THE FIRST COOL-DOWN TEST OF THE 6 METER-LONG-CRYOMODULES FOR SUPERCONDUCTING RF TEST FACILITY (STF) AT KEK

N. Ohuchi#, K. Tsuchiya, F. Furuta, K. Hara, H. Hayano, N. Higashi, Y. Higashi, H. Hisamatsu, K. Hosoyama, E. Kako, Y. Kojima, M. Masuzawa, H. Matsumoto, H. Nakai, S. Noguchi, T. Saeki, K. Saito, T. Shishido, A. Terashima, N. Toge and K. Yokoya, KEK, Tsukuba, Japan
Tsai Ming Hsun, NSRRC, Hsinchu, Taiwan
Xu QingJin, IHEP, Beijin, Chaina

Abstract

KEK has been constructing the STF as the center of the ILC-R&D in Asia from 2005. In this construction, KEK developed two 6-m cryomodules in order to get manufacturing and operational experiences of the superconducting RF cavity and cryomodule toward the ILC. Two cryomodules were designed to accommodate 4 nine-cell cavities in each cryostat. At the first step, the cryomodules with one cavity were assembled and their cold tests were performed. And in the following test, the cryomodule with four cavities was reassembled and the cold test of this module is being carried out now. In this paper, we will report the design of the cryomodules briefly and the thermal results of the cold tests.

INTRODUCTION

In order to get the superconducting RF technology for the International Linear Collider, ILC, KEK initiated the construction of the Superconducting RF Test Facility, STF, at 2005. The design work of two cryomodules began at 2005, and these cryomodules were assembled from October 2006 [1-2]. The cross sectional designs of the cryomodules were based on TESLA type-III [3], however, each cryostat had a different type of cavities, TESLA type [4] and Low-Loss type [5]. At February 2007, the two cryomodules with one cavity were completed at the first stage of this R&D and connected in the STF-tunnel. Due to the helium leak problems, the system was disassembled and these two cryomodules were separately tested at 2 K from October 2007 to March 2008. During these cold tests, four TESLA type cavities were assembled in a string. The cavity string was installed into the cryostat and the cryomodule was completed. This cryomodule was successfully cooled down to 2K, and the heat load measurements and low-power tests of four cavities were completed. In the following section, we will describe the design of the cryomodules and the results of the cold test at 2K with focusing on thermal issues.

STF CRYOMODULE DESIGN

The parameters of two cryomodules are listed in Table 1. The cross sectional view of the STF cryomodule with Tesla type cavity is shown in Fig. 1. The cavities are supported from the gas return pipe, GRP, of which outer diameter and thickness are 318.5 mm and 10.3 mm, respectively. The GRP was hanged from the vacuum vessel with two support posts. Two GRPs are connected with the reduced pipe, as shown in Fig. 2. The total length of the connected two modules is 13195 mm. The cavities are covered with 5K and 80K thermal radiation shields. The inner diameter of cooling pipes for the shields is 22 mm, and the cooling pipes of forward and return lines are attached to the shield plates by screws. The thicknesses of upper and lower plates are 6 mm and 3 mm, respectively. The 5 K and 80 K shields are covered with 10 layers and 30 layers of MLI, respectively. 2K LHe supply pipe has an inner diameter of 72.1 mm.

Heat loads at static condition are calculated for each cryomodule, and they are listed in the Table 1. For the module-A, the heat load at 2K is 4.1 W, and 87% of this load is due to the RF cables without 5K thermal anchors.

Table 1: STF Cryomodule Parameters

	Module-A	Module-B
Cavity type	TESLA-like	Low-Loss
Vacuum vessel length (SS400)	5515 mm	5950 mm
Vac. vessel outer diameter	965.2 mm	965.2 mm
Gas return pipe length (SUS316L)	5832 mm	5830 mm
Cold mass, kg		
4 cavities	410	500
Gas return pipe	515	520
5 K shield (A1050)	185	190
80 K shield (A1050)	210	215
Helium supply pipe (SUS316L)	50	50
Heat Load (Static, 4 Cavities), W		
2 K	4.1	0.8
5 K	10.1	11.1
80 K	71.1	41.1

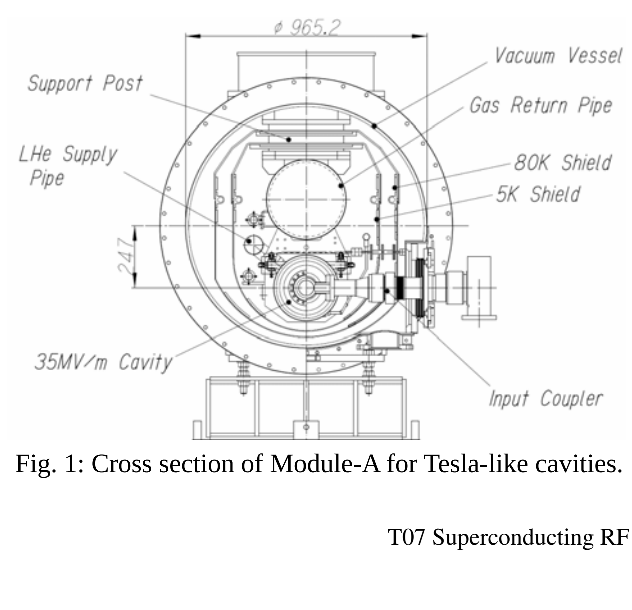

Fig. 1: Cross section of Module-A for Tesla-like cavities.

#norihito.ohuchi@kek.jp

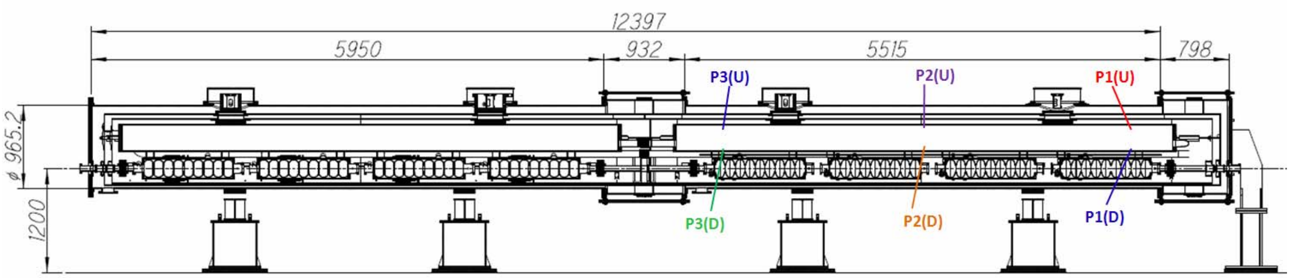

Fig. 2: Cross sectional view of STF cryomodules (Module-B in the left side and Module-A in the right side).

COLD TEST RESULTS

Cool-down and Warm-up of Cryomodule

The cold tests of Modules A and B were separately performed. Module A with one cavity was cold-tested at first, and after this test, Module B with one cavity and Module A with four cavities were tested. In the test of Module-A with four cavities, warm couplers were not assembled. This installation is scheduled after this test, and the Module-A will be cooled again from July 2008.

Fig. 3 shows the cool-down of the Module-A with four cavities, which was performed from 20 to 26 May 2008. In the first two days, four cavities and the GRP were cooled to 200 K by helium gas at 90 K. The cooling process was stopped at night. The total mass flow rate was 1.0 g/s, and the typical cooling speed of the cavities was 7.3 K/h. After this cooling stage, liquid helium at 4 K was directly transferred from the liquid helium dewar of 2000 L on the ground level to the cryomodule in the tunnel [6]. For cooling the four cavities down to 4 K, liquid helium of 1630 L was consumed. In the cooling process, the cooling speed of cavities was 12.5 K/h. The total time for cooling four cavities from room temperature to 4K was 49 hours.

Fig. 4 shows the warm-up process of four cavities. In the first two days, the cold mass was warmed up by the heat load from room temperature. In the following two days, helium gas at room temperature was circulated at 1.0 g/s for warming the cold mass up to 180 K. From 180 K to room temperature, nitrogen gas at room temperature was blown at 9.2 g/s through the cold mass.

Temperature distribution of the GRP was measured in order to estimate the distortion of this pipe by thermal contraction during the cooling and warming processes. Six locations of the temperature sensors are shown in Fig. 2, and the sensors were attached on the upper and lower surfaces of the GRP, designated by U and D, respectively. The measured results are shown in Figs. 5 and 6. The gas flowed through the GRP from P3 to P1, and then the temperature difference between the upper and lower surfaces at P3 reached to 79.4 K and 42.5 K in the cooling and warming processes, respectively. The distortion of the GRP was measured by five wire position sensors, and the data will be reported after the analysis.

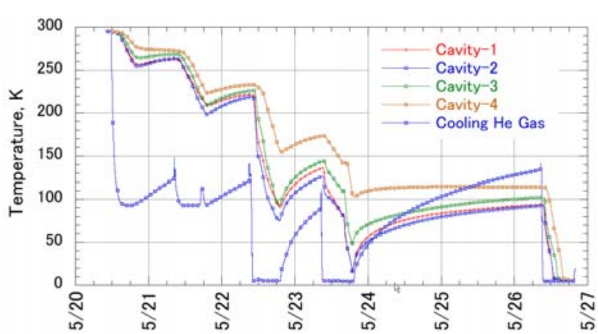

Fig. 3: Cool-down of Module-A with four cavities.

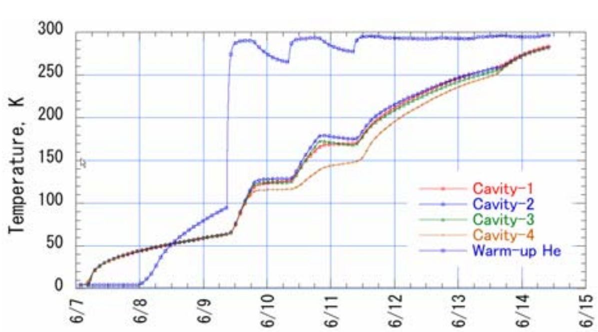

Fig.4: Warm-up of Module-A with four cavities.

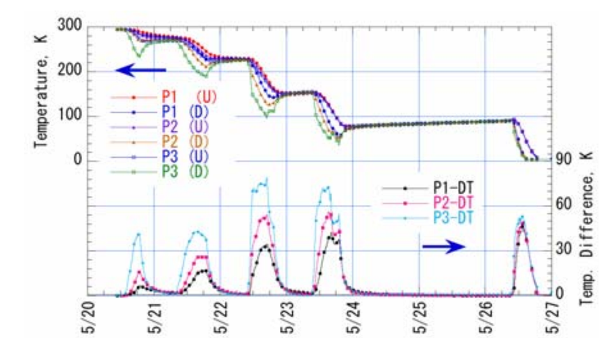

Fig. 5: Temperature profile of GRP during cool-down.

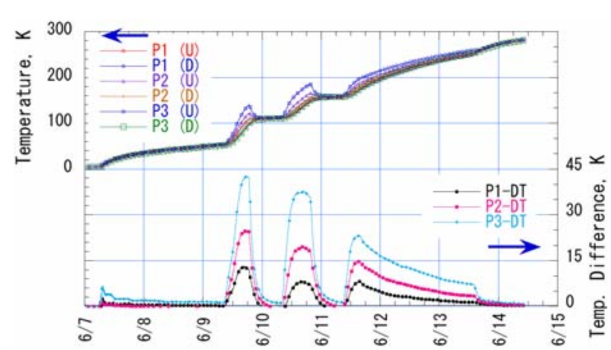

Fig. 6: Temperature profile of GRP during warm-up.

Heat Load Measurements at 2K

In Table 2, the thermal conditions during the measurement are listed. 5K shield temperatures were measured at 13 and 12 locations for Module-A and Module-B, respectively, and for 80K shields, temperatures at 12 and 8 locations were measured. The values for shield are averages of these temperatures. Temperatures of the support post, the beam pipe and the input coupler were measured at the locations of the thermal anchors at 5K and 80K. The static heat loads of the cryomodules were measured by evaporation of liquid helium at 2K. The evaporation rate was measured by the mass flow rate of helium gas at room temperature. The measured rate included those by the heat loads of the 2K cold box and the cryogenic transfer tube. Latent heat of saturated liquid helium at the measured pressure was calculated by HEPAK [7]. The calculated latent heat at 2.71 kPa was 23.08 J/g. In Table 3, the heat loads of the cryomodules are summarized. For Module-A with 4 cavities, the evaporation rate was 0.440 g/s and this rate corresponds to the heat load of 9.8 W. The heat loads of the 2K cold box and the cryogenic transfer tube were measured, and they are 1.0 W and 3.4 W, respectively. From these measured values, the heat load of Module-A with 4 cavities was calculated to be 5.4 W. The heat loads of Module-A and -B with one cavity were 1.2 W and 1.7 W. The heat sources to 2K are considered to be input couplers, beam pipes, cables and tuner. Therefore, their heat loads were recalculated with the measured temperature distribution. They are listed in Table 3.

Table 2: Thermal Conditions during Measurements

	Module-A 1 cavity	Module-B 1 cavity	Module-A 4 cavities
5K shield	4.6 K	5.5 K	5.5 K
80K shield	85.1 K	86.1 K	87.8 K
Support post at 5K anch.	4.7 K	5.3 K	5.3 K
Support post at 80K anch.	86.7 K	87.2 K	88.0 K
Beam pipe at 5K anch.	12.2 K	16.2 K	14.8 K
Beam pipe at 80K anch.	90.2 K	92.7 K	92.3 K
Input coupler at 5K anch.	7.23 K	21.9 K	16.1 K
Input coupler at 80K anch.	111.9 K	144.2 K	145.1 K
GRP in lower side	2.4 K	2.5 K	2.5 K
Helium pressure	2.71 kPa	2.71 kPa	2.73 kPa
Evaporation rate	0.244 g/s	0.265 g/s	0.440 g/s

Table 3: Heat Loads of Cryomodules at 2K

	Module-A 1 cavity	Module-B 1 cavity	Module-A 4 cavities
Measured heat load	5.6 W	6.1 W	9.8 W
2K cold box	1.0 W	1.0 W	1.0 W
Transfer tube	3.4 W	3.4 W	3.4 W
Cryomodule	**1.2 W**	**1.7 W**	**5.4 W**
Input couplers	0.13 W	0.23 W	1.4 W
Beam pipe	0.002W	0.01 W	0.003 W
RF cables	0.9 W	0.03 W	3.6 W
Signal cables	0.05 W	0.14 W	0.05 W
Tuner	0.12 W	NA	0.48 W

From these thermal analyses, the sums of the heat loads of components for Module-A are consistent with the measured heat loads by the evaporation rates, and the RF-cables without 5K anchors turned out to be the largest heat source. In the test of four cavities, 80K thermal anchors were not connected to input couplers because of the absence of warm couplers. Therefore, temperatures of input couplers were higher than the design, and the calculated heat load reached 1.4 W. The complete module test is scheduled from July 2008, and the heat load of the cryomodule will be measured again. For Module-B, the RF cables were thermal-anchored with the 5K shield, and then the heat load was calculated to be 0.03 W. The sum of the component heat loads can not be compared at present with the measured one for lack of heat load from the tuner system. Since temperature profile of the tuner system was measured, this thermal analysis will be done by the FEM.

CONCLUSION

(1) As the ILC-R&D activities, KEK has been constructing the STF and two 6 meter cryomodules have been developed.
(2) The two cryomodules with one cavity were assembled and cold-tested at 2K as the first R&D work. After these tests, the cryomodule with four Tesla-type cavities was reassembled and this cryomodule was successfully cooled down to 2K.
(3) From the thermal measurements, the contents of heat loads for the cryomodule of the Tesla-type cavities were defined and the thermal design of RF cables should be improved. For the cryomodule of low-loss cavities, the thermal analysis of tuner system is required for getting the consistency with the measured heat load.

REFERENCES

[1] K. Tsuchiya, et al., “Cryomodule Development for Superconducting RF Test Facility (STF) at KEK”, EPAC’06, Edinburgh, pp. 505-507.
[2] T. Semba, et al., “Manufacture and Assembly of the 6 Meter-Long Cryomodules for Superconducting RF Test Facility (STF) at KEK”, PAC’07, Albuquerque, pp. 2674-2676.
[3] C. Pagani, et al., “The TESLA Cryogenic Accelerator Modules”, TESLA Report 2001-36.
[4] E. Kako, et al., “Cryomodule Tests of the STF Baseline 9-cell Cavities at KEK”, MOPP131, this conference.
[5] T. Saeki, et al., “The First Measurement of Low-Loss 9-cell Cavity in a Cryomodule at STF”, MOPP029, this conference.
[6] S. Kaneda, et al., “First Test Results of ILC/STF Cryogenic System at KEK”, MOPD014, this conference.
[7] HEPAK is a computer program for calculating the thermo-physical properties of helium of CRYODATA. INC.