

FIRST TEST RESULTS OF ILC/STF CRYOGENIC SYSTEM AT KEK

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Abstract

The STF (Superconducting RF Test Facility) cryogenic system, of which capacity is 30W at 2K, has been constructed and commissioned for testing STF cryomodule for ILC (International Linear Collider). In the first operation phase, the STF cryogenic system was successfully cooled down to maintain a superconducting RF cavity at the working temperature of 2K. Presented in this session will be the results of the first operation of the cryogenic system and the future collaboration plan among KEK (High Energy Accelerator Research Organization) and Japanese cryogenic industrial members.

In addition, another test facility for testing all sorts of 2K-cryogenic components, which is now under construction, will be also mentioned.

INTRODUCTION

The STF cryogenic study team consisting of KEK and some Japanese cryogenic industrial members was organized in 2004, and started the conceptual design of STF cryogenic system with the cooling capacity of 30W at 2K. Since then, numbers of regular meeting have been held among the above mentioned members, and the test stand with the dummy cryostat which simulates the heat load of the cryomodule has been discussed and designed. With the test stand, we are aiming to develop the elemental technology related to 2K-cryogenic components such as high-efficient heat exchangers, evacuation unit, transfer line, cryogenic valves, cold compressors and so on. [1]

In parallel, the STF 2K cryogenic system to cool down the superconducting RF cavities in the cryomodule has also been designed and manufactured. [2], [3] And finally we could cool down the superconducting RF cavities with the STF cryogenic system successfully.

STF CRYOGENIC SYSTEM

The STF 2K cryogenic system is designed to enable various testing of STF cryomodule which is installed in the underground tunnel. It provides 2K superfluid helium for RF cavities, 4K liquid helium for cool-down and 5K thermal shield, and liquid nitrogen for 80K thermal shield to the cryomodule. The plant capacity is as shown in Table.1.

The system consists of a helium refrigerator, a liquid helium vessel, evacuation units, a gas bag, etc. which are installed on the ground, 2K cold box and STF cryomodule

installed under the ground, and the high performance transfer line in between. (see Table.2)

Table 1: Plant capacity of STF cryogenic system

Supply temp. [K]	Refrigerant	Refrigeration capacity [W]	Mass flow [g/s]
2.0	He II	30	1.5
4.5	LHe	60	3.0
80	LN2	250	1.3

Figure 1 shows the schematic flow diagram of STF cryogenic system. At first the liquid helium produced by the existing helium liquefier TCF200 is stored in the liquid helium vessel of 2000L, then supplied to the 4.2K pot in the 2K cold box underground through the multi-channel transfer line developed by KEK which features advanced structure and outstanding thermal performance. [4] In the 2K cold box, a counterflow gas-liquid helium heat exchanger with copper fin-tubes is equipped which has been developed by KEK over the last few years. This heat exchanger has good features in terms of minimal pressure drop (vapour side) and a small temperature difference between helium and copper, which enable to get the lowest temperature at the outlet of heat exchanger with a given evacuation unit (LHe side).

So the liquid helium in the 4.2K pot is further cooled down in the heat exchanger by return low pressure helium gas in counter flow, and is expanded by the J-T valve to generate the saturated liquid and gas of superfluid helium in the 2K pot.

Table 2: Outline specifications of STF cryogenic system

Item	Specification	Remarks
Helium Refrigerator	Ref. capacity: 600W at 4.4K Liq. capacity: 260L/h	TCF200 (Sulzer)
LHe vessel	Capacity: 2000L	0.12MPa, 4.4K
Evacuation units	MBP + RP (4 sets in parallel)	Less than 3.1kPa
2K cold box	comprises 4.2K pot, 2K pot, heat exchanger, J-T valve, 5K & 80K shield, etc.	
Transfer line	High performance Multi-channel type	150A, ~35m

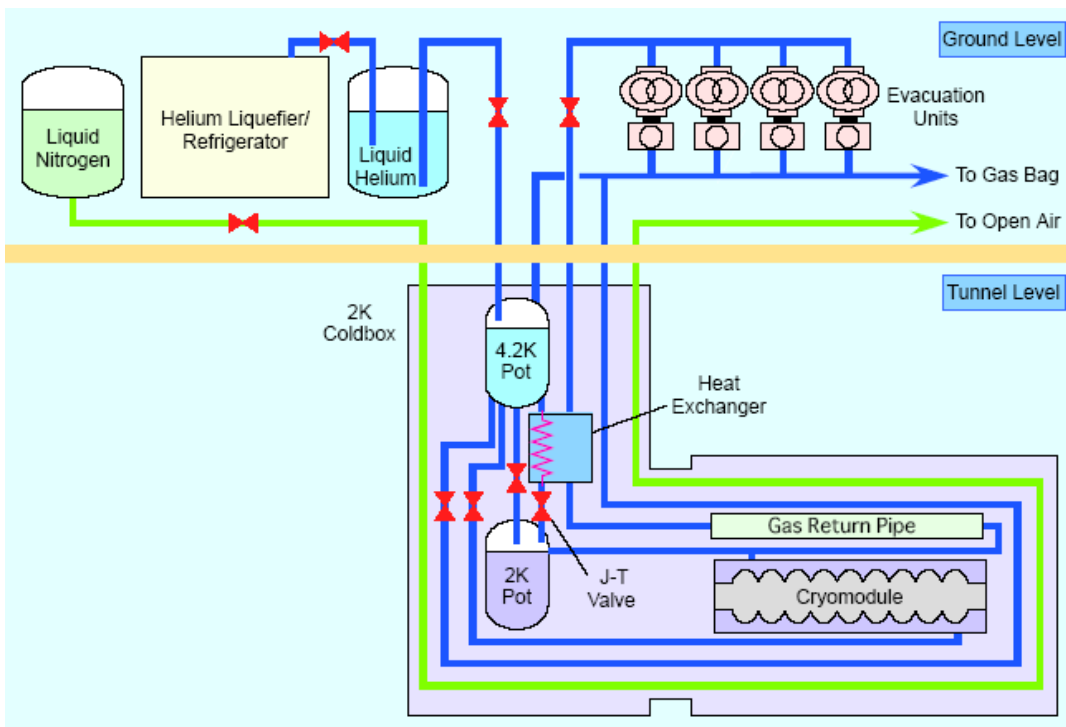


Figure 1: Schematic flow diagram of STF cryogenic system.

The 2K cold box is horizontally connected with the cavity cooling channel of STF cryomodule, which is evacuated down to approx. 3.1kPa (23 torr) by the evacuation unit consisting of 4 sets of mechanical booster pumps and rotary pumps in parallel. The pumping speed of the evacuation unit is automatically controlled by the mass flow of evacuating helium gas.

As the 2K cold box is designed so that the liquid level of superfluid helium in the cryomodule is equal to the one in the 2K pot in the 2K cold box, the liquid level of superfluid helium is automatically controlled by the J-T valve so as to keep it constant.

STF CRYOMODULE

A STF cryomodule contains eight superconducting RF cavities which are divided into two groups. Four of them are higher-gradient low-loss cavities developed by KEK (see figure 2), and the others are TESLA design cavities fabricated by the Japanese industry. In short, four low-loss cavities and four TESLA-like cavities are installed in a half-sized cryomodule respectively and integrated together by welding in tunnel afterwards.

In the first operation of this test, a TESLA-like RF cavity installed in the cryomodule has been cooled down to evaluate the heat load to the cryomodule. Then a low-loss RF cavity in the cryomodule has also been cooled down and tested subsequently. (The test results are described below.) Now four TESLA-like cavities in the half-sized cryomodule are being tested, and then eight cavities in the cryomodule shall be tested finally.

RESULT OF FIRST OPERATION

The cryomodule had been connected to the 2K cold box of STF cryogenic system last year (see figure 3) and commissioned since then. In the first operation phase, a TESLA-like cavity and/or a low-loss cavity in the cryomodule has been cooled down to 2.0K successfully. Figure 4 shows the first cool-down curve of low-loss cavity in the cryomodule.

From room temperature to ~100K, 80K helium gas cooled by the liquid nitrogen was supplied from the He Gas Circulation System. And later on, liquid helium was supplied directly from 100K to the steady state.

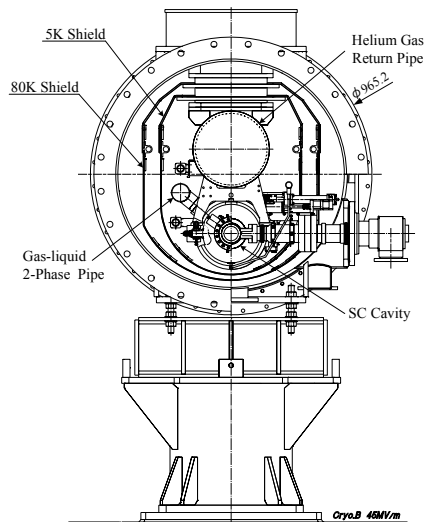


Figure 2: Cross-section of low-loss STF cryomodule.

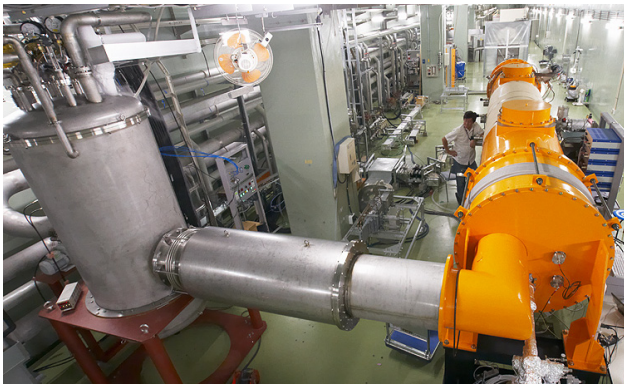


Figure 3: 2K Cold box and cryomodule.

As the heat capacities of GRP (Gas Return Pipe) and 5K shield were rather large, it took a long time to cool down the cryomodule to the steady state. As shown in the figure 4, the required cooling time was approximately 5 days, while it took 1 week to warm up to the room temperature.

Due to some restriction at the site, the operation had to be stopped during the nighttime and helium supply was suspended, so the cool down of the plant was made only in daytime intermittently. That is why the lines in the figures are jagged. (On the contrary, 80K shield temperature was stable since the liquid nitrogen was supplied even during the nighttime.)

In the steady state, the liquid level of saturated superfluid helium, which was a matter of our concern, was well controlled at the middle of supply helium piping from the 2K cold box to the cryomodule of which inner diameter was 72.1mm.

The static heat load to the STF cryogenic system was confirmed to be approx. 6W. According to our investigation about the breakdown of them, we think the heat inleaks from the GRP and vacuum barrier make up a considerable portion of them.

And the maximum heat load which was tolerable to the system was also confirmed to be approx. 35W by using the dummy heater at 2K pot. Therefore we confirmed eight cavities in the cryomodule could be tested with this system as originally planned, since the heat load to a cavity is estimated to be 1W/cavity.

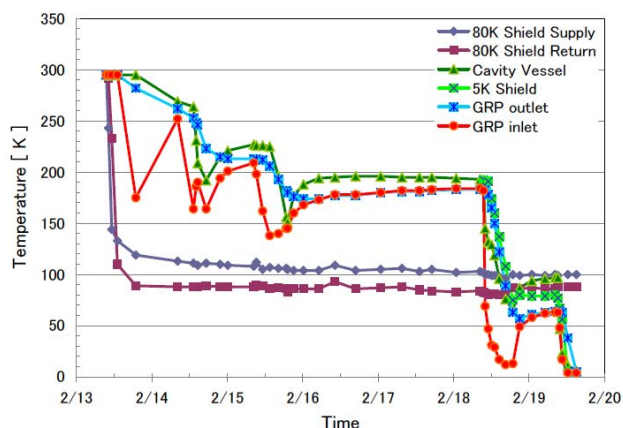


Figure 4: Cool-down curve of a low-loss cavity.

In addition, concerning the heat exchanger in the 2K cold box, we confirmed it functioned properly and adequately.

TEST STAND

Figure 5 shows the schematic flow diagram of test stand for testing all sorts of 2K-cryogenic components such as heat exchangers, J-T valve, 2K transfer line, cold compressor and so on. The main difference between the test stand and the STF cryogenic system is that the test stand has the dummy 2K cold box with the heater connected with the 4K cold box horizontally, while the STF cryogenic system has the vertical arrangement of 2K pot and 4.2K pot. The test stand has almost been manufactured and will be ready for testing soon.

We, the STF cryogenic study team will continue to develop the most efficient and reliable 2K cryogenic system with such test facilities under the leadership of KEK in the future.

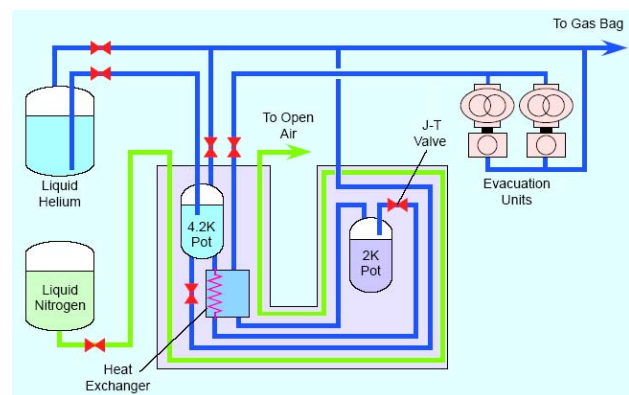


Figure 5: Schematic flow diagram of test stand.

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