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QWR AND HWR CRYOMODULES FOR HEAVY ION ACCELERATOR RAON *

W.K. Kim, M.K. Lee, Y. K. Kim, G. T. Park, H.J. Cha, H.J. Kim, H. Kim#
Rare Isotope Science Project, Institute for Basic Science, Daejeon 305-811, Republic of Korea

Abstract

The accelerator called RAON has five kinds of cryomodules such as QWR, HWR1, HWR2, SSR1 and SSR2. The QWR and HWR1 cryomodules are designed and fabricated. The cryomodules will be operated at 2 K and 4 K in order to operate the superconducting cavities. The static heat load of the system was analytically computed for each configuration. The functional requirement of the cryomodules and the static heat load measurement of the QWR and HWR1 cryomodules are presented in this research.

INTRODUCTION

The accelerator called RAON which accelerates beam to 200 MeV/u has five kinds of cryomodules such as QWR, HWR1, HWR2, SSR1 and SSR2. The cryomodule of QWR and HWR1 cryomodules are designed and fabricated. The cryomodules will be operated with liquid helium of 2 K and 4 K in order to operate the superconducting cavities. Liquid helium above 2.172 K is normal fluid and liquid helium below 2.172 K is called superfluid. Superfluid properties of liquid helium are well-known and properties of superfluid fog were intensively investigated [1-4]. Blackbody radiation is changed due to size effect [5, 6]. The effective temperature for non-uniform temperature distribution was studied [7-9] and the thermal radiation from arbitrary fractional dimension was investigated [10]. The main role of the cryomodules is to minimize heat leak and heat generation, to supply cryogenic fluid and to align beam through superconducting cavities. The static heat load of the system was analytically computed for each configuration.

In this research, we show the fabrication design and static heat load measurement for QWR and HWR1 cryomodules.

CRYOMODULES

The cryomodule has Mu-metal magnetic shield to reduce earth's magnetic field by less than 10 mG. The crymododule consists of thermal shield of 40 K, intercepts and strong-back made of invar to align the cavity. The SCL11 section accelerates beam from 0.5 to 2.7 MeV/u. Table 1 shows the summary of SCL1 cryomodules for RAON. QWR cryomodule has one cavity, HWR1 has two cavities and HWR2 has four cavities. The length of QWR cryomodule is 450 mm, that of HWR1 cryomodule is 1,400 mm and that of HWR2 cryomodule is 2,720 mm. The SCL11 consists of 22 quarter wave resonators and SCL12 consists of 32 half wave resonators.

Table 1: Summary of SCL1 Cryomodules for RAON

SCL	Cavity	No. of cavity in CM	No. of CM	CM length (mm)
SCL11	QWR	1	22	450
SCL12	HWR	2	13	1,400
		4	19	2,720

Functional requirements of cryomodule are shown in Table 2. Cavity alignment is mainly changed by pumping chambers and cool-down process. Air pressure outside of cryomodule and thermal contraction due to cool-down process make alignment change. The alignment requirement is important for beam dynamics. Vacuum of cavity and chamber is required to reduce the heat load in cryomodule operation.

Table 2: Functional Requirements of Cryomodule

Note	Conditions	Requirement
Cavity alignment	X, Y	±0.25 mm
	Z	± 0.5 mm
	Tilt	± 0.1 °
Vacuum	Chamber	~10^{-5} torr
Vacuum	Cavity	~10^{-7} torr
System pressure rating	Reservoir 4.5 K pipe 40 K pipe	4 bar 20 bar 20 bar

EXPERIMENT

The main roles of cryomodules are to maintain operating condition of superconducting cavities and to keep alignment of beam line. High vacuum and thermal insulation are required for the cryomodules to maintain the operating temperature of superconducting cavities. A detailed conceptual design is performed to fabricate cryomodules. The stiffness of the strong back is designed sufficiently to make device alignment to remain within

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# kim_ht7@yahoo.com

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tolerance when all devices are installed. The static heat load on the support posts and strong back is included.

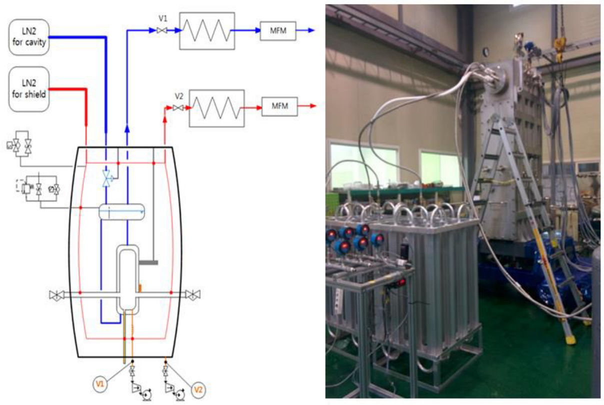

Figure 1: Experimental layout (left) and photograph (right) of QWR cryomodule test apparatus.

The main components of the cryomodule are dressed cavities, two phase pipe, power couplers which supply RF power to the cavities, tuners which control the operation of the cavities, and support systems which fix the cavities along the beam line. Since the operating temperature of the superconducting cavities for HWR cryomodules is 2 K, thermal shield of 70 K which is cooled by cold helium gas and thermal intercepts of 4.5 K are installed to minimize the thermal load.

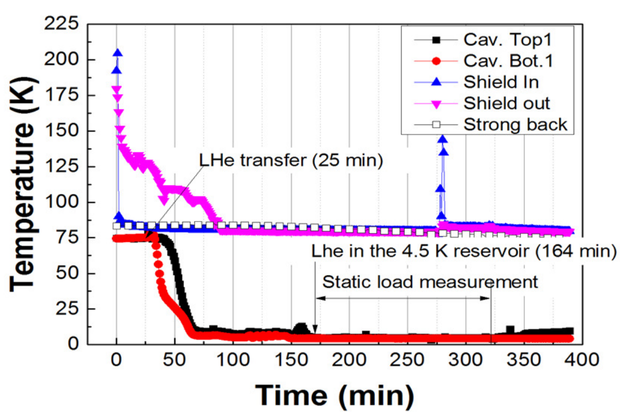

Figure 2: Cool-down with liquid nitrogen pre-cooling of QWR cryomodule.

Figure 1 shows the experimental layout and photograph of QWR cryomodule test apparatus. To cool down the QWR cryomodule for the first time, liquid nitrogen is supplied to thermal shield and cavity, separately. Fig. 2 shows the cool-down with liquid nitrogen pre-cooling of QWR cryomodule. Liquid helium is supplied to 4.5 K reservoir and cavity.

Figure 3 shows the liquid helium level as a function of time for QWR cryomodule. Static heat load is measured at 4. 2 K. The level of liquid helium is decreased while static heat load is measured. Fig. 4 shows the static heat load measurement of QWR cryomodule by evaporated mass flow rate. The static heat load for QWR cryomodule is 3.9 W.

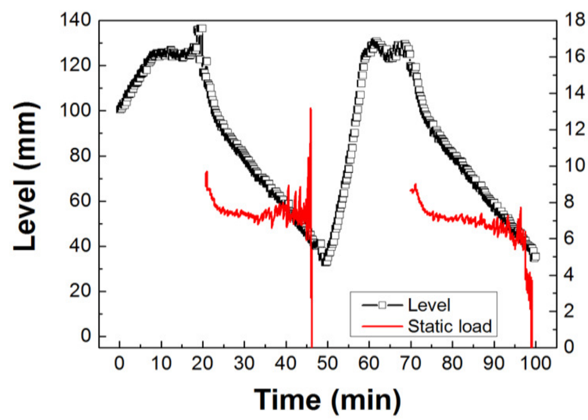

Figure 3: Liquid helium level is shown as a function of time for QWR cryomodule.

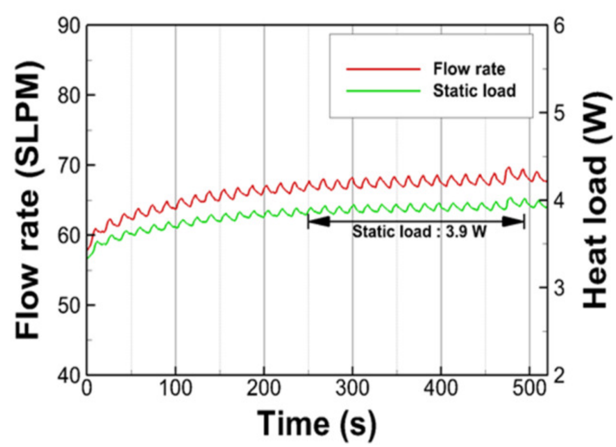

Figure 4: Static heat load measurement of QWR cryomodule by evaporated mass flow rate.

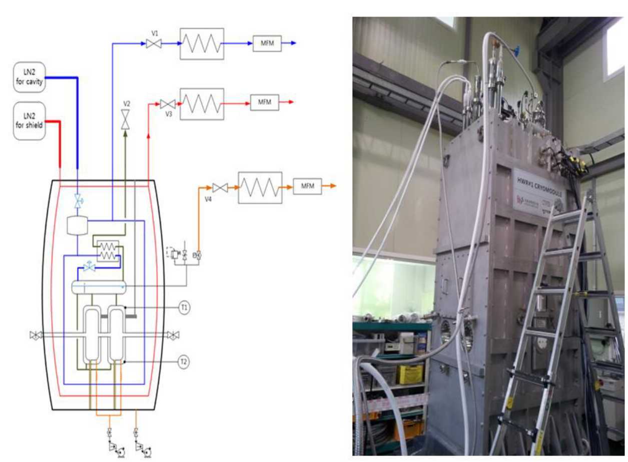

Figure 5: P&ID (left) and photograph (right) for HWR1 cryomodule test apparatus.

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Figure 5 shows the P&ID and photograph for HWR1 cryomodule test apparatus. To cool down the HWR 1 cryomodule in the beginning, liquid nitrogen is supplied to thermal shield and cavity, separately. Vacuum pressure for cavity and chamber was below 1×10^{-7} torr and 1×10^{-6} torr, respectively. Fig. 6 shows the static heat load measurement of HWR1 cryomodule by evaporated mass flow rate. The volume flow rate is decreased as time increases. The measured static heat loads for 2 K reservoir and 4.5 K reservoir with the liquid helium of 4.2 K are 4 W and 1 W, respectively.

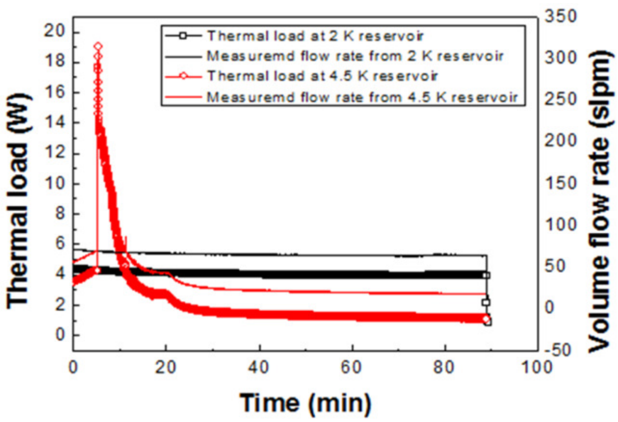

Figure 6: Static heat load measurement of HWR1 cryomodule by evaporated mass flow rate.

SUMMARY

We have fabricated and measured the static heat load for QWR and HWR cryomodules. The cryomodules was cool-down with liquid nitrogen in the beginning, and then liquid helium was supplied to helium reservoir and cavity after pre-cooling. The static heat load for QWR cryomodule was 3.9 W. The static heat load for HWR1 cryomodule was 4 W for 2 K reservoir and 1 W for 4.5 K reservoir.

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