FEBRICATION DESIGN OF QWR AND HWR CRYOMODULES *

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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 is installed on the strong-back and then inserted into the vacuum vessel with thermal shield and MLI.

<table>
<thead>
<tr>
<th>SCL</th>
<th>Cavity</th>
<th>No. of cavity in CM</th>
<th>No. of CM</th>
<th>CM length (mm)</th>
<th>1 period (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCL11/ SCL31</td>
<td>QWR</td>
<td>1</td>
<td>21</td>
<td>450</td>
<td>1130</td>
</tr>
<tr>
<td>SCL12/ SCL32</td>
<td>HWR</td>
<td>2</td>
<td>13</td>
<td>960</td>
<td>1800</td>
</tr>
<tr>
<td>SCL21</td>
<td>SSR1</td>
<td>3</td>
<td>18</td>
<td>1682</td>
<td>2672</td>
</tr>
<tr>
<td>SCL22</td>
<td>SSR2</td>
<td>6</td>
<td>23</td>
<td>4220</td>
<td>5210</td>
</tr>
</tbody>
</table>

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 comparison between actual and predicted thermal performance of two components unique to this cryomodule design. The RAON linac employs cavities to accelerate the particle beam from an 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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Table 1: Summary of Cryomodules for RAON

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Multilayer Insulation

The pressure relief devices such as rupture disk and reseat 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/cm² [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.

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.
**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.

**REFERENCES**