DEVELOPMENT OF A TEMPERATURE CONTROL SYSTEM FOR LARGE SCALE ELECTRON-POSITRON COLLIDERS

M. Yoshioka, H. Matsumoto, Shigeru Takeda, Y. Takeuchi and M. Tawada, KEK, High Energy Accelerator Research Organization, Oho, Tsukuba-shi, Ibaraki-ken Japan
Y. Ishikawa, Takenaka Corporation, Ohtsuka, Inzai-machi, Inba-gun, Chiba-ken, Japan

Abstract

We have developed a cooling water system for normal-conducting magnets, which are located at the KEKB interaction region. The water temperature is coarsely controlled by the direct mixing of hot water returned from the magnets and cold water from a buffer tank. Then fine control is carried out by a small electric heater. It showed that the water temperature can be controlled within ±0.02-°C. This system can be effectively used as an unit of distributed cooling water system for a large scale linear collider. We have also used a 3D computer code to simulate the room temperature distribution and the air convection velocity in the accelerator tunnel which will be used to design the air conditioning system at the KEKB interaction region.

I INTRODUCTION

Temperature of the accelerator components of large scale electron-positron colliders such as KEKB and future linear colliders should be controlled to be better than ±0.1~0.05 °C in order to realize high luminosity of the order of 10^{33}~10^{34} $cm^{-2}s^{-1}$, which can be easily degraded by the thermal expansion of the steel and concrete (12 μm/m/°C). Especially, the temperature control at the interaction region should be carried out with better performance than the above values since the beam collision should be controlled within an accuracy of μm for B-factory and nm for linear colliders. In any system design of these large scale colliders, the cooling water system is one of the important issues, which affects the reliability, availability, maintainability and cost of the entire system [1].

The room temperature of the accelerator tunnel should be also controlled to be better than, for instance, ±0.2 °C from the operational experiences of accelerators and requirements by the KEKB design group. In the air conditioning system, strong air blow to the accelerator components, which may cause unexpected drift of the accelerator performance, should be avoided.

2 KEKB AND C-BAND LINEAR COLLIDER

2.1 KEKB

The overall parameters and general outline of the KEKB accelerator are given in [2]. Beam collision with ±11 mrad finite crossing angle scheme is chosen, so as to fill bunches to all the RF buckets. A pair of the super-conducting focusing magnets are used for both electron and positron beams and six special type (septum focusing) normal-conducting magnets are used at the interaction region, where the BELLE detector is located, as listed in Table 1. The QC1LE, QC2LP and QC2LE are located at the side from where electron beam comes and QC1RE, QC2RP and QC2RE are located at the opposite side. The total power consumption of six magnets amounts to 250 kW, which are cooled by the water. It should be mentioned that the required field gradient and the maximum power consumption of QC1LE are 15.6 T/m and 125 kW, respectively, and the temperature rise of the cooling water becomes 50 °C. Thus, a peculiar cooling water system is necessary for the fine temperature control for above magnets, since the characteristics are too different from all other magnets.

Table 1: Parameters of KEKB interaction region magnets.

ITEM	unit	QC1LE	QC1RE	QC2LE	QC2RE	QC2LP	QC2RP
Field gradient	T/m	15.60	11.69	3.11	9.99	6.11	2.88
Bore radius	mm	38	70	60	60	45	42
Pole length	mm	600	600	2,000	600	600	1,000
Current	A/mm^2	85	12	8	30	17	21
Coil turn	turns/P	3	36	18	10	9	3
Max. current	A	3,000	709	275	1,584	611	733
Max. voltage	V	42	33	38	47	19	11
Power	kW	125	23	11	75	12	8
Flow rate	l/min	40.00	8.30	7.50	26.70	8.40	7.80
Water lines		12	4	4	4	4	4
Magnet size	mm^W	600	500	800	900	580	600
	mm^H	830	800	500	700	410	320
	mm^L	1,098	750	2,157	742	716	1,080

2.2 C-band 500 GeV Linear Collider

A system design of a C-band 500 GeV Linear Collider has been performed [3] and high power RF components including 50 MW klystron have already been demonstrated [4]. In this design, the total number of RF unit in the two main linacs comes to 2,040 and the total wall plug power is 150 MW most of which has to be cooled by the water. In the design of the cooling water system, since the total length of the two linacs is about 26 km, the system is divided into 26 sub-systems in order to reduce the length of each sub-system to 1 km. A distributed cooling water system which consists of a large number of small unit are connected to the sub-system. One unit of the cooling water system is used for the one RF

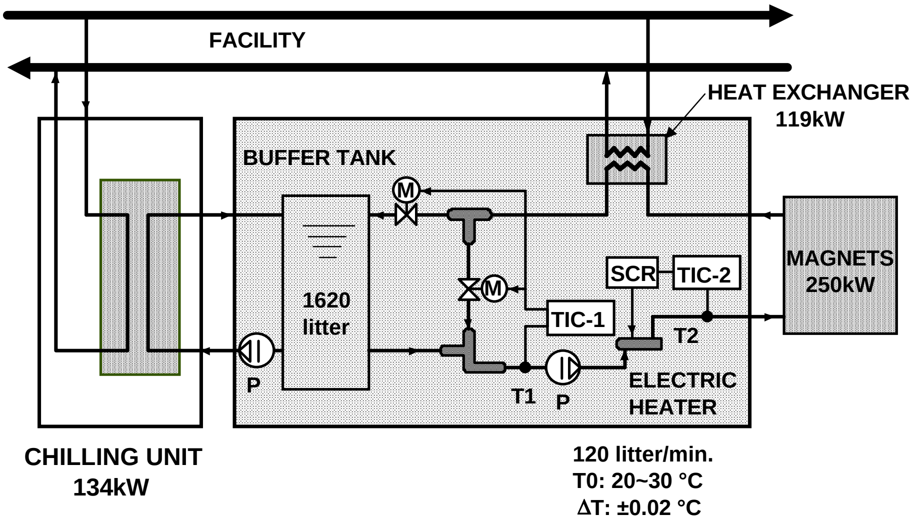

Figure 1: Block diagram of the cooling water system.

unit which consists of two 50 MW klystrons, an RF pulse compressor and four 1.8 m long choke-mode accelerating structures. The total power consumption in the one RF unit is 100 kW. The principle and performance of these small cooling water units are similar to the above system for the KEKB interaction region.

3 COOLING WATER SYSTEM

We fabricated a cooling water system in which the water temperature is coarsely controlled by the direct mixing of hot water heated by the magnets and cold water from a buffer tank by using the temperature at T1, then fine control is carried out with a small electric heater by using the temperature at T2, which are shown in Fig. 1. The necessary flow rate for six magnets amounts to 100 litter/min. The essential part of the system is (a) how to control the divide ratio of the return water which partly goes to the buffer tank and another part to the magnets again and (b) how to mix the water from the buffer tank and the above returned water from the magnets, uniformly. To satisfy these requirements, (a) two sets of two-way valves are used and (b) two chambers to mix the water from two ports and to divide the water into two ports are developed [5].

Fig. 2 shows that the water temperature can be controlled within ±0.04 °C and ±0.02 °C with and without the fine control feedback, respectively. In the present system, a heat exchanger is used at the 1st stage temperature control, which can be omitted if the heat loads is not so significant. A chilling unit is also used, which enables us to set the water temperature at any option from 20 to 30 °C. The principle of this system can be effectively used as an unit of distributed cooling water system for a large scale linear collider.

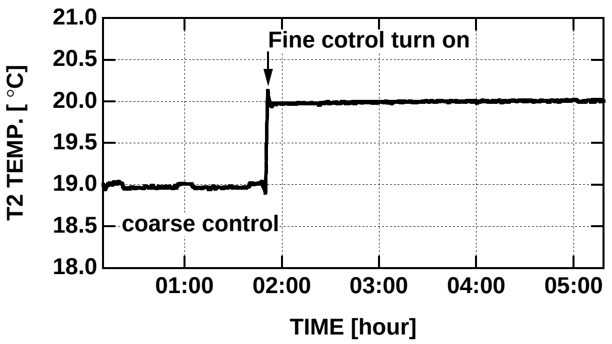

Figure 2-(a): Water temperature at T2 before and after the turning on of the fine temperature feedback.

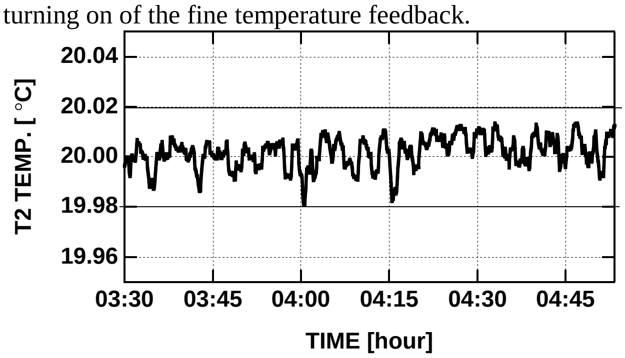

Figure 2-(b): expanded view of the water temperature after the tuning on of fine temperature feed back.

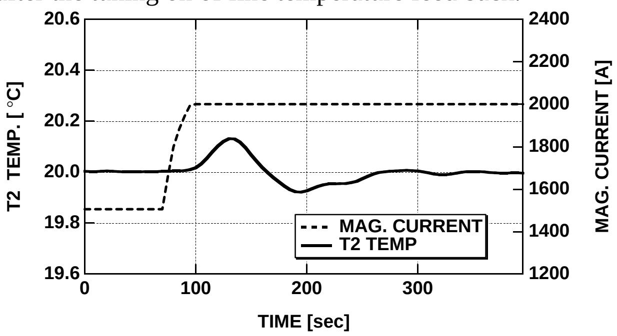

Figure 2-(c): Water temperature at T2 (solid line) and the magnet current (dashed line). A good response of the feedback can be seen when the magnet is turned on.

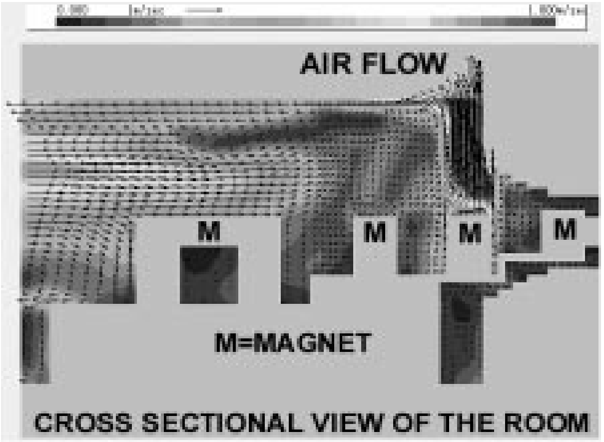

Figure 3-(a): 3D simulation of air convection flow without cooling panel.

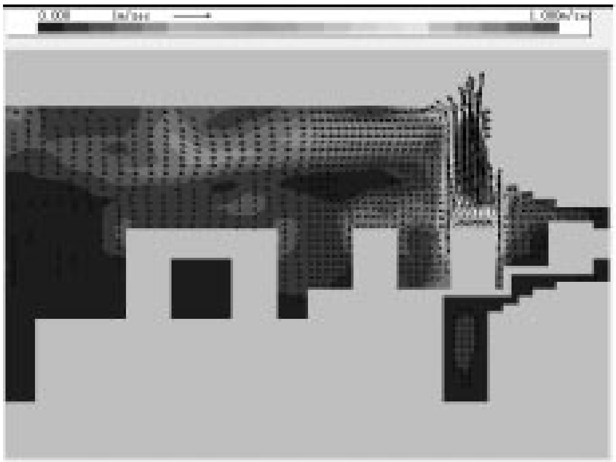

Figure 3-(b): 3D simulation of air convection flow with cooling panel.

4 3D SIMULATION OF ROOM TEMPERATURE DISTRIBUTION AT KEKB IR

It has been reported that the drift of the magnet performance becomes disallowable when the air flow, which is stronger than 1m/s, is blowing against the magnets [6]. In order to develop a proper air conditioning system for KEKB interaction region, we use a three dimensional computer code to simulate the room temperature distribution and the air convection velocity. Fig. 3 shows the results of the simulation at the KEKB interaction region where the QC1LE (right), QC2LP (middle) and QC2LE (left) are located. As is mentioned previously, the power of the QC1LE is so high (125 kw) and the flow rate of the cooling water is only 40 litter/min., that 14% of the power (18 kW) propagates to the air. Fig. 3-(a) shows the results of the simulation when the room temperature is set to 24 °C. The strong air convection flow takes place at the QC1LE, which causes another air flow from the left side of the magnets. In order to moderate this strong airflow, a cold panel (0.5 m long along the beam axis and 3.9 m width) which is cooled at 12 °C is installed at the roof to absorb the heat. As can be seen in Fig. 3-(b), the strong air convection flow at the top of QC1LE is moderated and the airflow from the left side becomes negligibly small.

5 SUMMARY

The simple cooling water system for KEKB interaction region is fabricated and can give a good performance, which will be used for the C-band Linear Collider. By using the 3D computer simulation, we have designed an air conditioning system at the KEKB interaction region considering to avoid a strong air convection flow.

6 ACKNOWLEDGMENTS

The authors thank Drs. T. Shintake of KEK, N. Holtkamp of DESY, J. S. Oh of Pohang Accelerator Laboratory for their valuable discussions and suggestions. It should be mentioned that the hardware of the cooling water system has been fabricated and commissioned by Mr. M. Hirata and his colleagues of Taiyo Valve MFG. CO., LTD.

7 REFERENCES

[1] H. Matsumoto Shigeru Takeda, Yasunori Takeuchi, M. Yoshioka, N. Holtkamp, J.S. Oh: 'Design Study of a Cooling Water System for a Large Scale Linear Collider", 1997 PAC,1997, BC, Canada, 1997'.

[2] S. Kurokawa: 'Present Status of KEKB Project, Asian Particle Accelerator Conference, KEK, Tsukuba, 1998'.

[3] T. Shintake, N. Akasaka, H. Matsumoto, J. S. Oh, C. Suzuki, K. Watanabe and H. Baba: 'C-band RF-system Development for e^+e^- Linear Collider, Asian Particle Accelerator Conference, KEK, Tsukuba, 1998'.

[4] H. Matsumoto, N. Akasaka, T. Shintake and J. S. Oh: 'Operation of the C-band Klystron with SMART Modulator, Asian Particle Accelerator Conference, KEK, Tsukuba, 1998'.

[5] Taiyo Valve MFG. CO., LTD: 'The chambers to mix the water from two ports and to divide the water into two ports are developed'.

[6] K. Egawa and M. Masuzawa: 'Private Communications. They made a mass measurement of KEKB magnets. In the beginning of the measurements, they observed a drift of the magnet length of the order of 10^{-3} and unexpected multi-pole components when the magnets are blown by air whose velocity is stronger than 1m/s'.