RF HIGH POWER WATER-LOADS FOR KEKB

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Abstract

In order to absorb a large reflected power from RF cavities, we have developed CW high power water-loads for the use of KEKB. The loads can absorb a CW power of up to ~1.2MW and an operational frequency range is 508.9±5MHz. They are filled with water as an RF absorber, which is sealed with an RF window made of alumina ceramics. We have developed two types of water-loads: one is a rectangular waveguide made of a stainless steel, and the other a cylindrical tank made of aluminum. We made the high power test of all the loads at KEK when they were delivered. A load absorbed a maximum power of ~1.1MW. We also measured RF properties of tap water using a network analyzer with a dielectric probe.

Cooling water as an RF power absorber is circulated with a pump and exchanges heat with facility cooling water using a heat exchanger at each power-supply room of KEKB. The heat exchange systems for LER have been built for KEKB, while those for HER are the reuse of TRISTAN components. The flow rate of the LER heat exchanger is 1,200 l/min and the allowable temperature rise of water is ~23˚C. Power handling capability of the heat exchanger is about 1.8MW, which is well over a maximum reflected power from four cavities. The flow rate and the temperature rise of the HER heat exchanger are about 1,500 l/min and 25˚C respectively.

At an early stage of the KEKB operation, we used the tap water as an absorber material for its high absorption rate and easy handing. We found out later that an inside surface of the aluminum tank suffered corrosion by interaction with impurities in the water. We changed the cooling water for the cylindrical tank type from the tap water to the deionized water, while the waveguide-type load made of stainless steel still uses tap water.

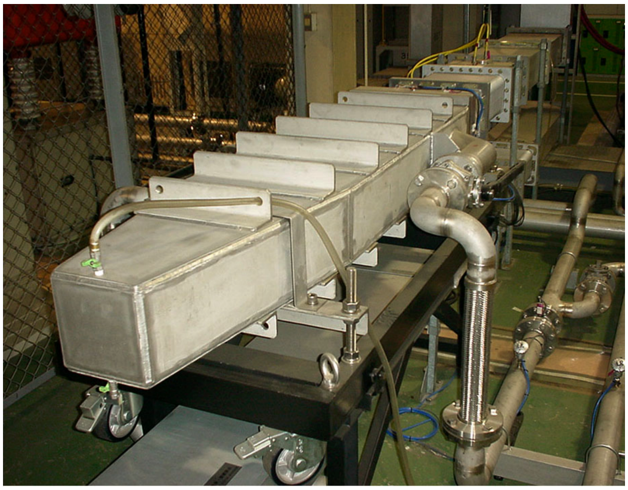
1 INTRODUCTION

The KEKB, an asymmetric electron-positron collider for B-factory at KEK, was commissioned in December 1998. The RF system of KEKB has been operating stably since the commissioning started. Two types of RF cavities are used for KEKB: the ARES normal conducting cavities [1] and superconducting cavities (SCC) [2]. As given in a previous paper [3], an RF power is fed to two ARESs by one klystron, while fed to one SCC by one klystron. The maximum reflected power is 320kW per cavity in LER (Low Energy Ring) and 170kW in HER (High Energy Ring) for ARES. When an RF station with two ARESs fails, the load dissipates twice the RF power given above. For SCC, the maximum reflected power is estimated to be ~450kW per cavity.

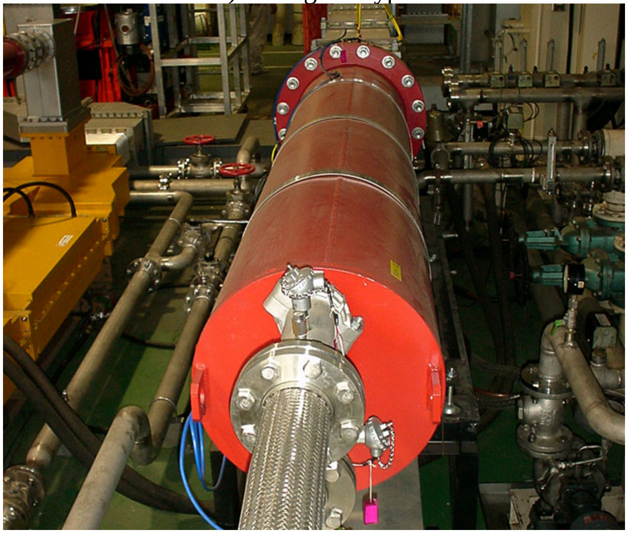
A 1MW CW water-load called the slanted-tube type [4] developed for the klystron test stand of TRISTAN and the improved version of the load [5] has been used at the test stand stably. However, it has a length of 5.5m and is used at a low water pressure because of employing of the long Teflon (PFA) tube to guide water. For KEKB, we have developed a compact 2.5~3m long load which withstands a high water pressure up to 10kgf/cm^2. The loads have been used to absorb the reflected power from cavities in the RF system of KEKB.

2 STRUCTURE AND HIGH-POWER TEST

We have developed two types of the water-loads: the rectangular waveguide made of a stainless steel [3] and the cylindrical tank made of aluminum. Figure 1 shows the pictures of each load installed in the RF stations. The loads are connected to the WR-1500 waveguides. The loads are filled with water as an RF absorber and have the



a) Waveguide type



b) Cylindrical tank type

Figure 1: Pictures of the water-load installed in the RF stations.

RF window made of alumina ceramics, which separates the water of the load from the waveguide. The thickness of the window is chosen to be a quarter wavelength for impedance matching. Table 1 shows the specification of the load.

Table 1: Specification of the water-load

Operational frequency	508.9±5 MHz
Maximum power	>1MW(CW) >2MW(Pulse*)
Input VSWR	<1.1 (508.9±2MHz) <1.2 (508.9±5MHz)
Water flow	>600 l/min.
Water pressure	>10 kgf/cm^2
Temperature of inlet water	<40˚C
Temperature of outlet water	<70˚C
Whole length	2.5~3 m
Number of load	9 (waveguide type) 7 (cylinder type)

*) The pulse maximum width is 1msec.

We have made the high power test of all loads at the test stand of KEK for acceptance since 1997. We measured the forward and backward RF power by a directional coupler and surface temperatures of the load by 8 thermocouples. Especially the temperatures of the flange which includes the window are important because a rough contact between the flanges may induce a discharge. We fed the power of above 800kW to all loads. A load absorbed the maximum power of ~1.1kW, which was limited by an available klystron power. The measured VSWRs were distributed in the range of 1.02~1.14 at 508.9MHz. Figure 2 shows a typical example of the high power test for loads. The horizontal axis in the graph represents the time after a start of the high power test. The vertical axes represent the input power and the surface temperature near the flange. The loads that had high temperature at the flange were repaired to make a smooth contact between the flanges.

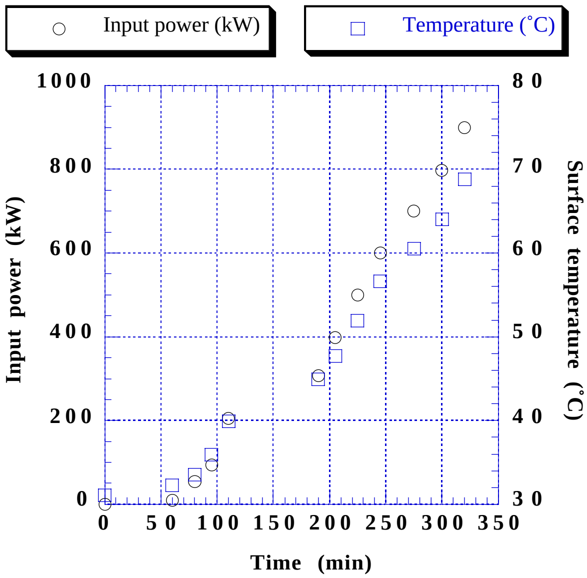


Figure 2: A typical result of the high power test for water-loads at KEK.

3 COOLING WATER AND SYSTEM

The cooling water of the load must be lossy so as to serve as an RF power absorber. Attenuation rate of the waveguide filled with dielectric material whose dielectric constant is ε is expressed as

$$\alpha = 91\times10^{-9} f\sqrt{\varepsilon}\tan\delta.[dB/m]$$

where f is the operational frequency and tanδ is the loss tangent of the material. Figure 3 shows the temperature dependence on ε and tanδ for the tap water and pure water. The RF properties of tap water were measured using the network analyzer (HP8510) with the dielectric probe. The ones for pure water are cited from Ref. [6]. Pure water does not absorb RF power enough due to a small loss tangent at high temperature. Attenuation rate calculated for the tap water is more than 15dB/m. A dielectric loss is dominant for the water of ~10˚C and under. A conductive (Joule) loss increases gradually with temperature and then is dominant for the water of ~40˚C and over. The conductivity of the tap water is ~290μS/cm at ~20˚C and also increases with temperature. We cannot use the un-deionized facility-water that is often contaminated with iron rust, so that mesh-filters are clogged in a short time. For the load made of stainless stall, we have used the tap water because of its high absorption rate and easy handling. However, for the load made of aluminum, we changed to the deionized water from the tap water as described later.

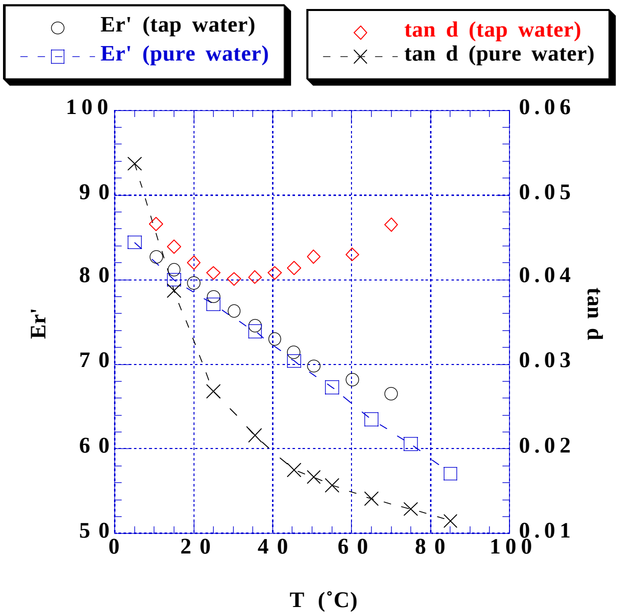


Figure 3: Temperature dependence on ε and tanδ for the tap water and pure water.

The cooling water for the load is circulated with the pump and exchanges heat with facility cooling water through the heat exchanger. The heat exchange systems are located at four buildings called D7, D8, D10 and D11 of KEKB. Figure 4 shows the cooling water system installed at D7 or D8 in LER. To control the temperature of water we set there an adjusting valve and a bypass tube of the heat exchanger. They are used for rising water temperature of the load in a cold winter.

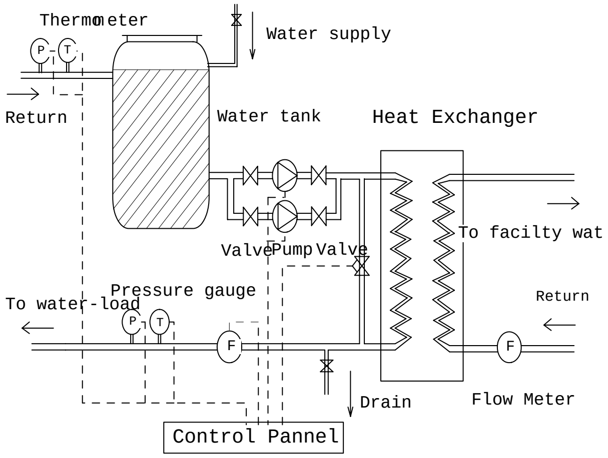


Figure 4: Cooling water system at the D7 or D8 building.

The heat exchange systems for LER have been built for KEKB, while those for HER are the reuse of TRISTAN components. The flow rate of the LER heat exchanger is 1,200 l/min and the allowable temperature rise of circulating water is ~23˚C. From these figures, power handling capability of the heat exchanger is about 1.8MW, which is well over a maximum reflected power from four ARES cavities. The system of D10 or D11 in HER, which was originally constructed for cooling the klystrons at the time of TRISTAN, is almost identical to D7 or D8 except for the bypassing water circuit. The flow rate and the temperature rise of the HER heat exchanger are about 1,500 l/min and 25˚C respectively. The capability of heat exchange is sufficient for the reflected power from all the four SCCs positioned in D10 or D11. This capability is very useful at coupler aging of SCC.

4 OPERATION EXPERIENCE

Now a maximum current of 1.03A is stored in LER for the purpose of storing the design current of 2.7A and a maximum of 0.87A is stored in HER for the purpose of storing the design current of 1.1A. When a klystron suddenly fails to supply to cavities in operation or when the stored current is suddenly aborted due to troubles, the reflected power is still under ~220kW per station at present. Therefore, we have not a trouble related to high power dissipation of the water-load. However, we had some mechanical troubles: 1) water leak from a small crack of the ceramics window for the waveguide type, 2) disconnection of an inner pipe made of polyethylene for the cylinder type, 3) shearing of bolts made of polyethylene for the cylinder type. In the first case, a ceramics window cracked due to improper contact to the flange, which made a small amount of water leak to the inside of the waveguide connected to the window. The leaked water was then heated by the coming RF power up to a temperature at which a thermometer attached under the waveguide gave an alarm. In the last case, some of the polyethylene nuts dropped and were carried away by the water flow into a turbine-type flow meter. There, a nut was caught by the vane of turbine and eventually stopped the turbine. In all cases, we exchanged all trouble parts with new ones.

At the early stage of the KEKB operation, we had a chemical problem that a load had corroded on the inside surface of the aluminum tank. It was found when a load was disassembled at the time of trouble 3) mentioned above. The corroding particles appeared to be a colloid-like in water and a powder-like after it became dry. X-ray fluorescence analysis shows that main elements of the powder were aluminum and sulfer. The powder was dissolved in a hydrochloric acid of 0.1M and concentration of its components was obtained using ion chromatography method. The concentration of aluminum was measured by ICP emission spectrochemical analysis. It was estimated that the main substances formed were aluminum hydroxide ($Al(OH)_3$), aluminum oxide (Al_2O_3), aluminum sulfate ($Al_2(SO_4)_3$) and aluminum sulfide (Al_2S_3) [7]. An examination of corrosion was made actually as follows: we put aluminum samples in a bottle filled with waters. The samples in the tap water corroded step by step, while the samples in the deionized water did not corrode even after five months. To avoid corrosion we changed the water for the load of aluminum cylinder type from the tap to deionized water. After that rate of corrosion is fairly slower than before. The deionized water has the conductivity of ~3μS/cm at 20˚C and is more lossy than the pure water.

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