# CONSTRUCTION AND 2K COOLING TEST OF HORIZONTAL TEST CRYOSTAT AT KEK*

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*Abstract*

A horizontal test cryostat was designed and constructed at AR-East building at KEK. Main purposes of test stand are improvement of module assembly technique and effective development of module components. The horizontal test cryostat has a cold box, and 80K Nitrogen and 2K and 5K He are supplied. An SRF cavity mounted a He jacket is installed into the cryostat and cooled down to 2K by using a He pumping system. 2K cooldown tests of the cryostat were successfully carried out. High power test will be realized in a future.

## INTRODUCTION

In accelerators, SRF (Superconducting RF) cavities are installed into cryomodules and operated for beam acceleration. Horizontal test cryostats have simplified structure of cryomodules and are used for development of SRF technologies [1, 2]. Main targets are, for example, improvement of string assembly of SRF cavities and development of cryomodule components.

In KEK, a horizontal test cryostat was designed and constructed in AR-East building. Its size is big enough to realize performance tests of 9-cell L-band SRF cavity with full assembly condition, including input couplers, HOM dampers / couplers, frequency tunes, gate valves and so on.

In the following, details of design and construction of the horizontal test cryostat is described and results of the cooling tests are shown.

## HORIZONTAL TEST CRYOSTAT

Figure 1: (left) Installed horizontal test cryostat. (right) Inside cold box.

Left of Figure 1 shows the horizontal test cryostat, which is constructed inside concrete shields for radiation safety. Size of a vacuum chamber is 1m diameter and 3m length. An SRF cavity is prepared on the table and installed into the cryostat. Right of Figure 1 shows inside a cold box, which is located on the top part of the cryostat. Not only an L-band 9-cell cavity, other cavities can be also tested by preparing adequate attachment. There are several flanges on both side of the cryostat to access inside. Components, such as input couplers and frequency tuners, can be installed and tested.

Figure 2 shows conceptual view of the horizontal test cryostat. There are 2 K He lines, 5 K He lines and 80 K $N_2$ lines. A 4 K He pod, prepared inside the cold box, feed 4 K He to pre-cooling line and 5 K He supply line, and 2 K He to 2 K He supply line through a J-T valve. A He pumping system evacuates the 2 K line. Inside the vacuum chamber and cold box is covered with 80 K shields, which are cooled by liquid $N_2$.

The table to support a SRF cavity is shown in left of Figure 1. This table has a pipe inside, in which liquid He is filled, and is cooled down to 4 K. It can also be used for 5 K thermal anchors to cool down cryomodule components. This table can slide on 80 K rails to be installed into the cryostat. Inside of 80 K rails are also pipes and liquid $N_2$ is filled. They can be used for 80 K thermal anchors.

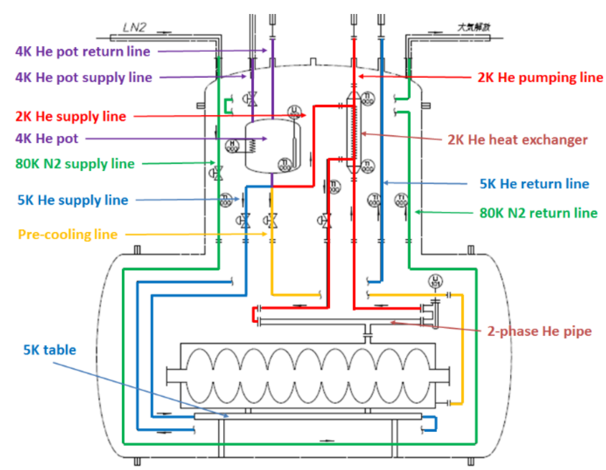


Figure 2: Conceptual view of the horizontal test cryostat.

## 2K COOLING TEST

An L-band 9-cell SRF cavity was installed into the cryostat and 2K cooling tests were carried out two times up to now.

Cooling tests took four days. Pre-cooling was done at first two days, and temperature reached to 80 – 100 K. Then, using next two days, 4 K He was transferred and pumped down to 2 K. Tests were only done during day time around 10 hours for each days. A cooling system had been stopped during night.

Liquid $N_2$ and liquid He were feed from dewars. Around 800 litter liquid $N_2$ and 2000 litter liquid He were used.

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## *Experimental System*

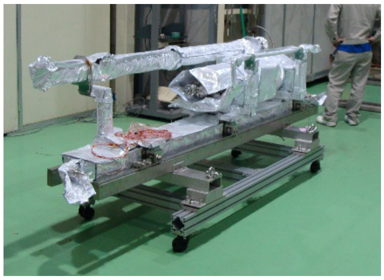

Figure 3: The L-band 9-cell cavity before installed into the cryostat. It has the He jacket and two phase He pipe.

The test cavity was mounted with a He jacket and a two phase He pipe, as shown in Figure 3. A He level meter was installed inside a 2 K pod, which was placed at end of the two phase pipe.

Left of Figure 4 shows a He gas recirculation system, which used for pre-cooling of the He lines. Circulating He gas exchanged heat with liquid $N_2$ and cooled the 2 K and 5 K He line down to 80 K. It was very effective to suppress consumption of liquid He.

Right of Figure 4 shows the He pumping system. It consists of three rotary pumps. It is used to cool down a cavity down to less than 2 K.

To measure temperature at 80 K and 5K / 2K lines, T-type (Cu-constantan) thermocouples and Si diode sensors are used, respectively.

Figure 4: (left) He gas recirculation system. (right) He pumping system.

## *Cooling of 80 K Line*

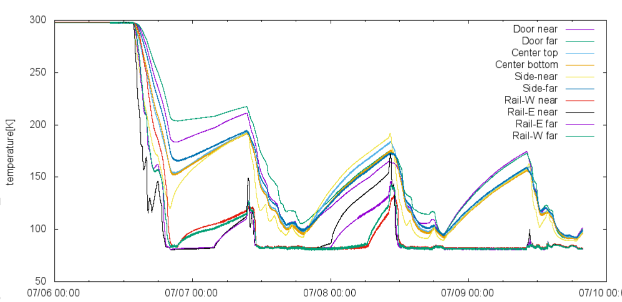


Figure 5: History of 80 K line temperatures. Six and four sensors monitor temperature of 80 K shields and 80 K rails, respectively.

80 K lines are one-pass line and cool 80 K shields and 80 K rails. Total of 10 sensors are monitored. Four sensors are set on 80 K rails and other six are set on shields. Figure 5 shows History of 80 K lines during four days' operation.

After filling with liquid $N_2$, 80 K rails became liquid $N_2$ temperature and kept even during night. 80 K shields were cooled down to ~100 K during operation.

## *Cooling of 5 K Line*

5 K line consists from the pre-cooling line and the 5 K He supply line, which mainly cools the 5 K table. These two lines are controlled by different valves. Figure 6 shows History of 5 K lines during four days' operation.

As mentioned before, these lines were pre-cooled by using the He gas circulation system. Temperature reached to around 100 K after two days pre-cooling. The 5 K line could be quickly cooled down to 4 K after filling liquid He.

At the first cooling test, He transfer to the 4 K pod was difficult due to thermal oscillation. Details are described later.

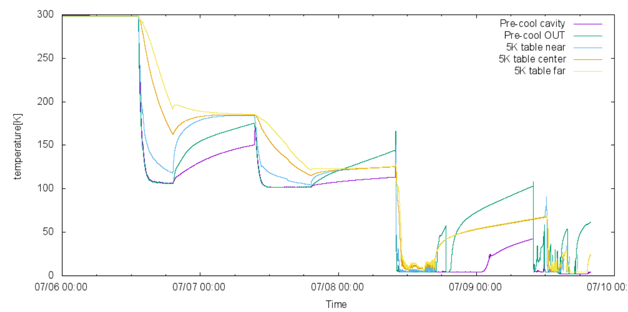


Figure 6: History of 5 K line temperatures. Two and three sensors monitor temperature of pre-cooling lines and 5 K table.

## *Cooling of 2 K Line*

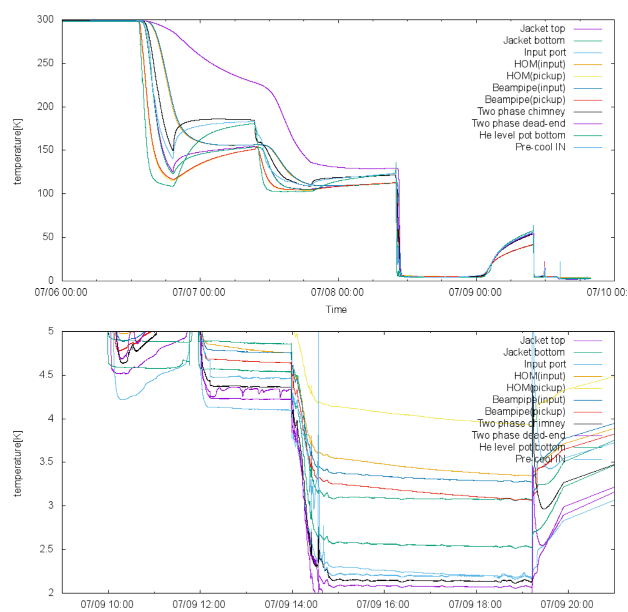


Figure 7: (Top) History of 2 K line temperature for four days. (Bottom) Enlargement for 2 K operation. Total of 12 sensors monitor temperature of the He jacket and surrounding components.



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2 K line is the line to cool the SRF cavity to 2 K. Total of 12 sensors monitor temperature of components such as He jacket, beampipes, HOM couplers, the two-phase pipe and the 2 K He level pot.

Figure 7 show history of 2 K line. The top figure shows temperature during four days' operation and the bottom figure is enlargement during 2 K operation. Again, first two days the 2 K line was pre-cooled down to ~100 K by using the He gas circulation system.

The 2 K line was also easily cooled down to 4 K after filled by liquid He. Furthermore, the 2 K line was pumped out by the He pumping system, which consists of three rotary pumps. The SRF cavity was successfully cooled down to 2 K. As shown in bottom of Figure 6, temperature around the He jacket became close to 2 K and beamline components, which were cooled by thermal transfer, became 3 ~ 3.5 K.

Temperature of 2 K line is controlled by two valves. One is for 2 K He pumping line and another one is the J-T valve for supplying 2 K He. Measured pressure of the 2 K line is shown in Figure 8. The pressure was 3.0 +/- 0.1 kPa, which corresponds to 1.99 +/- 0.01 K. Stability was good enough.

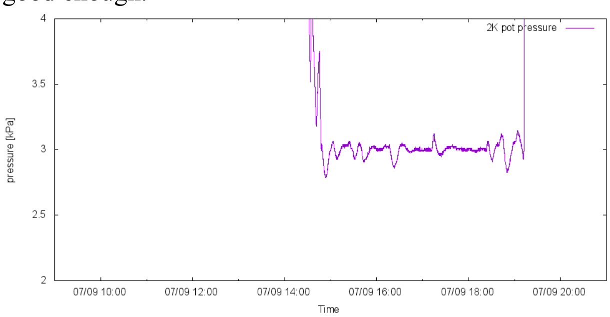


Figure 8: Pressure at the 2 K line during 2 K operation.

### *Thermal Oscillation*

At the first cooling test, it was little bit difficult to store liquid He to the 4 K pod. The reason was that thermal oscillation occurred between the 4 K pod and room temperature part of the return line from the pod. Frequency of thermal oscillation was several Hz. Figure 9 shows vibration of pressure of the 4 K line.

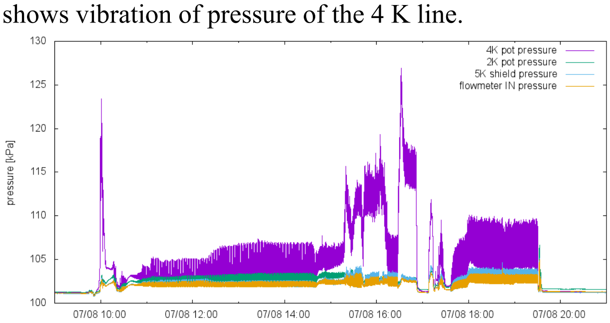


Figure 9: Pressure vibration observed during He transfer to the 4 K pod. Purple shows the one for the 4 K pod.

Left of Figure 10 shows the return pipe from the 4 K pod which became white with frost due to thermal oscillation.

After the first test, as shown in right of Figure 10, the position of valve was changed to be close to the cold box, where the return pipe was thermal insulated. It avoids the situation that the cold return gas touch to room temperature parts.

At the second cooling test, thermal oscillation disappeared.

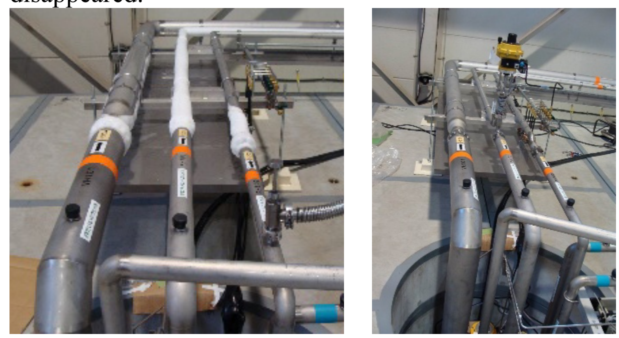

Figure 10 (left) Due to thermal oscillation, pipe became white with frost. (right) After first cooling test, position of a valve was changed to avoid thermal oscillation.

### *Comments on Static Loss*

Static loss is important issue related to amount of He consumption. We tried to estimate static loss. Even precise measurement could not be carried out at moment, it seems that static loss is not large and around 3~4 W or less from rough estimation. Precise measurement of static loss, using a heater for calibration, is planned near future.

## FUTURE PLAN

One of the main aim of the horizontal test cryostat is development of string assembly technique. Procedure against radiation safety issue is on-going now. High power tests will be realized very near future.

## SUMMARY

The horizontal test cryostat was designed and constructed in AR-East building at KEK. Cooldown tests to 2 K were successfully carried out. He components were pre-cooled to 80 K by using liquid $N_2$. Cooling down to 4 K using liquid He and pumping down to 2 K were also successful. Thermal oscillation occurred at the first test between the 4 K pod and room temperature part. It is cured by changing the position of the valve. First high power test will be performed very near future.

## REFERENCES

[1] P. Clay *et al.*, "Cryogenic and electrical test cryostat for instrumented superconductive RF cavities (Chechia)", *Advances in Cryogenic Engineering,* 41, p. 905, 1996.

[2] J. Knobloch *et al.*, "HoBiCaT - A Test Facility for Superconducting RF System", in *Proc. SRF'03*, Luebeck/Travemuender, Germany, Sep. 2003, p. 173.




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