Development of 1.2MW High Power Water Load

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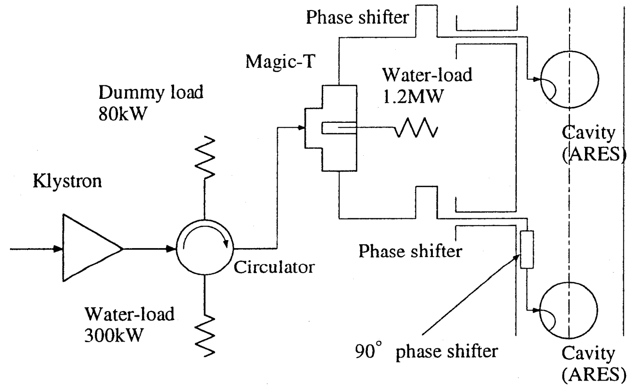
Abstract

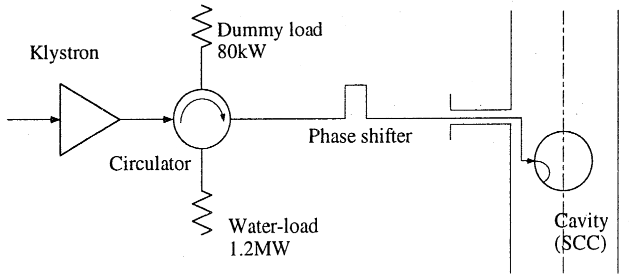
We have developed and manufactured CW 1.2MW high power water-loads for the use of the KEKB, an electron - positron double-ring collider. The water-load of a waveguide-type is filled with tap water as an RF absorber and the water is sealed by an RF window made of alumina ceramics. The VSWR of the water-load at low power levels is below 1.07 in the frequency range of 508.9±5MHz. We have tested the water-load at KEK up tp 1MW of absorbed power, which was the maximum reached with an available klystron power. The VSWR at high power levels was 1.03 or less.

1 Introduction

In KEKB, the accumulated current is 2.6A and 1.1A at LER (Low Energy Ring) and HER (High Energy Ring) respectively. The electrons and positrons in KEKB are accelerated by two types of RF cavities : a normal conducting cavity, called ARES, and a single-cell superconducting cavity (SCC).



(a) RF system for ARES



(b) RF system for SCC

Fig. 1 Block diagram of the high power RF system for (a) ARES and (b) SCC.

Fig.1 shows a simplified block diagram of the high power RF system. As shown in the figure, two ARESs are driven by one klystron, while one SCC is driven by one klystron. For ARES, reflection power from a cavity excited by the full beam current is 320kW per cavity in LER and 170kW in HER. When an RF station equipped with ARESs is tripped, the water-load is needed to absorb twice the RF power given above. A 5m long 1MW water-load was already developed and have been used practically[1]. For KEKB, we have developed a compact 2.5m long 1.2MW water-load. In this paper, we describe the design and the high power test results of the water-load.

Table 1
Specifications of Water-Load

Operation frequency	508.9±5MHz
Power allowable	1.2 MW (CW) 2.2MW (1msec pulse width, average power 1MW)
VSWR	<1.1
Water flow	>600 l/min
Whole length	2.5m
Pressure of water	10 kgf/cm^2
Coolant	tap water
Temp. of inlet water	20±5 ℃
Temp. of outlet water	70 ℃ or less
Waveguide	WR1500
Power leakage	40dB$\mu V/m$

2 Specificatsions and Structure

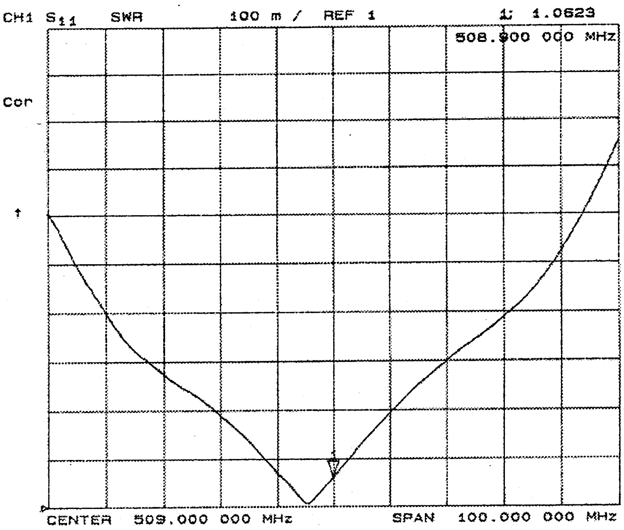


Fig. 2 VSWR of the water-load measured at a low power level.

Table 1 shows the specifications of the water-load and Fig.6 shows the structure and water flow of the water-load. In order to make the length of water-load short, we employed a waveguide-type load filled with tap water as an RF absorber. The water is sealed by an RF window made of almina ceramics whose thickness is chosen to be a quarter wavelength for impedance matching. This structure was previously developed for the L-band use and has proved to work well [2]. As shown in Fig.3, a loss tangent of tap water is about 0.04 at a temperature of 40 ℃. In the case of a waveguide (WR1500) filled with the water, an attenuation rate is 15dB/m. So the length of absorbing section was fixed to be 2m. In Fig.6 the direction of water flow inside the water-load is shown by arrows. A large portion of the RF power is absorbed near the ceramics. So we designed most of the water flow to pass near the ceramics. A portion of water flow passes through the side passage as shown in Fig.6. We confirmed this water flow experimentally by using an actual-size model made of clear polyvinyl chloride (PVC).

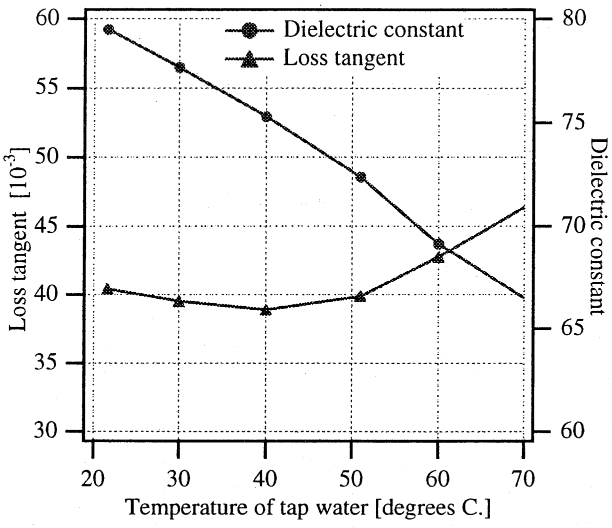


Fig. 3 The measurement data of dielectric constant (open circle) and loss tangent (triangle) of tap water as a function of temperature.

RF leakage from the water inlet and outlet part had to be reduced by at least 60dB under the condition that the water flow rate is over $600 l/min$. We solved this problem by using 13 small-diameter pipes in parallel, whose cutoff frequency is much higher than the operation frequency. Fig.2 shows the result of the low power measurement. The VSWR in the specified frequency range range was reduced to less than 1.07 by adjusting the size and position of the post.

3 High Power Test Setup

Fig.4 shows the setup of the high power test. The klystron used was E3786 (1.2MW output power) made by Toshiba corporation. The flow rate of cooling water (RF power absorber) for the load under test was $540 l/min$. We measured the RF power of the forward and backward waves by the directional couplers. The power absorbed in the water-load was also checked calorimetrically by measuring a temperature rise of cooling water. We measured the surface temperature of the water-load by 8 Ar-Cr thermocouples which were set at the positions shown as TC1-8 in Fig.4. The RF power was gradually increased in 50kW step up to 1MW. At each power level, RF processing was carried out for 15 minutes. Although the output power of the klystron was 1.2MW, the power delivered to the water-load was 1.0MW due to the loss in the waveguide and the circulator.

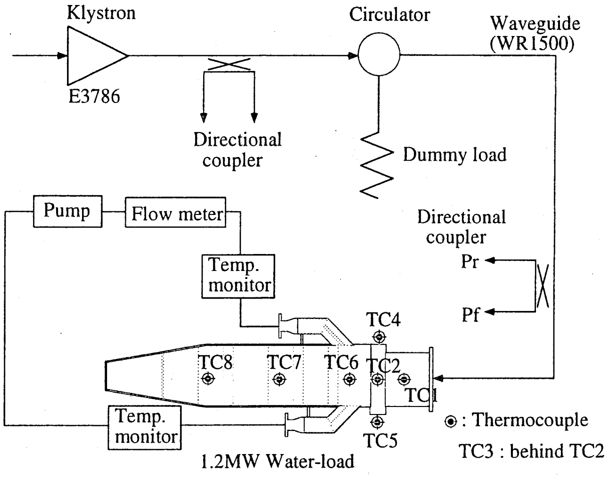


Fig. 4 High power test setup an arrangment.

4 The Results of High Power Test

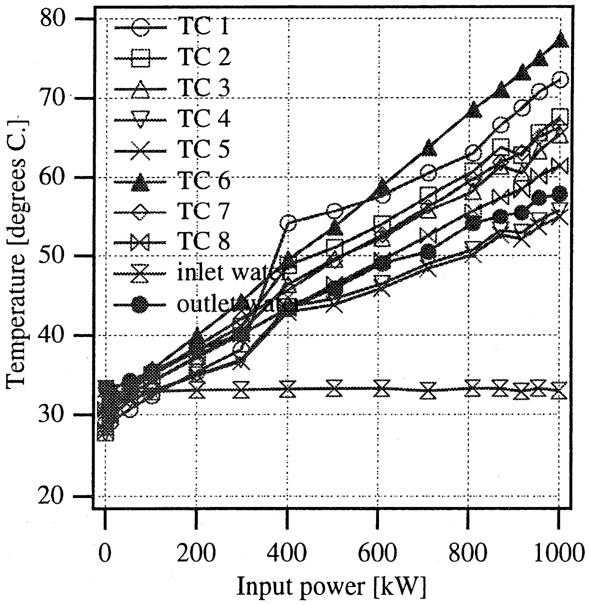


Fig. 5 Surface temperature versus input power. The arrangement of termocouples on the surface of the load is shown in Fig.4.

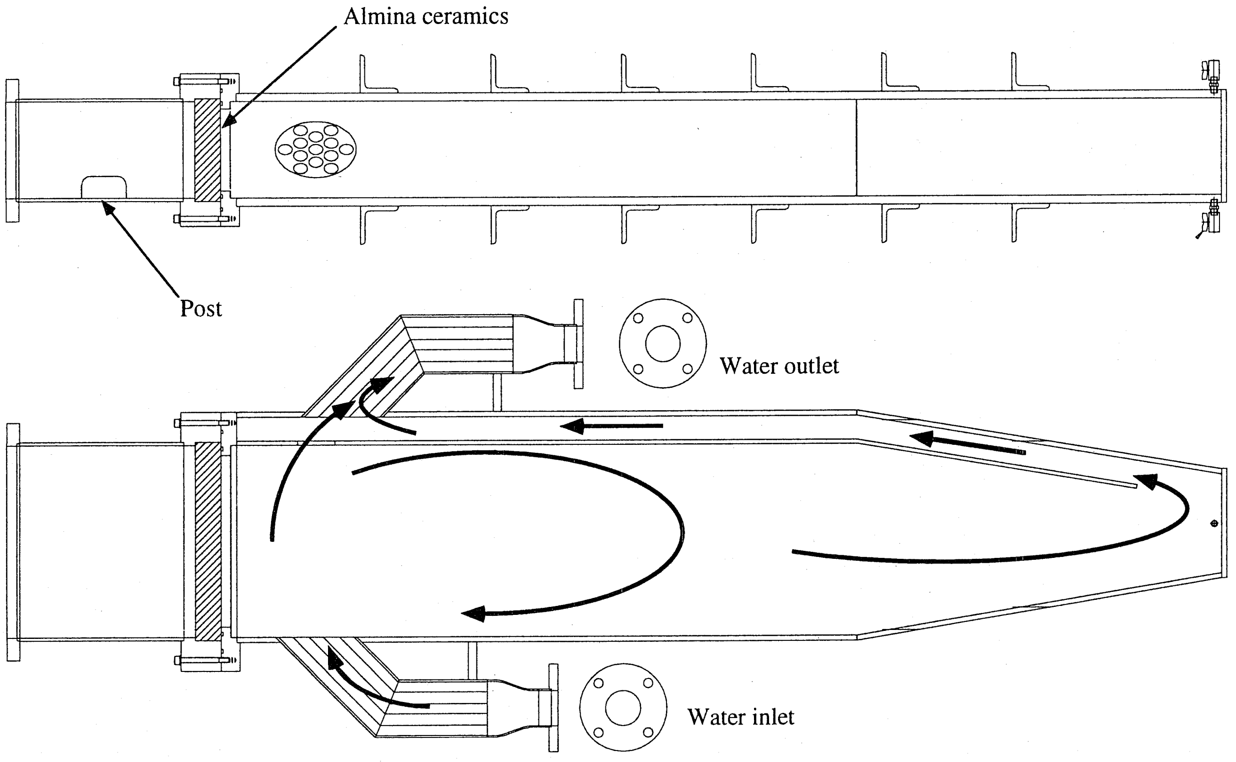


Fig. 6 Structure of water-load : the arrows show the direction of water flow.

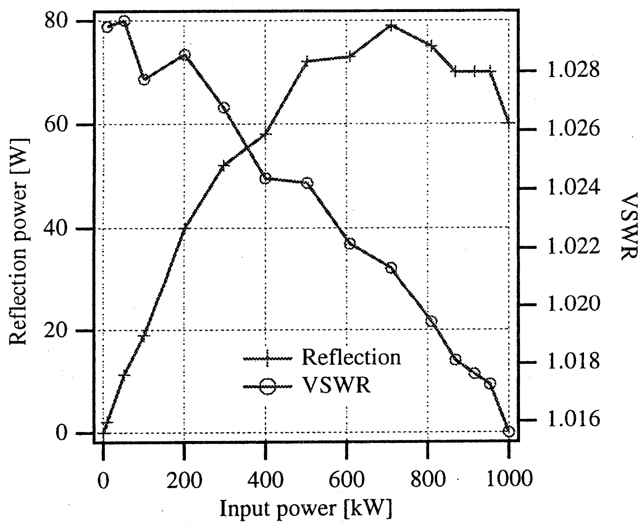


Fig. 7 Reflection power and VSWR versus input power : the power is monitored by the directional coupler.

Fig.5 shows the power dependence and distribution of surface temperature of the water-load. The temperature of inlet water was 34 ℃. Temperatures at TC2-5 set around the ceramics were comparable to those at TC7-8 set away from the ceramics. It clearly shows that there was no local heating at the ceramics and that the water-load operated stably as designed. The highest temperature was recorded at TC6 and was 77.3 ℃ when the input power was 1.0MW. This value was 15 ℃ higher than TC7-8 and was attributable to insufficient water flow rate, which was 10% less than the specified value (600l/min). Therefore, we conclude that this temperature rise will not become a problem as long as the specified amount of water flow is available. Fig.7 shows the VSWR and the reflection power as a function of input power. The variation of VSWR was very small over a wide range of input power from 0 to 1MW. We have made the high power test of 6 water-loads up to the maximum power of 1.0MW, which was kept for 15 minutes for each water-load. After we had finished the high power test, we disassembled some of the loads and checked the inside. There was no trace of electric arc around the ceramics. These 1.2MW water-loads will replace the present 250kW loads in LER and will join in the KEKB operation scheduled to resume in this October.

Acknowledgement

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