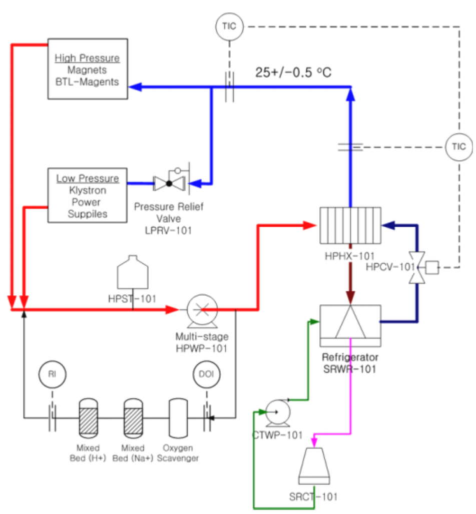

Figure 2: Schematic flow diagram of storage ring cooling system (SR/BTL main pump station).

The operating water pressure of 10 kgf/cm^2 and the flow rate of 270 m^3/hr for high pressure cooling of magnet components, and the pressure of 6 kgf/cm^2 through relief valve and the flow rate of 108 m^3/hr for low pressure cooling of klystron and power supplies components are sustained at a temperature of 25±0.5°C. The flow control valves for each subsystem cooling are adopted to make balancing of constant volume flow, reducing high installation cost and complex piping networks. For heat removal, the refrigerator of 2500 Mcal/hr is operated at interface between the primary and the secondary loops, regulating the supply water temperature. For the vacuum chambers (for baking) and photon absorbers, the LCW water is also supplied within a stable range of ±0.5°C. The cooling water temperature and pressure optimization are conducted to minimize the effect of air temperature in tunnel and flow induced vibration on beam stability.

SR Cavity Cooling System

For higher order mode (HOM) frequency suppression from PLS SR 500 MHz cavities (thermal load of about 22.5 kW), the thermal tuning for a range of 30°C to 60°C using the cooling system has been used since first improvement in 1997. In recent years, as for rf power upgrade in SR due to newly installed insertion devices, the cooling system has been reconstructed with an addition of a cooling circuit for fifth cavity. The cooling system has two loops; primary loop consisting of two circuits for cold water from the heat exchanger and hot water from the electric heaters. Secondary loop is connected with SR main LCW cooling system through the heat exchanger to dissipate the rf thermal load. The operating supply water pressure is 7.5 kgf/cm^2 and the flow rate is 30 m^3/hr for five cavities. The temperature of cold circuit is maintained at 27°C and that of hot circuit maintained at 60°C. The supply water temperature is controlled from mixing the cold and hot water with control valves, depending on the operation temperature of each cavity for thermal tuning. The final temperature stability of incoming water into each cavity was sustained within ±0.1°C.

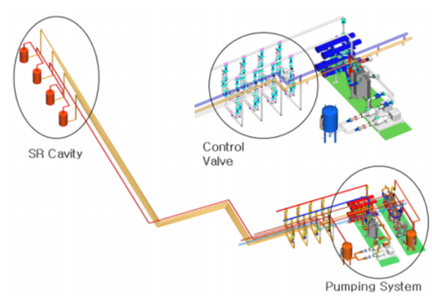

Figure 3: Installation layout of SR rf cavity cooling system (rf local pump station).

SYSTEM PERFORMANCE

Linac Temperature Stability

The temperature control of the accelerator structures (supplied with rf maximum power of 80 MW and duty of 0.00024 into module by module) is accomplished in two stages. In first stage, the cold and hot circuit water temperature is coarsely controlled into ±0.5°C using heat exchanger and electric heaters in localized linac pump station. Second, a line of two way valves on each sub-circuit of the cold and hot side makes finer temperature stabilization by blending the water, depending on the set point temperature (45°C) of accelerating structures. The direct digital controller (DDC) is adopted for localized

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temperature control of accelerating structures, module by module (12 modules for PLS linac). The quartz crystal of resonant frequency of 10 MHz (1kHz/°C) at 45°C is used for measurement of the blended water and target temperature of accelerator structures. The cascade control scheme with Smith predictor algorithm, as shown in Fig. 4, to compensate the delay time and pressure fluctuation keeps temperature stable in responding to dissipated rf power variation. Figure 5 shows an example of controller tuning for temperature stability of the accelerating structure of MK05 module within ±0.1°C during normal operation mode of 65 MW rf operation. Recently, EPICS operating interface has been employed to monitor the temperature of accelerating structures at operator room, checking out the rf phase status in linac.

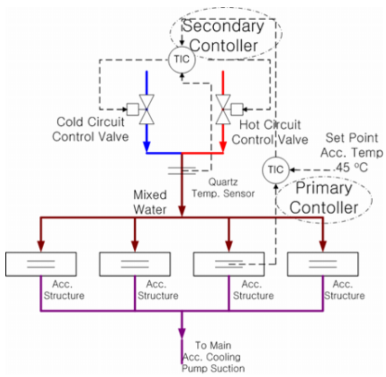

Figure 4: Temperature control scheme of accelerating structures with Smith predictor compensation.

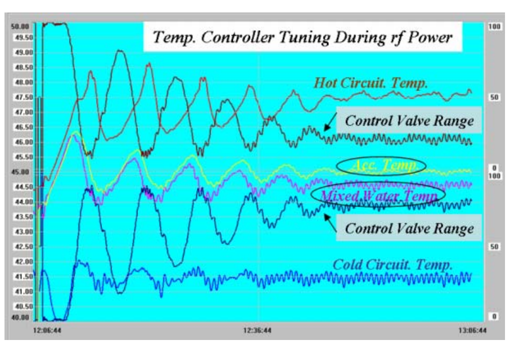

Figure 5: Temperature stability of MK05 accelerating structures during controller tuning (yellow line for acc. temperature as of 44.98°C after tuning about 20 min.).

SR Cooling and Cavity Temperature Stability

The magnets and power supplies are successfully cooled by SR cooling system without any critical failures except the magnet cooling tube replacement (loosened by hose fittings). However, the radiation damage is not clear to the magnetic flexible rubber hose. The rf cavity cooling system also maintains resonance frequency suppressing the higher order modes (HOMs) through active thermal tuning with temperature stability of less than 0.1°C [3].

Fault Status: Case Study

The water leaks appeared at the brazing joint of the linac SiC rf load and SLED components, as shown in Fig. 7. The white luster material is identified into sliver, copper, nickel and chromium in SiC rf load. It is estimated that this is from brazing filler by corrosion-erosion adhered to the surface of stainless steel-copper water jacket. For SLED system, the end plate copper tube is also joined by brazing with dissimilar water tube, and some leaks are produced by the corrosion outside water tube. During the shut down period, the parts were replaced or repaired by rejoining. Through ten year's operation of PLS, we have experienced some water leaks and other cases of cooling water faults such as hose joint loosening of the magnets, corrosion at the surface of joined parts. Further, considering the beam stability in PLS, the water flow through small piping is assumed to affect the beam gain by flow induced vibration. However, the water flow effect is not observed thoroughly yet and the flow velocity should be reduced as slow as possible in allowing the cooling performance.

Figure 6: Water leaks at brazed joint (left: SiC rf load, right: SLED in linac).

CONCLUSIONS

The PLS cooling water system maintains an efficient and stable operation through the performance improvements since the commissioning. The temperature stability is also sustained well within designed ranges in contributing the beam gain effectively. Nevertheless, there are provisions that any troubles of cooling water system could cause severe failures and damages to the accelerator components. The corrosion inevitable in cooling system is especially recognized as one of main faults, and thus periodic maintenance and/or protecting devices should be equipped to avoid sudden failures.

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