A COOLING-WATER SYSTEM FOR THE ACCELERATOR TEST FACILITY

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Abstract[1]

A cooling-water system for the Accelerator Test Facility of Japan Linear Collider has been constructed and operated successfully. The input temperature of the cooling-water supplied to the subharmonic bunchers, prebunchers and accelerating structures is required to hold at 36.5 ± 0.1 °C in order to insure the electrical phase stability. The temperature control for this system employs a three-way valve, a tank and line heaters. The design, specifications and results of performance tests of the system are described.

I. INTRODUCTION

A TeV electron-positron linear collider JLC (Japan Linear Collider) has been proposed in KEK. In order to realize the JLC, there are many technical problems to be solved. In order to solve the technical problems and develop the linear collider technologies, the Accelerator Test Facility (ATF) has been built [1]. In the ATF in Phase-I, we have constructed the injection system consisting of a 240 keV electron gun, subhermonic bunchers (SHB), prebunchers and a short regular section which is 0.6 m long of a 2856 MHz, $2\pi/3$ mode, constant-gradient structure [2]. A cooling-water system has to be developed in order to realize the stable operation of the ATF. A cooling-water system for the ATF is classified into two types as a dummy load cooling-water system and a 0.1 °C control cooling-water system. The former supplies the cooling-water to the dummy load of the accelerating structure, helmholtz coils and so on, which are not necessary for high precision temperature control. The latter supplies the cooling-water to the SHBs, prebunchers and accelerating structures, which are necessary to control the temperature of the cooling-water with an accuracy of ± 0.1 °C in order to insure the electrical phase stability. In this paper, the design, specifications and results of performance tests of the 0.1 °C control cooling-water system are described.

II. DESIGN AND SPECIFICATIONS

The temperature control of the accelerating structure is necessary to maintain electrical phase stability. In the ATF, we use the 0.6 m accelerating structure which is $2\pi/3$ traveling wave constant gradient type with 17-cells. The phase shift caused by the deviation of the temperature of this accelerating structure is about 7 °/°C. Therefore, the stability of water temperature must be < ± 0.1 °C.

The input temperature of the cooling-water in the accelerating structure is usually around 30 °C. The cooling-water system for this input temperature needs a refrigerator since maximum atmospheric temperature is more than 30 °C in summer. If the input temperature is set at more than 35 °C, we can adapt a simple cooling-water system using a heater and cooling tower. Thus, the input temperature was set at 36.5 °C to employ a cooling-water system controlling water temperature only by heaters. The control system with the heater is easy and adaptable for high precision temperature control. Thus, the temperature of the cooling-water supplied to the injector must be held at 36.5 ± 0.1 °C. Design and operating parameters for this system are shown in Table 1.

Table 1
Design parameters of the 0.1 °C control cooling-water system

Component	Flow(l/min.)	Heat load(kW)
SHB(119 MHz)	5	0.027
SHB(238 MHz)	5	0.027
SHB(476 MHz)	5	0.027
Prebuncher I	10	0.1
Prebuncher II	10	0.1
Buncher	15	0.5
0.6 m accelerating structure	20	7.2
Accelerating structure*	20x3	7.2x3
Total	130	29.581

(* Three accelerating structures will be installed in future.)

III. SYSTEM DESCRIPTION

A. Equipment

A flow diagram of the system is shown in Fig. 1. It consists of three loops as follows; the primary, the secondary and the accelerator cooling-water loop. Two heat exchangers HEX1

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and HEX2 are used to separate the primary cooling-water from the radioactive water of the injector.

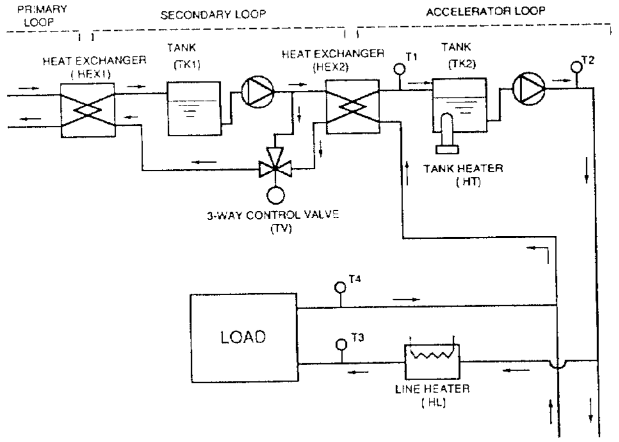

Fig. 1. Flow diagram of the 0.1 °C control cooling-water system

As a primary loop, we uses the laboratory cooling-water system which consists of a closed-loop and a cooling tower having a 0.44 MW rating at 30 °C and a flow of 850 l/min, and is automatically operated at the setting value of 30 °C.

The secondary cooling-water loop consists of a pump, a storage tank (TK1), two heat exchangers HEX1 and HEX2, and the three-way valve. It is connected to the primary and the accelerator cooling-water loop through the HEX1 and HEX2, which have a rated capacity of 59 kW. The three-way valve is used to control the temperature of cooling-water of self-loop. The pump has a rated delivery of 200 l/min. and a discharged pressure of ~ 2 kg/cm^2.

The accelerator cooling-water loop consists of a storage tank (TK2) with a heater, a pump and line heaters. It is used to provide the cooling-water to accelerator components such as the SHBs, prebunchers and accelerating structures. The tank TK2 has a 5 kw heater (HT) to control its water temperature, and a pump to keep the water temperature uniformly. The capacity of the tank TK2 and the capability of the heater HT were determined experimentally. The circulating pump has a rated delivery of 150 l/min. and a discharged pressure of ~ 3 kg/cm^2. The line heater is set just before each load and controlled with an accuracy of ± 0.1 °C. The heater capability for the 0.6 m accelerating structure is 2kW. All pipes are made from the stainless steel SUS 304. Table 2 shows specifications of the system. The storage tanks, pumps and heat exchangers are housed in the same equipment.

B.Temperature monitor and control

In order to monitor the water temperature and control the three-way valve, the tank heater and line heaters, we use four thermistor sensors T1, T2, T3 and T4, which have an accuracy of ± 0.01 °C. The sensors are located as shown in Fig. 1. The procedure of the temperature control in this system consists of three steps such as the three-way valve control, the tank heater control and the line heater control. Firstly, the three-way valve is controlled at the setting value of 36.0 °C by the feedback control using the thermistor sensor T1. Secondary, the heater set in the tank TK2 is controlled at the setting value of 36.3 °C by the feedback control using the thermistor sensor T2. Finally, the line heater for each load is controlled at the setting value of 36.5 °C by the feedback control using the thermistor sensor T3. All controls for the three-way valve and heaters are carried out by using PID control.

The distance between the cooling-water equipment and line heater is about 20 m and the system is distributed in wide range. In order to operate this system, we adapt the intensive control and monitoring system. It is also necessary for the easiness of both a maintenance and a operation. The controls console is located near the cooling-water equipment and has the control panel which contains all the necessary controls, meters, and interlock displays to operate this system.

Table 2

Specifications of the 0.1 °C control cooling-water system

(1)Primary cooling-water loop	
Pipe diameter	$2\frac{1}{2}$B(JIS* 65 A)
Water flow	200 l/min.
Input temperature	33 °C (max.)
Heat Exchanger capability (HEX1)	59 kW
(2)Secondary cooling-water loop	
Pipe diameter	$2\frac{1}{2}$B(JIS 65 A)
Capacity of storage tank (TK1)	300 l
Heat Exchanger capability (HEX2)	59 kW
(3)Accelerator cooling-water loop	
Pipe diameter	$1\frac{1}{2}$B(JIS 40 A)
Capacity of storage tank (TK2)	300 l
Tank heater (HT)	5 kW
Line heater (HL)	0.5 ~ 2 kW
Accuracy of thermistor sensor	± 0.01 °C
Total heat load	29.581 kW

*JIS : Japanese Industrial Standards

IV. PERFORMANCE TESTS

Prior to the practical use of the ATF cooling-water system, we performed tests by feeding the RF power to the 0.6 m accelerating structure. The procedure of the test is as follows: After adjusting the PID control, the RF power of 100 MW, 800 ns width and 50 pps is switched on and off after 20 minuets. During 30 minuets, we monitored the temperatures at T2, T3 and T4.

Figure 2 shows the temperatures at T2, T3 and T4 as a function of time. It shows that the input temperature (T3) of the cooling-water is sufficiently controlled with an accuracy of ± 0.1 °C.

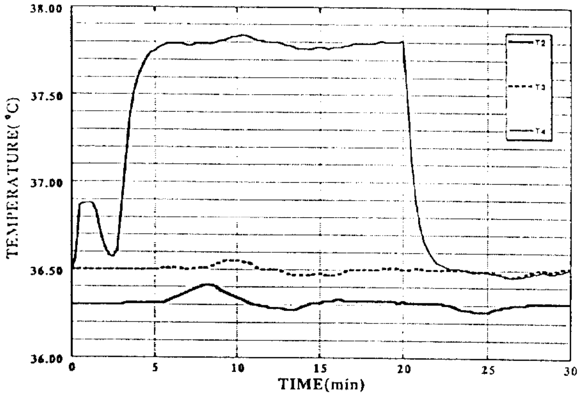

Fig. 2 Temperature at T2,T3 and T4 as a function of time. The first peak at T4 is due to RF-OFF for the interlock.

Next, we tested the system under the condition that the capacity of the storage tank TK2 was 100, 200 and 300 litters because it was one of the most important parameters in this system. Figure 3 shows the temperature at T3 as a function of time for the tank TK2 of 100, 200 and 300 litters. It shows that the temperature control becomes difficult as decreasing the capacity of the TK2 but the accuracy of ± 0.1 °C is obtainable for the capacity of the TK2 of more than 200 litters.

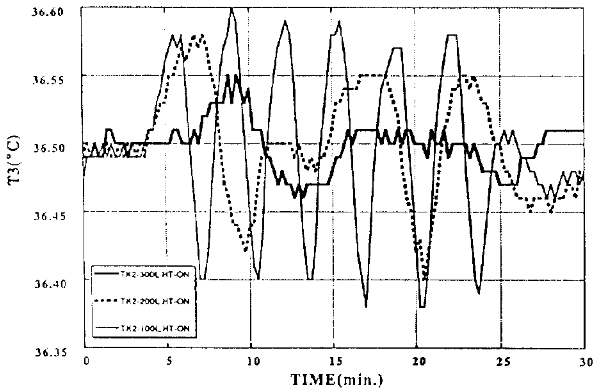

Fig. 3 Temperature at T3 as a function of time for the storage tank TK2 of 100, 200 and 300 litters.

Finally, we performed the test mentioned above under the condition that the heater of the TK2 was off. Figure 3 shows the temperature at T3 as a function of time. It shows that if the capacity of the TK2 is more than 300 litters, the temperature control with an accuracy of ± 0.1 °C is possible even in the case that the heater of the TK2 is off.

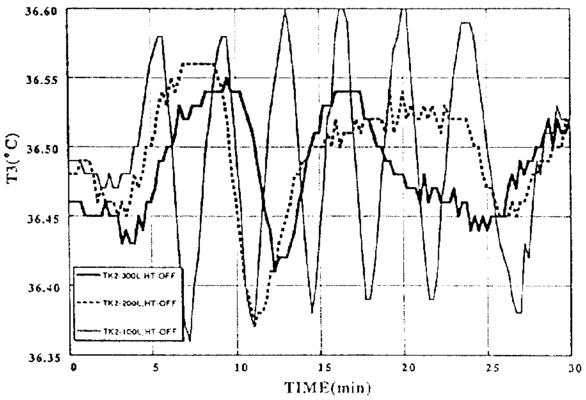

Fig. 4 Temperature at T3 as a function of time for the storage tank TK2 of 100, 200 and 300 litters. The heater of TK2 is off.

V. SUMMARY

The construction of the water-cooling system for the ATF has been completed and operated successfully. The high precision temperature control of 36.5 ± 0.1 °C was performed by using the three-way valve, the tank heater and the line heater without any serious problem.

VI. ACKNOWLEDGEMENTS

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VII. REFERENCES

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