DESIGN OF THE COOLING SYSTEM FOR A 25 KW LANDAU CAVITY AT SRRC

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Abstract

A passive Landau Cavity is going to be installed in the storage ring at Synchrotron Radiation Research Center (SRRC) in Taiwan. It was calculated that the total thermal power induced on the cavity body is about 25 kW. A cooling system has been designed to bring away the thermal power to make this cavity work well. The temperature variation on the cavity body is expected to be less than 0.5 ^oC. Some electronic temperature and flow sensors, as well as a motorized control valve and two PID controllers, are therefore used to control the temperature. As a passive cavity, a heater is also necessary for heating it up to desired temperature. However, it is also designed to change the water temperature between 30 ^oC to 60 ^oC for avoiding unexpected high order modes in the cavity. Detailed design concept on this cooling system is described herein.

1 INTRODUCTION

A L-band passive Landau cavity has been designed[1-3] and going to be installed in the storage ring at Synchrotron Radiation Research Center (SRRC) soon. This cavity is designed to work with the fundamental mode of about 1.5 GHz, the third harmonic of the electron beam for SRRC storage ring. Not only the Touschek life-time will be increased by bunch lengthening with implementation of this Landau cavity[4,5], but also the Landau damping will be enhanced[6]. These are helpful on suppressing the longitudinal coupled-bunch instabilities observed in the storage ring of SRRC.

The SRRC Landau cavity is mainly consisted of oxygen-free electrical copper OFEC10100, only a portion of outer structure is made of stainless steel. Under the maximum operating gap voltage of 250 kV, the total CW power dissipation is 22.2 kW with its corresponding maximum power flow density of 36.15 W/cm^2[1,3]. Some cooling channels in the cavity body were designed to bring away the thermal power[3]. A cooling system is thus necessary to provide suitable cooling water flow.

Referred to the cooling system of ALS[7] and the existing system for DORIS-I cavity at SRRC, the cooling system for the Landau cavity has been designed. The construction of the cooling system for this cavity is almost finished and going to be operated soon. The design concepts and main functions for this system are described herein.

2 FLOW CHARACTERIESTICS

To bring the thermal power, there are 6 ring-typed cooling channels on both the longitudinal end parts of the SRRC Landau cavity, and 20 straight parallel channels on the central part. The ring-typed cooling channels on each end are connected serially by internal connecting short channels. And the straight parallel channels are separated to four groups that each group contains 5 straight channels which connected by external pipes. For good cooling efficiency, the turbulent flow in all the cooling channels is expected. That is, the Reynolds number of the flow must be larger than 10,000. Because the Reynolds number depends on flow velocity, it is necessary to increase the flow velocity and hence the flow rate for better cooling. On the other hand, the water pressure drop increases as the flow velocity increases and this is not desired. Therefore an estimation on the suitable cooling water flow is performed.

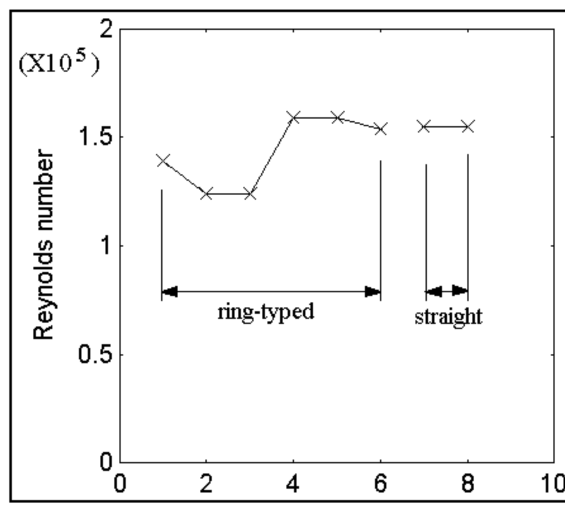

Fig. 1 Reynolds number for ring-typed cooling channels (1-6) and straight parallel channels (7-8)

After spread-sheet calculations, the water flow rate for ring-typed cooling channel is chosen to be 3.0 m^3/hr, and 3.5 m^3/hr for straight parallel ones. The corresponding Reynolds number Re_D for the cooling channels is then calculated and shown in Fig. 1. Notice that cooling channels 1-6 are of ring-typed which with different cross section. And channels 8 and 7 are respectively straight parallel channels and external connecting pipes that with same cross section and thus same Reynolds number. It is shown that all the values of Reynolds number are large than 1×10^5, and hence the turbulent flow is obtained.

The surface heat transfer coefficient *h* for a noncircular tube is usually calculated from[8]:

$$h = Nu_D \, k_m \, / \, D_h \tag{1}$$

in which Nu_D is the dimensionless Nusselt number; k_m is the coefficient of thermal conductivity coefficient of fluid, water here; and D_h is an effective diameter. The Nusselt number can be calculated from:

$$Nu_D = 0.023 \, Re_D^{\,0.8} \, P_r^{\,0.4} \tag{2}$$

in which P_r is the Prandtl number, 5.829 for water at 300 ^{o}K. From Eqs. (1) and (2), we can obtain the surface heat transfer coefficient h on all cooling channel walls as shown in Fig. 2. These surface hear transfer coefficients have been used to calculate the temperature distribution and thermal stress on the cavity body by finite element analysis. The results show the surface hear transfer coefficients are sufficient for cooling the cavity body.

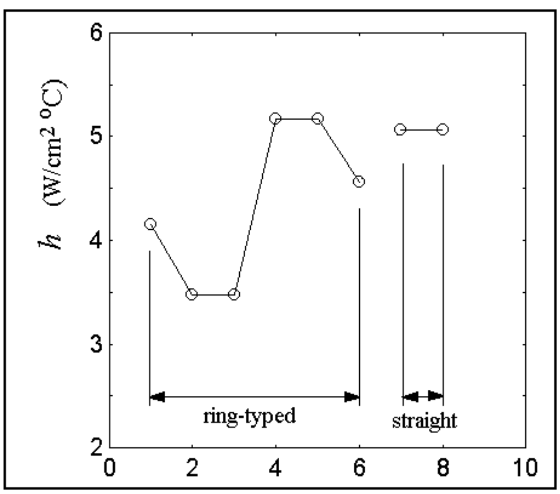

Fig. 2 Surface heat transfer coefficient h for ring-typed cooling channels(1-6) and straight parallel ones(7-8)

The water pressure drop is calculated from

$$\frac{dP}{dL} = 0.184 \, Re_D^{\,-0.2} \, \frac{\rho \, u_m^{\,2}}{2 \, D_h} \tag{3}$$

in which dP/dL is the pressure difference per unit cooling channel length; u_m the mean flow velocity, and ρ the density of water. The cumulated water pressure drop are shown in Fig. 3. It can be seen that the overall pressure drop for each single cooling channel group is less than 5 kgw/cm^2 as expected. Notice that the pressure drop is limited to 5 kgw/cm^2 at the very beginning of spread-sheet calculations for the cooling water flow rate. It means the flow rates 3.0 m^3/hr, and 3.5 m^3/hr are decided with a consideration on the pressure drop.

3 COOLING SYSTEM LAYOUT

A close-loop cooling system was designed to supply de-ionized cooling water for the Landau cavity. The

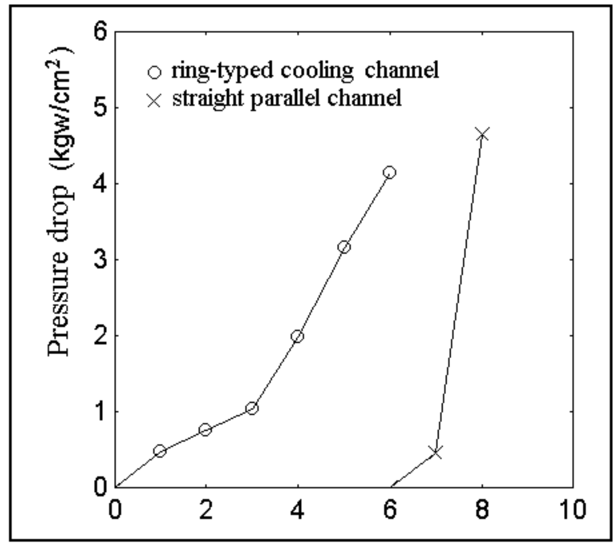

Fig. 3 Cumulated water pressure drop for ring-typed cooling channels(1-6) and straight parallel ones(7-8)

heated water in the close-loop, secondary loop, is then cooled by an open-loop cooling water system, primary loop, with a heat exchanger. A schematic drawing of the cooling system is shown in Fig. 4. From the water flow characteristics obtained, some components of the cooling system, such as pump, heat exchanger, indicators for flow rate and pressure, and safety valve, were selected.

Furthermore, this cooling system is expected to have temperature control function. Hence a temperature indicator is put at the outlet of the secondary loop. The signal is sent to a PID controller to control a motorized control valve, which locates at the outlet of the primary loop, for adjusting the flow primary flow rate . When the water of secondary loop is too hot, the primary flow rate will be increased and hence increasing the cooling efficiency of the heat exchanger, and vise versa.

A 9 kW heater is put between the outlet of the heat exchanger and the inlet of the cavity. Because a passive cavity can not be heated if no electron beam flying through, this heater is able to heat the secondary water to the operating temperature every time the system power on. It can also be used to adjust the operating temperature to avoid unexpected high order modes. From Fig. 4 it can be seen that the heater is controlled by a temperature indicator and a PID controller that locate at the outlet of the cavity. It is so designed that the operating temperature can be adjusted between 20 ^{o}C to 60 ^{o}C. Limited to the room space, the cooling system is installed at a distance of 60 m away from the Landau cavity. Considering the heat loss on the piping for high operating water temperature, the 60 m transport pipes of diameter 2 inches are wrapped in isolated material. However, the hunting between the motorized control valve and the heater may occur. Therefore it should be very careful in setting the parameters for both the PID controllers of the motorized control valve and the heater.

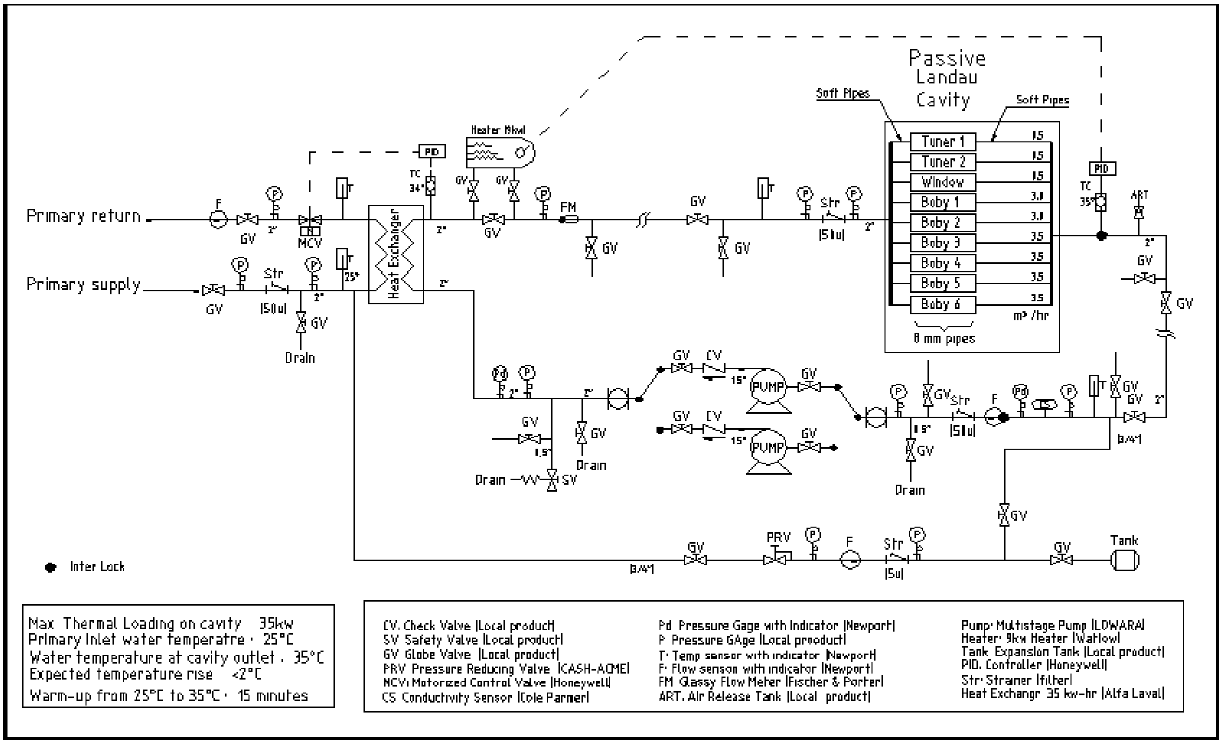

Fig. 4 Schematic drawing of the water cooling system for the passive Landau cavity at SRRC.

Two flow meters and one temperature indicator in the second loop are used as interlocks. As the water flow or the water temperature are beyond the normal ranges, both the cooling system and low level system of the Landau cavity will be shut down for protection. For easy maintenance, a spare pump is also installed . In case the working pump is damaged, the system can be switched to the spare pump soon. In addition, an auto-supplying mechanism is also designed with the help of a pressure deducing valve. When the pressure at the secondary loop is too low, the cooling water will be supplied from the primary loop and filtered by a 5 μm filter. Moreover, a flow meter with accumulation function is used to record the coming water to indicate if leakage on the secondary loop happens.

4. CONCLUSIONS

A calculation on the cooling water characteristics is necessary for designing a cooling system. The flow rate and flow velocity on all cooling branch channels must be enough for cooling the cavity body. In our case, finite element analyses were even performed to check if the flow conditions is suitable. The cooling system was then designed with considering on operating conditions, efficiency, safety and maintenance. This cooling system is being built up and will be operated soon.

ACKNOWLEDGMENTS

The authors would like to thank Mr. Bob Miller who works at American Light Source (ALS) for his suggestions on the cooling system.

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