5th International Particle Accelerator Conference IPAC2014, Dresden, Germany JACoW Publishing
ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-WEPRI036

FEBRICATION DESIGN OF QWR AND HWR CRYOMOUDLES *

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Abstract

The superconducting linac of RAON consists of five types of cryomodules. The cryomodules host QWR, HWR1, HWR2, SSR1, and SSR2 superconducting cavities, cryogenic pipe lines, magnetic shields and thermal shields. The cryomodules will be operated at 2K and 4.5K in order to test the performance of the superconducting cavities. The main components of the cryomodule are dressed superconducting cavities and two phase pipe, power couplers to supply RF power to the cavities, tuners to control the operation of the cavities, and support systems to fix the cavities along the beam line. The detailed fabrication design of the cryomodules will be presented in this paper.

INTRODUCTION

The Uranium ions produced in an electron cyclotron resonance ion source are pre-accelerated to an energy of 500 keV/u by a radio frequency quadrupole and transported to the superconducting cavities by a medium energy beam transport. The driver linac is divided into three different sections: low energy superconducting linac (SCL1), charge stripper section and high energy superconducting linac (SCL2). The SCL1 uses the two different families of superconducting resonators, quarter wave resonator (QWR) and half wave resonator (HWR). The SCL11 consists of 22 QWR's whose geometrical beta is 0.047. The resonance frequency of QWR is 81.25 MHz. The cryomodule of the SCL11 hosts one superconducting cavity. The SCL12 consists of 102 HWR's whose geometrical beta is 0.12. The resonance frequency of HWR is 162.5 MHz. This segment has the two families of cryomodules [1].

The linac has five types of cryomodules for four different kinds of cavities as shown in Table 1. The main roles of the cryomodule are maintaining operating condition of superconducting cavities and alignment of the cavities along the beam line. High level of vacuum and thermal insulation is required for the cryomodule to maintain the operating temperature of superconducting cavities. The design of the cryomodule components has been conducted based on the thermal and structural concerns. The cold mass including cavity string, coupler and tuner are installed on the strong-back and then inserted into the vacuum vessel with a thermal shield and Multilayer Insulation (MLI)

Table 1: Summary of Cryomodules for RAON

SCL	Cavity	No. of cavity in CM	No. of CM	CM length (mm)	1 period (mm)
SCL11/ SCL31	QWR	1	21	450	1130
SCL12/ SCL32	HWR	2	13	960	1800
		4	18	1840	2680
SCL21	SSR1	3	23	1682	2672
SCL22	SSR2	6	23	4220	5210

Both QWR and HWRs are vertically installed in the cryomodule. Since the operating temperature of the superconducting cavities are 4.5 K and the 40 K thermal shield which is cooled by cold helium gas and 40 K and 4.5 K thermal intercepts are installed to minimize the thermal load. The cold mass including cavity string, coupler and tuner is installed on the strong-back and then inserted into the vacuum vessel with thermal shield and MLI.

COMPONENT DESIGN

The design of the cryomodule components has been conducted based on the thermal and structural concerns. The thermal design starts from the estimation of the thermal loads that determines the required size of the components such as two phase pipes and other cryogenic pipes and so on. The uncertainty factor 1.5 is multiplied on the estimated thermal load value to design conservatively. The structural design is conducted based on the KS codes [2] on the pressure vessel design.

Design of QWR

Fig. 1 shows cross section of QWR cryomodule design. 22 Superconducting Radio-Frequency (SRF) cavities are housed in a total of 22 cryomodules (CMs) operating at 4.5K. Minimization of the total heat load is critical to machine performance since the refrigerator capacity is fixed. The total load of the cryomodules consists of the fixed static load and the dynamic heat load, which is proportional to the cavity performance. Temperature measurements taken allow a comparision between actural and predicted thermal performance of two components unique to this cryomodule design. The RAON linac employs cavities to accelerate the particle beam from am energy of 0.5 MeV up to 200MeV in a segment of tunnel approximately 5m in length [3]. Table 2 shows summary of linac lattice design for RAON. The deformation simulation of QWR cryomodule is shown in Fig. 2.

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* This work was supported by the Rare Isotope Science Project of Institute for Basic Science funded by the Ministry of Science, ICT and Future Planning (MSIP) and the National Research Foundation (NRF) of the Republic of Korea under Contract 2013M7A1A1075764.

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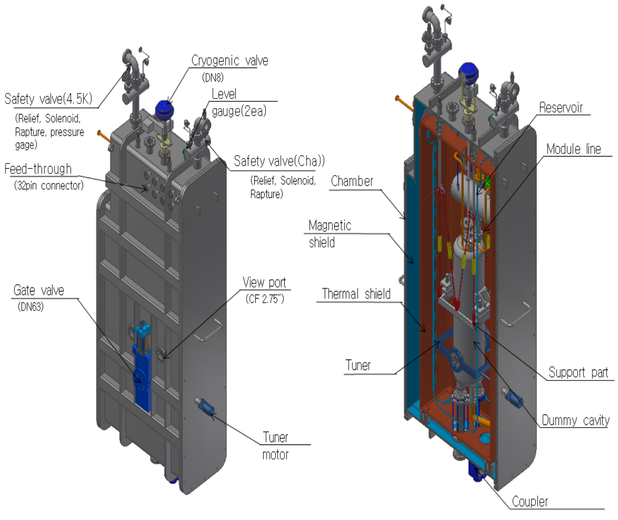

Figure 1: Cross section of QWR cryomodule design.

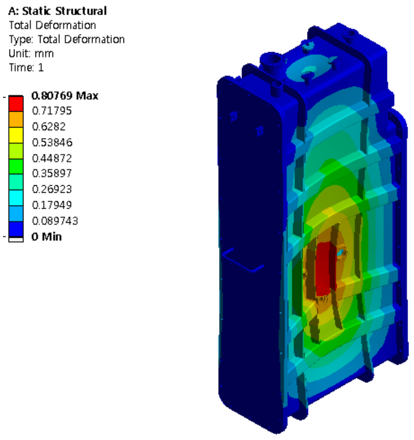

Figure 2: Deformation of QWR cryomodule design.

Table 2 : Summary of Linac Lattice Design for RAON

SCL	Cavity	beta	CM(included Gate Valve) (mm)	Section length (m)
SCL11/ SCL31	QWR	0.047	610	23.9
SCL12/ SCL32	HWR	0.12	1130	23.4
		0.12	2010	52.9
SCL21	SSR1	0.3	1852	61.5
SCL22	SSR2	0.51	4390	119.8

Design of HWR

The pressure relief devices such as rupture disk and re-seat relief valve is necessary. The worst heat ingress situation is caused by the loss of vacuum in the beam pipe and the heat flux at that case can be estimated 4 W/cm^2 [4]. The helium jacket and two phase pipe would be the most dangerous place of increasing pressure since there are large amount of liquid helium during the operation. Therefore, the rupture disk whose diameter is around 300 mm will be installed. Also, the small relief valves and the rupture disks are will be installed other pipe lines such as 40 K and 4.5 K pipes and vacuum vessel [5]. Fig. 3 shows cross section of HWR cryomodule design and the deformation simulation of HWR cryomodule is shown in Fig. 4.

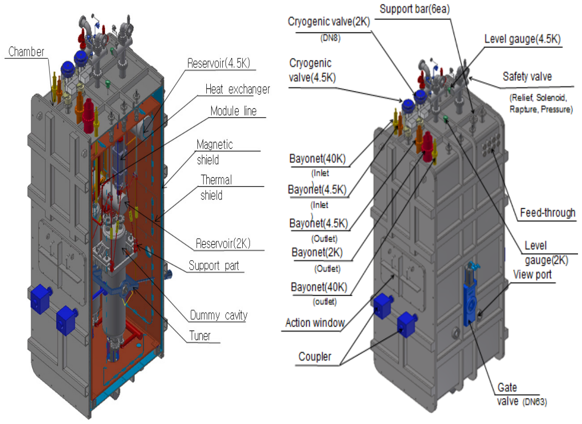

Figure 3: Cross section of HWR crymodule design.

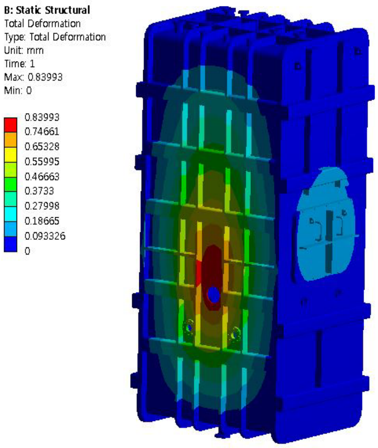

Figure 4: Deformation of HWR cryomodule design.

Multilayer Insulation

The insulation schematic reduces the radiation heat load to the cold surfaces, provides ample mass and heat capacity to mitigate thermal transients and is comprised of materials suitable for use in a high radiation environment. To prevent the potential of a magnetic component producing a remnant field after the solenoid is off, stringent degaussing procedures have been developed. The 2K and 4.5K shields require active cooling at 4.5K to achieve their maximum effectiveness, prior to cooling the resonator. The vacuum vessel is primarily composed of steel and attenuates the surrounding magnetic field.

Thermal Radiation Shield

The thermal radiation shield is a segmented construction which simplifies assembly and allows for differential contraction between the three alignments rails. The thermal shield is constructed from copper and cooled via a custom extrusion to distribute 40K helium. Fig. 5 shows Thermal shield of QWR and HWR cryomodule.

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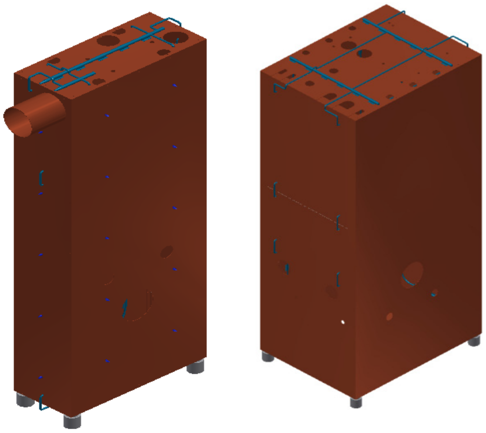

Figure 5: Thermal shield of QWR and HWR cryomodule.

Vacuum Vessel

The vacuum vessel is constructed primarily from STS316L. The primarily components are the bottom plate, the vacuum vessel lid, and the interfaces to the sealed beam line. Fig. 6 shows vacuum vessel of QWR and HWR cryomodule.

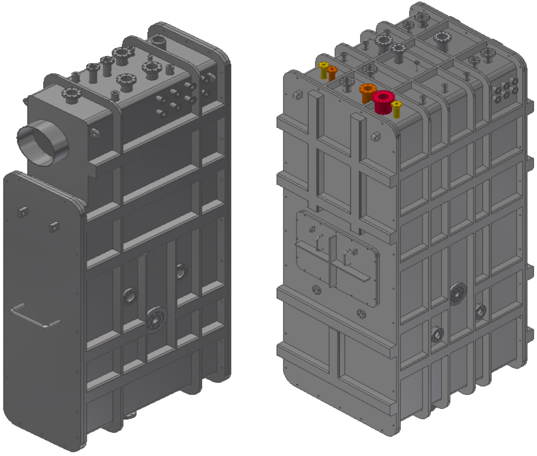

Figure 6: Vacuum vessel of QWR and HWR cryomodule.

Magnetic Shield

The magnetic shield is constructed primarily from Mu metal. Fig. 7 shows magnetic shield of QWR and HWR cryomodule.

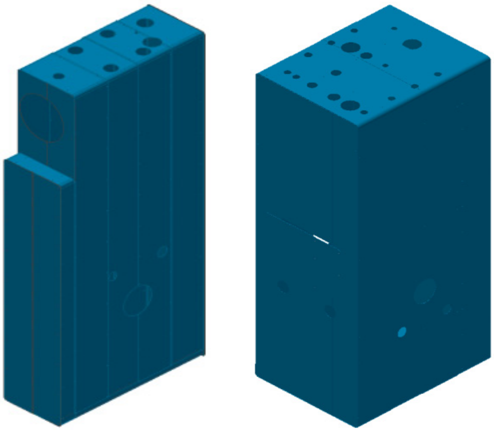

Figure 7: Magnetic shield of QWR and HWR cryomodule.

SUMMARY

RAON cryomodule continues to prepare for mass-production. Cryomodule designs are finalized. Next focus will be on building cryomodule prototypes to verify performance. RAON has been designing in RISP and their current status on the thermal design is presented. A first draft of 3 dimensional drawing for the cryomodules is on-going based on the design results presented in this paper.

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