Heat Load and Cooling Configurations of the PEFP DTL

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1. Introduction

A 100 MeV proton linac is under development for Proton Engineering Frontier Project (PEFP) [1]. It consists of a 50 keV injector, 3 MeV RFQ and 100 MeV DTL. The accelerated proton beam can be extracted at 20 MeV and 100 MeV by using bending magnets. Therefore, the DTL for PEFP can be divided into two sections; one for 20 MeV DTL and the other is 100 MeV DTL. The 20 MeV DTL is composed of 4 tanks and driven by a single klystron. Duty factor of the 20 MeV section is 24%. To accelerate the beam from 20 MeV to 100 MeV, we use 7 tanks, which are driven by 7 independent RF sources. Duty factor of the 100 MeV section is reduced to 8%. From the viewpoint of the heat load, there are several differences between the 20 MeV section and 100 MeV section. First, as mentioned before, the duty factors are different. Second, the accelerating gradient is changed from 1.3 MV/m for 20 MeV section to 2.58 MV/m for 100 MeV section. Third, the types of the electroquadrupole magnets inside each drift tube are different. For the 20 MeV section, we used the pool type quadrupole magnets made of enamel wires due to the limited space. The hollow conductor type quadrupole magnets are used for 100 MeV section. The heat generations of each quadrupole magnet are 1.5 kW and 0.4 kW for 20 MeV section and 100 MeV section, respectively. Detailed heat load of DTL and the configuration of cooling loop are presented in this paper.

2. Heat Load of the DTL

From the electromagnetic simulation of the DTL structure, the peak copper loss can be found to be about 150 kW for 20 MeV section and 800 kW for 100 MeV section [2]. The reason for the increased loss for 100 MeV section is mainly due to the increased accelerating gradient. The reduced duty factor partially compensates the increased loss for 100 MeV section in the average loss point of view. The average copper loss for 20 MeV section and 100 MeV section is about 35 kW and 72 kW, respectively. We analyzed the copper loss which is distributed in each components of DTL such as tank wall, drift tube, stem, post coupler end plates and slug tuners. Figure 1 shows the copper loss distribution in the first tank of 20 MeV section (DTL21) and fig. 2 shows the same data for the first tank of 100 MeV section (DTL101). More than 40% of copper loss is generated in the tank wall and about 25% of loss is due to the drift tube region. About 15% of total copper loss is explained by loss in the stem region. The average wall power densities are 2.1 kW/m^2 and 3.2 kW/m^2 for 20 MeV section and 100 MeV section, respectively.

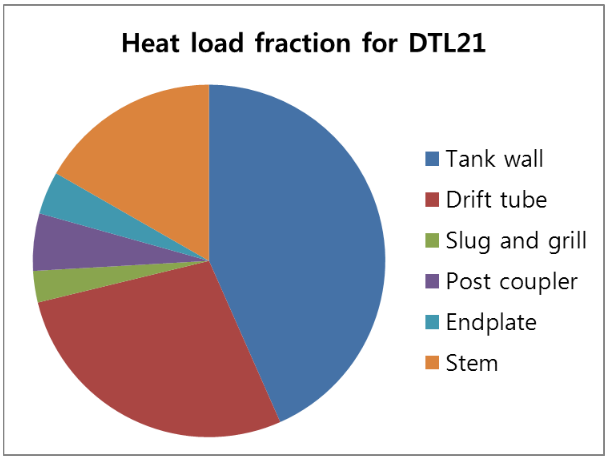

Fig. 1. Heat load distribution in DTL21.

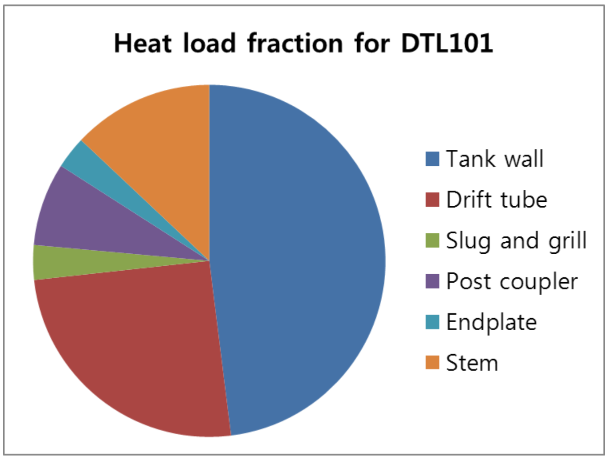

Fig. 2. Heat load distribution in DTL101.

The coolant for the DTL cooling is supplied in two separate ways. For the cooling of the tank wall, end plates, post couplers, slug tuner and vacuum grill, we use the constant temperature coolant supply from the conventional utility. For the heat removal of the drift tube including the stem and electroquadrupole magnets, we adapted a resonant control cooling system (RCCS). By changing the temperature of the RCCS water coolant, we can control the resonant frequency of the DTL tank. For the independent resonant frequency control of each tank, we use one RCCS for each DTL tank [3]. Figure 3 shows the heat load for each RCCS. The highest heat load of RCCS is about 92 kW for DTL21. This is because the DTL21 has more drift tubes as well as electroquadrupoles than any other tanks. The RCCS heat load for 100 MeV section is almost uniform and about 40 kW for each DTL tank.

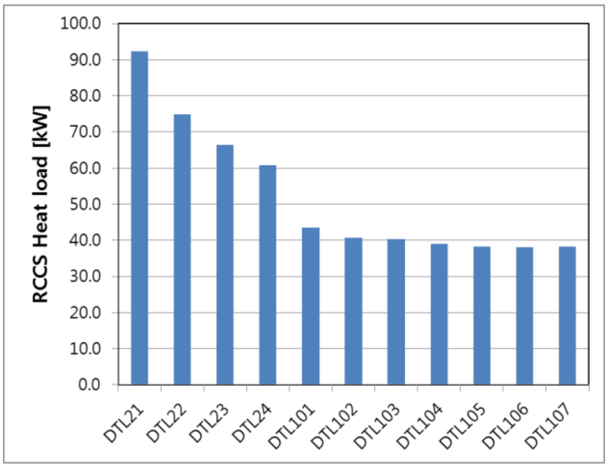

Fig. 3. RCCS heat load for each DTL tank.

3. Cooling Configurations

Considering the heat load of each DTL components and coolant temperature rise and pressure drop, we assign the cooling loop as shown in Table 1. With these configurations, the flow rate of the coolant in each loop is limited below 15 lpm and temperature rise is lower than 2 degree centigrade. Figure 4 and 5 shows the schematics of coolant flow configurations. For coolant flow control purpose, we are going to use constant flow valves in each drift tube cooling loop at return side.

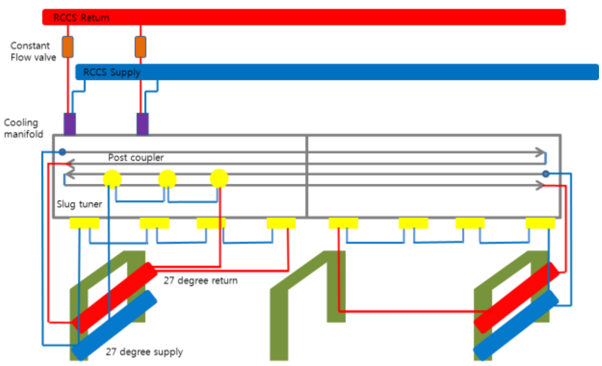

Fig. 4. Coolant flow schematics of 20 MeV section.

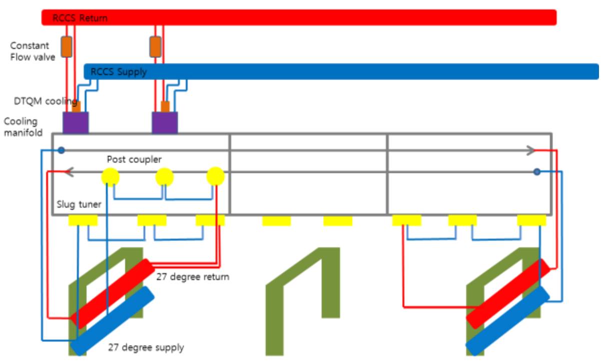

Fig. 5. Coolant flow schematics of 100 MeV section.

Main piping material is stainless steel, but flex hoses should be used to connect the main coolant pipe and each drift tubes for avoiding the vibration. Buna-N type flexible hoses are chosen due to the radiation damage resistance. Buna-N type flexible hoses have been used on the LANSCE 800 MeV particle accelerator at Los Alamos National Laboratory with good success. Even though those hoses on LANSCE CCL have been observed to harden over time by a combination of radiation and atmospheric damage, they have maintained working lifetimes of well over ten years [4].

4. Summary

The heat load on the PEFP DTL was analyzed and showed that most of the heat was generated at the tank wall and drift tubes. RCCS heat load of DTL21 is as large as 92 kW, however that of most tanks in 100 MeV section remains below 40 kW. Considering the heat load of each DTL components and coolant temperature rise and pressure drop, we assign the cooling loops with limiting the temperature rise and flow rate in acceptable ranges.

ACKNOWLEDGEMENTS

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