DESIGN STUDY OF COOLING WATER SYSTEM FOR A LARGE SCALE LINEAR COLLIDER

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Abstract

A distributed cooling water system was designed for a large scale linear collider. It consists of a large number of small cooling water units and several main cooling systems. One small unit is installed for each RF unit of the main linac. The heat removed from the accelerator is transferred from the small unit to the main cooling system through a heat exchanger and moved to a cooling tower outside the accelerator tunnel. The fine temperature control is carried out in each small unit by utilizing waste heat from klystrons and a small electric heater. A prototype unit was made and has shown that the temperature of cooling water can be controlled within ±0.03°C.

1 INTRODUCTION

The next generation linear collider with the c.m. energy of 200~500 GeV is the most suitable machine to unveil the mystery of the origin of mass, to understand the symmetry breaking mechanism in the standard theory and to determine the direction of the physics beyond the standard theory. Thus, an early construction of the linear collider corresponding to the LHC is the world-wide issue. In order to realize this requirement, a linear collider using C-band frequency (5.712 GHz) for the main acceleration is proposed [1], since the straightness tolerance for the accelerating structure is 30 μm which is achievable with the conventional technology and the klystron and its power supply can be also fabricated with the conventional technology. In the system design of such a large scale linear collider, the cooling water system is one of the important elements which affects the reliability and cost of the whole system and a structure of the accelerator tunnel. A design study of the cooling water system has been carried out to reduce the mechanical vibration due to the fast water flow in the main water pipe, isolate the pressure between the main cooling system and accelerator components and reduce the cost of main pipe not to make sacrifices for the reliability and a distributed cooling water system is investigated [2]. A test by using a prototype model has been carried out to prove the temperature stability.

2 C-BAND LINEAR COLLIDER AND THE COOLING WATER SYSTEM

The overall parameter of the C-band linear collider is given in Ref. 3 and a schematic diagram of one unit in the main linac RF-system is shown in Ref. 1. The design luminosity is $6.6\infty10^{33}/cm^2/s$ and the length of the linac for electron and positron is 13 km. In the RF unit, accelerator components to be cooled with water can be classified into two groups such as (1) four 1.8 m-long choke-mode type accelerating structures which have an accelerating gradient of 40 MeV/m(nominal) and 31 MeV/m (loaded), a coupled cell type RF-pulse compressor, a waveguide system, and two 50 MW klystrons and (2) klystron focusing magnets, RF windows of the klystron and klystron modulators, and a quadrupole magnet. The groups (1) and (2) require fine and rough temperature control, respectively. Total number of the unit in the two main linacs amounts to 2040 and the total wall plug power is 150 MW. Since the total length of the two linacs is about 26 km, the cooling water system is divided into 26 sub-systems in order to reduce the unit length to 1 km. An average density of the dissipated power in the tunnel is 5.8 kW/m, most of which is cooled with water. The other part of the dissipated power including the power loss in the cable, lighting etc. is 0.5~1 kW/m, which have to be moved out of the tunnel with an air conditioner.

3 CONCEPTUAL DESIGN

Requirements for the cooling water system of the linear collider are summarized as follows:
(1) the temperature of cooling water for accelerating structure must be controlled better than ±0.05°C,
(2) the system should not cause vibration to the accelerator components which is larger than 20 nm in the frequency region above 1 Hz [4], and
(3) the diameter of main water pipes should be as small as possible.
The items (1) and (2) are required by the stable operation of the linear collider. The litem (3) is related with the construction cost and the tunnel design.

To satisfy these requirements, we adopt a distributed cooling water system in which many small cooling water units are distributed along the linacs, one cooling unit for each RF unit, and one large cooling water system (Main cooling water system) is installed for each 1 km-section to receive the heat from small units and to move it out of the tunnel. As the fine temperature control is carried out in each unit, rather rough temperature control (±2.5°C) is enough for the main system.

A schematic diagram of the small cooling unit is shown in Fig. 1. The temperature control is carried out in two stages: coarse and fine. The coarse control is done

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using waste heat. A part of hot water from the load, such as klystrons, is led to the inlet port of the pump through the valve V2 and mixed with cold water from the tank. Valves V1 and V2 are controlled by single controller to act as one 3-way valve. These valves are controlled so that the temperature at T0 is kept constant which is slightly lower than the final temperature at T2. Some water is led from here to the group (2) components (see Sec. 2). The rest of water enters the next section where the fine control is carried out by the electric heater 2. Then, it is supplied to the group (1) components. The heater 1 is installed as auxiliary heat source which is used at start-up or break down of the RF.

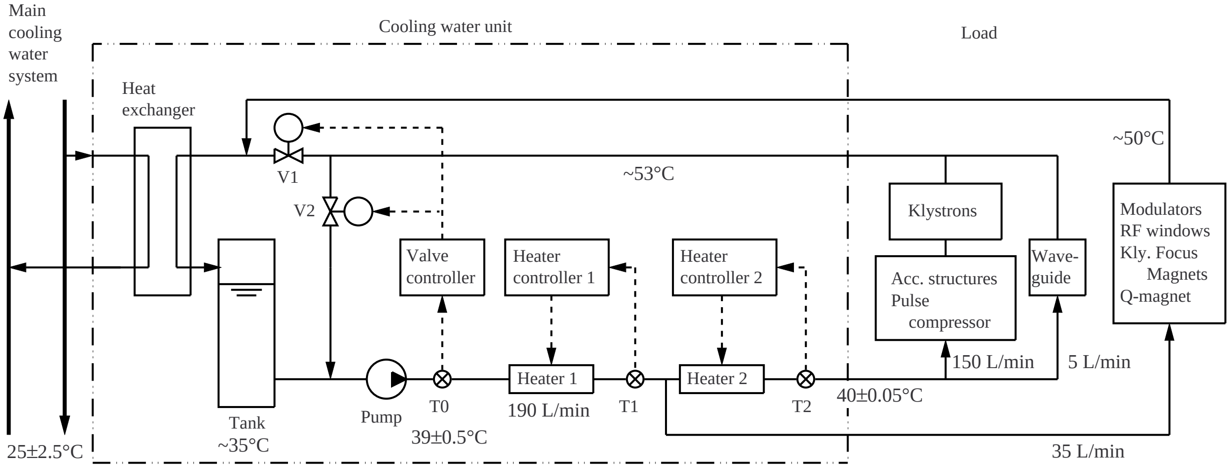

Fig. 1 Blockdiagram of the cooling unit.

4 PROTOTYPE OF THE UNIT

A prototype of the cooling unit has been made and is used at the magnetic measurement station of the KEKB project [5]. The maximum flow rate and the maximum heat load of the prototype unit are 50 l/min and 50 kW, respectively. Figure 2 shows a block diagram of the unit.

Water temperature of the main cooling system is usually maintained at about 25°C and its temperature control is rather coarse (±3°C). Therefore, we have to introduce the present unit. The difference of the two units (Fig. 1 and Fig. 2) is that the prototype unit has chiller unit while the unit of Fig. 1 does not. This is because the water temperature to be fed to the magnets must be maintained at about 28°C even in summer where the temperature of main cooling system may be above 30°C.

Cooling power of the chiller unit is discretely controlled (0-50-100%) and the water temperature of the buffer tank is cooled to 15-20°C. Cooling water is supplied to magnets by pump2. The method of temperature control is the same as described in Sec. 3: coarse control using waste heat and fine control by the electric heater. The target temperature at T1 is 27°C, lower than the final temperature of 28°C by 1°C. As shown in Fig. 3, althoug the temperature of the main cooling water changes ±3°C, the water temperature at T2 is maintained at 28.2±0.02°C, the stability of which is considerably better than the target value of ±0.05°C.

5 CONCLUDING REMARKS

We have designed the distributed cooling water system in which one small cooling water unit is installed for each RF unit. The water temperature in the unit is coarsely controlled by the direct mixing of hot water heated by the klystrons and cold water from the buffer tank. Then the fine control is carried out by the small electric heater. The prototype of the unit was constructed. It shows that the water temperature can be controlled within ±0.05°C by the present method. In the next step, we will pursue better operation parameters to minimize the power consumption. The life and reliability of parts are also important issues to be pursued, because it depends on them whether this method can be adopted by the linear collider or not.

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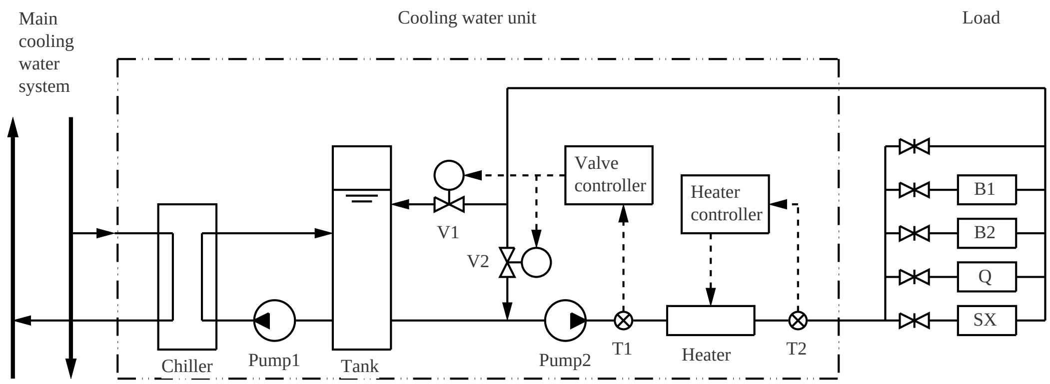

Fig. 2 Block diagram of the prototype cooling water unit.
B1, B2: Bending magnets, Q: Quadrupole magnet,
SX: Sextupole magnet.

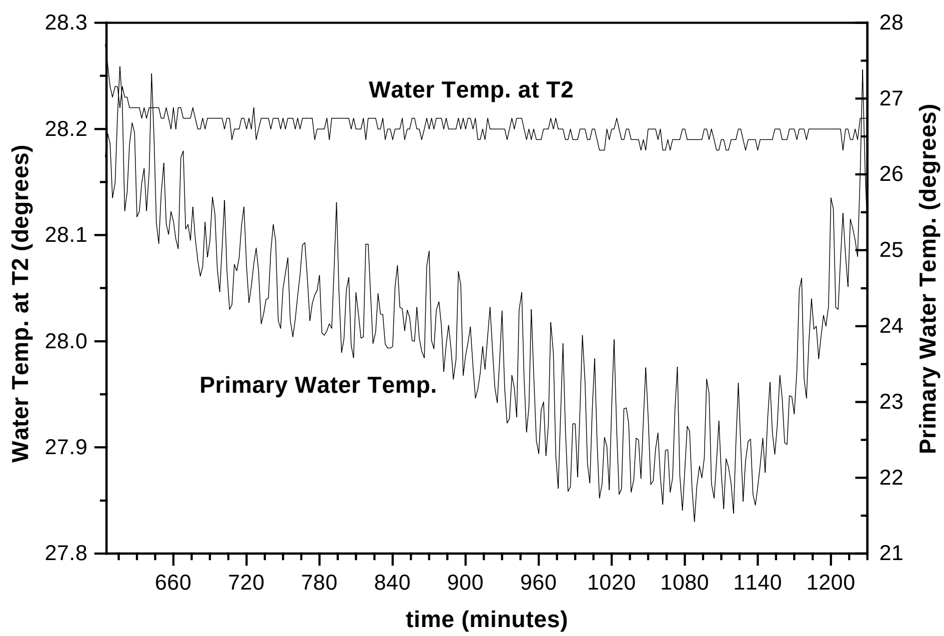

Fig. 3 Water temperature in the prototype coolingwater unit.