RAON SUPERCONDUCTING RADIO FREQUENCY TEST FACILITY CONSTRUCTION*

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Abstract

Superconducting Radio Frequency (SRF) test facility for RAON is under construction process. It consists of cryogenic system, clean room for cavity process and assembles vertical test, horizontal test, and the radiation shield. The cryoplant has 330 W (4.5 K equivalent) which supplies 4.5K supercritical helium to the cavity test and cryomodule test bench. Clean rooms are for cavity process and assemble whose class is from 10 to 10000. The layout for the vertical and horizontal test bench is shown and the radiation shield for the test bench is shown to reduce X-ray coming from cavity. To estimate the thickness of concrete, radiation simulation is performed.

INTRODUCTION

Properties of superfluid fog were studied [1-3]. Size effect of thermal radiation [4, 5] and the effective temperature for non-uniform temperature distribution were investigated [6, 7]. Thermal analysis was studied for cryogenic system design [8]. To accomplish Rare Isotope Science Project, the construction of superconducting radio frequency test facility is important.

In this report, we show schematic design of Superconducting Radio Frequency (SRF) test facility, which includes cryoplant, clean room for cavity process and assembles, vertical test bench, horizontal test bench, and radiation shield to protect X-ray coming from the test.

SRF TEST FACILITY

Superconducting Radio Frequency (SRF) test facility for RAON is under construction process. The SRF test facility consists of cryogenic system, clean room for cavity process and assembles vertical test bench, and horizontal test bench. Fig. 1 shows the layout of SRF test facility. The remodelling area for the facility is 1482 m^2 and most of utilities such as air compressor, process cooling water, deionized (DI) water system, and transformer will be reused. The total electric power to run the facility is about 2500 kW. Clean room includes buffered chemical polishing (BCP), high pressure rinsing (HPR), high vacuum furnace, cavity assemble place, etc. Cryogenic system consists of cold box, dewar, compressors, pumps, oil removal system, distribution line, etc. The power of cryoplant is 330 W (4.5 K equivalent), which supplies 4.5 K supercritical helium to cavity and cryomodule test bench. The supercritical helium of 4.5 K is supplied to cryostat, and the cavity test can be performed at 2 K while the liquid helium is being pumped to cool down.

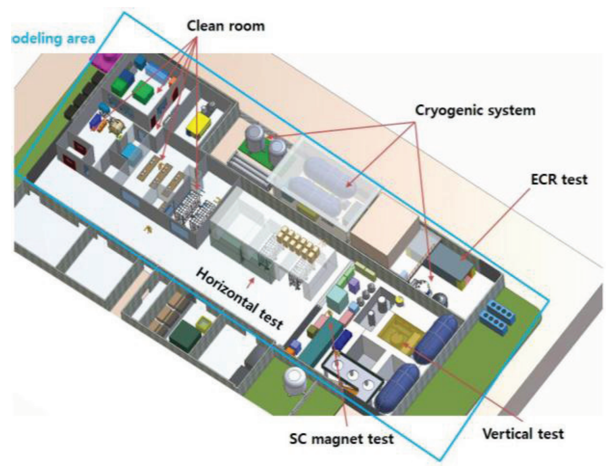

Figure 1: Layout of SRF test facility.

Cryogenic System

Fig.1 shows the layout for cryogenic system. Cryogenic system consists of cold box, liquid helium dewar, compressors, pumps, oil removal system, distribution line, and helium gas bag. Two cryoplants having 330 W and 200 W are used in order to supply liquid helium for

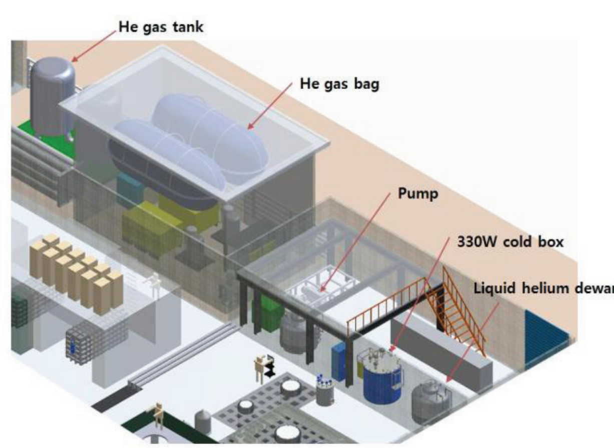

Figure 2: Layout for cryogenic system.

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low temperature test. 330 W cryoplant has the liquefaction rate of 140 l/h, supplies the helium gas of 80K, the supercritical helium of 4.5 K, and the liquid helium of 4.2 K. The operation temperatures for QWR, HWR1, HWR2, SSR1, SSR2 are 4.2 K, 2.1 K, 2.1 K, 2.1 K, and 2.1 K, respectively. So, the test temperature range for cavity and cryomodule is from 2 K to 4.5 K.

Cleanroom

Fig. 3 represents the schematic layout of clean room. Equipment of clean room is eddy-current testing (ECT), buffered chemical polishing (BCP), high pressure rinsing (HPR), high vacuum furnace, microscope, ultrasonic cleaning, scrubber, deionized (DI) water supplier, and robot arms. The clean room class is from 10 to 10000, operating at 22 °C and 30 %. The mixed acid, $HF:HNO_3:H_3PO_4$ (1:1:2) is used for BCP. Vacuum furnace has the ultimate pressure of ~10^{-8} torr, operating vacuum of ~10^{-5} torr at 600 °C and ~10^{-6} torr at 100 °C, with the maximum temperature of 1400 °C and the temperature uniformity of ± 5 °C. The capacity of DI water supplier is 2000 l/hr and the resistivity of water is 18 M$\Omega \cdot$cm. Ducts are used in heating, ventilation, and air conditioning to deliver as well as remove air. The floor of clean room is installed about 60 cm above the bottom of the building to make a duct system. The floor of crymodule assembly room is strongly supported since the weight of the crymodule can be over 10 ton.

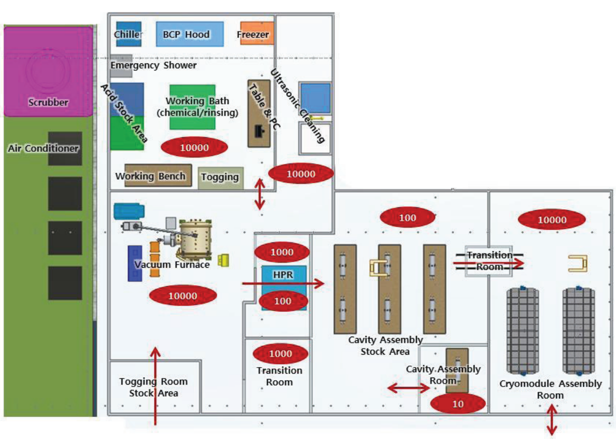

Figure 3: Layout of clean room.

Vertical Test

Two cryostats are used for vertical test. The diameters of cryostats are 80 cm and 120 cm, respectively. Fig. 4 represents the schematic design for vertical test. The thickness of concrete is 70 cm. Vertical test includes resonance frequency, Q_o vs. E_{acc} excitation curve, and residual resistance measurement. Liquid nitrogen and 4.5 K supercritical helium can be supplied to the cryostats. Liquid nitrogen is used to precool the cryostat for around 15 hours. And then, the supercritical helium of 4.5 K is supplied to fill the cryostat. We can pump the cryostat to cool down from 4.5 K to 2 K [8]. One of the cryostates can be fully tested while the sliding door protects the X-ray coming from the cavity.

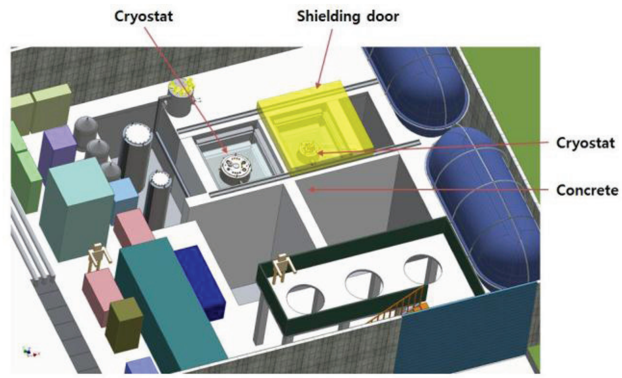

Figure 4: Schematic design for vertical test.

Horizontal Test

The cryomodule consists of QWR, HWR1, HWR2, SSR1, and SSR2, which are tested at horizontal test bench. Fig. 5 represents the schematic design for horizontal test. One-sliding door and 70 cm thick concrete will be used to protect X-ray radiation. Three horizontal test benches will be used. 4.5 K supercritical helium is supplied to the cryomodule and rf power is applied to cavities in the cryomodule.

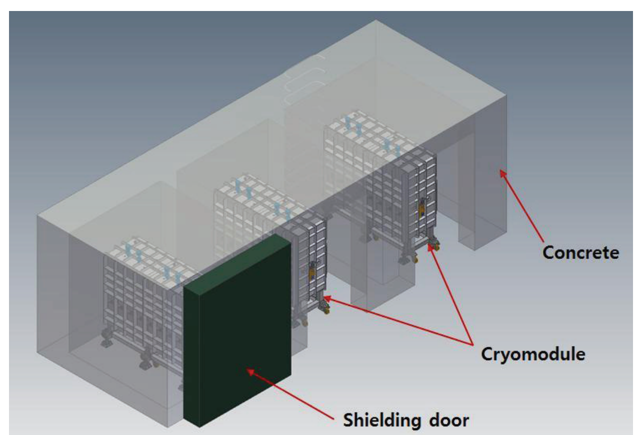

Figure 5: Schematic design for horizontal test.

Radiation Simulation

The cavity has surface roughness from fabrication imperfection, which causes field emission under rf power. The skin depth is around 40 nm in Nb cavity. Field emission is not effective for the surface roughness lower than the skin depth. The electric field is inversely proportional to the radius of curvature. Electron can mainly be emitted through field emission due to the focused electric field on the surface roughness. The temperature of emitted surface area is increased when electrons are emitted due to strong electric field, which causes field as well as thermionic emission. Generalized electron emission coming from field and thermionic emission was investigated [9]. The emitted electrons are accelerated and then hit the Nb cavity wall, which generates photon radiation. So, it is important to reduce

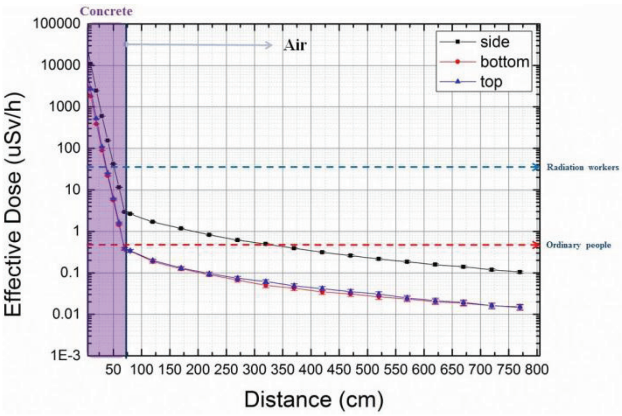

Figure 6: Effective dose vs. distance for vertical test.

the surface roughness of Nb cavity by using polishing techniques such as BCP and electropolishing (EP). We assumed electrons having 2 MeV and 60 W are incident on the surface of Nb cavity to estimate X-ray radiation. Effective dose is obtained by radiation simulation using Monte Carlo N-Particle Transport Code (MCNPX) for vertical test. Fig. 6 shows the effective dose as a function of distance for vertical test. Effective dose level for radiation workers and ordinary people are shown in Fig. 6. The thickness of concrete is 70 cm which is enough to protect ordinary people when the operation time is 3.2 h/day in our vertical test.

CONCLUSION

We have shown the schematic design of Superconducting Radio Frequency (SRF) test facility, which includes cryogenic system, clean room for cavity process and assembles, vertical test bench, horizontal test bench, and radiation shield to protect X-ray coming from the cavity. Cryogenic system consisted of cold box, liquid helium dewar, compressors, pumps, oil removal system, distribution line, and helium gas bag. The clean room class was from 10 to 10000, operating at 22 ^{o}C and 30 %. Equipment of clean room was ECT, BCP, HPR, high vacuum furnace, microscope, ultrasonic cleaning, scrubber, DI water supplier, and robot arms. Layout for vertical and horizontal test bench was shown and radiation shield for the test bench was shown to protect X-ray coming from cavity. To estimate the thickness of concrete, radiation simulation was performed for vertical test.

ACKNOWLEDGMENT

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