RECENT ACTIVITIES IN ILC R&D AT HITACHI

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Abstract

We participated in the construction of STF (Superconducting RF Test Facility) cryomodule at KEK and conducted several feasibility studies. The cryostats are found to be reliable for this study. This paper describes our recent activities for the ILC.

INTRODUCTION

The manufacturing of the accelerator equipments such as magnets, vacuum and RF apparatus have become increasingly popular in last 50 years for Hitachi Ltd.

Hitachi makes significant contribution in promoting fundamental science by introducing new technologies all around the world. Hitachi will participate in constructing the International Linear Collider (ILC), which is believed to be one of the most important schemes in advancing elementary particle physics.

The high energy accelerator research organization known as KEK located at Ibaraki in Japan has made concrete measures to start the Superconducting RF Test Facility cryomodule (refer to Tsuchiya et al. [1]). The cryomodule is one of the most essential parts in the ILC. Hitachi intends to utilize its superconducting technology to contribute to the construction of this cryomodule.

This paper describes Hitachi's research and development activities for the ILC.

MANUFACTURE OF STF CRYOMODULE

Hitachi has manufactured cryostat components at its factories and conducted assembly of all these equipments (refer to Semba et al. [2]). The STF cryomodule consists of two cryostats, each of them about 6 meters long (see Figure 1).

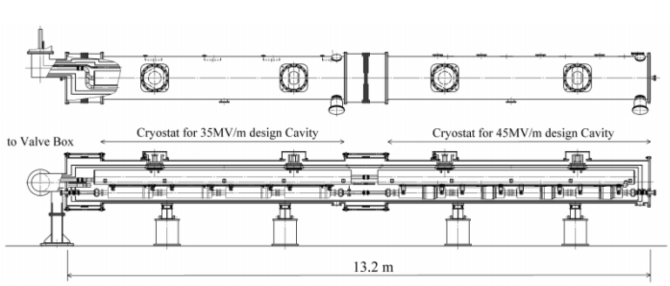


Figure 1 Overview of the STF Cryomodule

Figure 2 shows the cross-section of the STF cryostat. The structure of the vacuum vessel, the helium pipe, the support post and the radiation shields are designed based on the TESLA Test Facility (TTF) type III cryomodule (refer to Pagani et al. [3]). The cavity unit, the helium vessel, the input power coupler and the cavity tuning device (not shown in the Figure) are designed by KEK.

Major specifications of STF cryostat are shown in Table1.

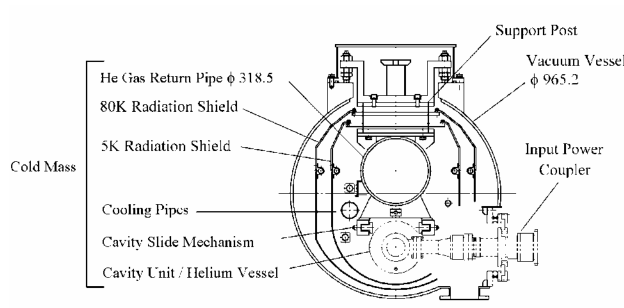


Figure 2 Cross section of STF Cryostat

Table 1 Major Specifications of STF Cryostat

Cryostat's length	5.6m, 5.9m
Cooling Method	Saturated Helium
Cooling Temp.	2K
Vacuum Vessel	Carbon Steel Pipe
Helium Gas Return Pipe	SS316L Pipe
Radiation Shield	Aluminum Dual Shield (5K, 80K)
Support Post	GFRP cylinder hollow with thermal anchoring
Cavity Units	35MV/m for Baseline Cavity 45MV/m for LL Cavity

One of the cryostats contains a structure called the baseline cavity unit. The other cryostat has the Low-Loss (LL) cavity unit. The Outer diameter of vacuum vessels for each of the cryostats is 965.2 mm and 12 mm in thickness.

The helium gas return pipe (GRP, made of SS316L) with a diameter of 318.5 mm is placed slightly above the center of the cryostat (see Figure 2). The GRP is the backbone structure that specifies the overall position of the cold mass inside the cryostat. The vertical deflection of the GRP in supporting the cavity is less than 0.05 mm.

The cylindrical heat insulating structure called the support posts are manufactured with Glass Fiber Reinforced Plastics (GFRP). It has the same specifications as those used in TTF.

Two radiation shields (5K and 80K) are placed in between the cavity unit and the vacuum vessel. The baseline cavity unit is manufactured by Mitsubishi Heavy Industries (refer to Sennyu et al. [4]), whereas the LL cavity unit is developed by KEK. Each of these items was assembled in the STF linac building of KEK.

Figure 3 shows the components and assembly of the STF cryostat.

(a) Components of Cryostat (b) Assembly of Cryostat
Figure 3 Components and Assembly of STF Cryostat

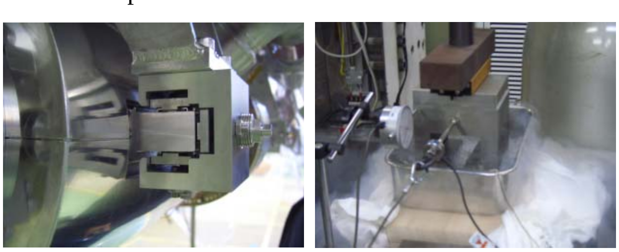
The assembly accuracy of the cold mass equipments must be less than 2 mm in the beam axis and 0.1 mm in the vertical axis, and these criteria had been achieved. The cold mass is inserted into the vacuum vessel, and the cryostats are finally assembled to complete one cryomodule. Figure 4 shows the final assembly of STF cryomodule.

(a) Transfer to underground tunnel (b) Completed Cryomodule
Figure 4 Final assembly of STF Cryomodule

EVALUATION TESTS FOR COMPONENTS

The overall reliability of the cryomodule needs to be investigated since it is operated under the low temperature (2K as indicated in Table 1).

We carried out a test to validate the slide mechanism of the cavity unit by applying the load, whose weight is equivalent with the weight of the cavity unit, at ordinary and LN2 temperature.



(a) Cavity Slide Mechanism (b) Load sliding test in LN2
Figure 5 Load Test of Cavity Slide Mechanism

The dynamic friction of this slide mechanism was 0.01-0.02, despite the low temperature. This is small enough in order to keep the cavity unit at the normal position.

The slide mechanism and actual load test are shown in Figure 5.

To validate the performance of the support post of the cryomodule, the displacement and the strain, in vertical and horizontal directions, were measured when the load was applied to the support post. The modulus of longitudinal elasticity was calculated, and it agreed well with the typical value of the GFRP (20GPa).

To further verify the performance of the support post, the above test was repeated with twice the usual load applied to it. There was no abnormality in the mechanical characteristics of this device after this test was carried out. Therefore, the support post of this type was strong enough to sustain the cold mass. The actual testing of the support post is shown in Figure 6.

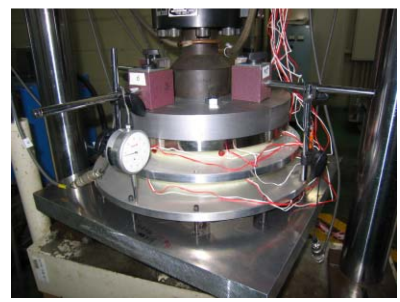
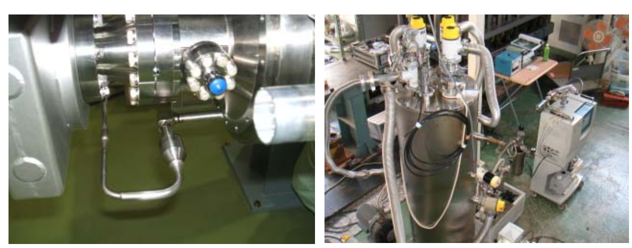


Figure 6 Loading Test of Support Post

The material of the jacket, of the baseline cavity unit, is titanium (refer to Figure 7). There is a titanium and stainless steel joint in between the jacket and the helium piping. This transition joint is made by Hot Isostatic Pressing (HIP) method. The leakage of helium gas at the stainless / titanium joint under the low temperature (2K) was investigated. This has been tested for all transition joints, and the helium leakage was not detected.



(a) Transition joint (b) Helium leakage test
Figure 7 Helium leakage test of transition joint at 2K

ASSEMBLY OF A CAVITY UNIT

The high-gradient Low-Loss (LL) type cavity unit, which is still under development in KEK, was assembled on a trial basis. The LL type 9-cell cavity unit, a ball-screw-type tuner and other parts were prepared by KEK. There are niobium / stainless steel transition joints at the end parts of the cavity. Since the material of the jacket of the LL cavity unit is stainless steel, welding of the unit (TIG welding) with other stainless steel apparatus can be performed under normal atmosphere. The welding of helium jacket and the insertion of the cavity unit is shown in Figure 8.

A series of tests have already been done on the cavity unit according to the work of Saeki et al [4].

(a) Welding of Helium Jacket (b) Cavity Insertion to Jacket
Figure 8 Assembly of a Cavity Unit

INTEGRATION WITH CRYO-SYSTEM

The cryogenic system for the STF was constructed by KEK in collaborations with other companies (refer to Yoshida et al. [6]). This system supplies 2.0 K superfluid helium into the RF cavities in the STF cryomodule.

The cooling pipes of the STF cryostat are made assuming their diameters of the attachment in the real ILC machine. The diameters and the lengths of the pre-cooling pipes are adjusted to suit their attachment with the STF cavity units (see pre-cooling line in Figure 9). This makes it possible to keep the balance of the helium flow to each cavity in the STF cryogenic system.

A feasibility study is currently in progress using four baseline cavity units. (refer to Ohuchi et al. [7]). Helium flow diagram for four baseline cavities is shown in Figure 9.

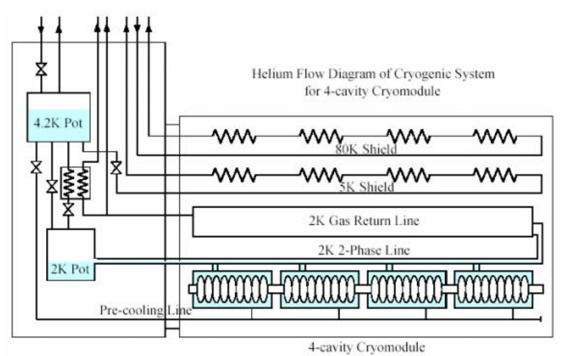


Figure 9 Helium Flow Diagram of STF Cryomodule

CONCLUSION

Hitachi manufactured a STF cryostat for the ILC research and development purposes. The product has been investigated in terms of reliability and proved to be reliable for its function under the low temperature. Hitachi intends to proceed to the next stage of the cryomodule design with the reflection of these results.

ACKNOWLEDGMENTS

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