Design of a water based cooling system to take out electronics heat load of MUCH detector in CBM experiment

Vikas Jain*, J. Saini, S. Chattopadhyay and A. K. Dubey
Variable Energy Cyclotron Centre,1/AF Bidhan Nagar, Kolkata-700054, INDIA
** email: vikasjain@vecc.gov.in*

Introduction

A GEM based detector system is being developed at VECC, Kolkata for use as muon tracker in the Compressed Baryonic Matter (CBM) experiment at the upcoming FAIR facility in Germany [1][2]. The Muon Chambers (MUCH) consists of alternating layers of six absorbers and detector stations. Out of the six stations, VECC has taken responsibility to build the detectors and related readout electronics for the first two stations where each station consists of three detector layers. MUCH will be use a custom built self-triggering ASIC, which will provide both timing and energy information for each incoming signal in its channel. MUCH uses the sensitive electronics where the desired operating temperature range is 25-30 °C. Temperature going above these limits will drift the biasing scheme and further increase may lead to damage of Front End Electronics (FEE) board itself.

Cooling requirements

In MUCH, total number of FEE boards for the first two stations are 1440. Each FEE dissipates power of 2.52 W which makes total power dissipation of 3.62 KW from these two stations. The three layers of the station has to be positioned within the gap of 30cms along the Z-axis. In X-Y plane, the dimension of each layer is in a circle of 1 meter radius. The Electronics to be used for MUCH are wire-bonded and hence air-cooling may vibrate the bonds which may get damaged in the long run. Hence air cooling is not considered as a cooling solution for the MUCH system. We have designed a water-cooling system to remove this large amount of heat generated in the given space constraints. Water cooling is more efficient then air cooling but precaution has to be taken for the dew-point to avoid water droplets on the electronics.

Prototype cooling Setup

Fig.1 shows the experimental cooling setup. Here we have simulated the heat load generated by MUCH FEE board using the resistors. Heat load of 4 W per resistor takes care of safety margin required. General purpose water chiller unit for cooling the normal water was used as the heat load sink as shown in Fig.1. We have modified the water outlet and inlet positions and submersed the pump inside the cooling tank of water chiller unit to make it a close loop cooling system.

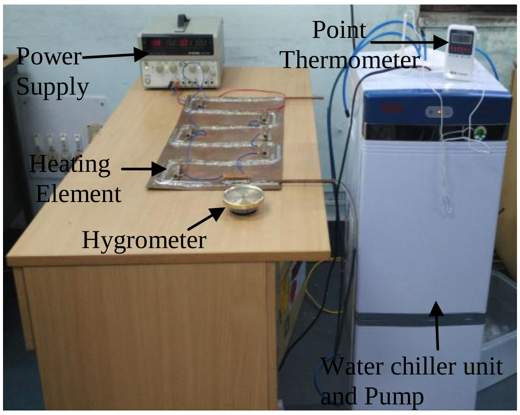

Fig. 1 FEE board cooling setup

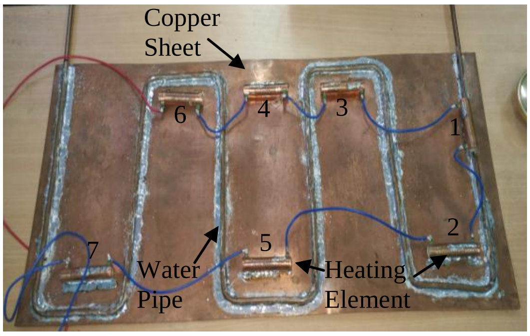

Fig. 2 FEE board position on copper sheet

In the present setup we have used 7-heating elements which are soldered on to the copper sheet and one of the heating elements is soldered on the top surface of the cooling pipe for the comparison of the cooling effect on the location of FEE placement. These heating elements along with the water cooling pipe of 6mm diameter are soldered on the copper plate of thickness 1mm at positions shown in Fig. 2.

Results

Initially we measured the environmental conditions, and for our setup, room temperature and Humidity was 26.5°C and 55%, respectively as controlled by room air conditioner. Later on at powered up, the setup and these 7-elements were dissipating total power of 28W in this system. We have recorded the temperature reading on all heating elements at the interval of 30 minutes. We have also recorded the copper sheet surface temperature in the same manner. Considering the thermal equilibrium in five hours, heating element temperature was found to be in the range of 36-40°C and the copper sheet was at 30.2°C without cooling. Fig. 3 shows plot of temperature of all heating elements v/s time.

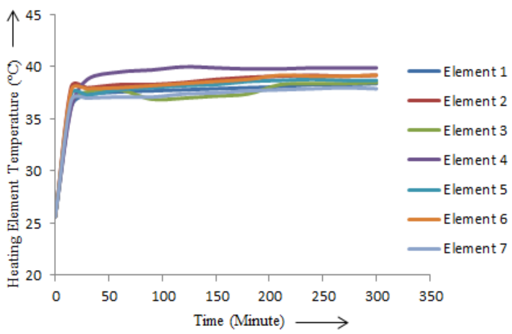

Fig.3 Before cooling heating element temperature v/s time

We then started the cooling with chilled water temperature at 16.0 °C with the flow rate of 15 liter/hour after the system reaches study state at 40 °C. Then we measured the heating element temperature every 30 minute. We also measured the inlet and outlet water temperatures to determine the heat load taken out by water flow. The temperature difference between the inlet and outlets was 2.1 °C and the heat power removed by the cooling was estimated to be 36.62 W. The temperature gradient along this cooling system was 127 Kelvin/meter. At steady state after 5 hours the surface temperature of all heating elements are between 28-30°C and the copper sheet temperature was 23°C. We also calculated the dew point of this cooling system and found that at 84% humidity was 25.43°C. Hence below this there, will be water droplet and this may damage the sensitive electronics. Fig.4 shows temperature v/s time for all the heating elements.

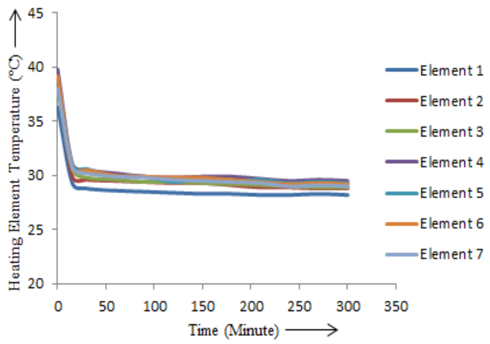

Fig.4 After cooling heating element temperature v/s time

Conclusion

The present setup of water cooling used here can be extended for the final heat removal requirements for MUCH like systems. Unlike air-cooling, water-cooling cools the devices directly rather than cooling the entire nearby environment, giving an advantage of power saving however at the same time it puts the constraints of maintaining the temperature below the dew point to avoid the damage due to water droplets.

References

[1] CBM Technical Design Report 2013 (TDR)
[2] A.K. Dubey, et. al, DAE Symp. On Nucl. Phys. vv, ppp (2010), Anna Kiseleva, P.P. Bhaduri, et.al. 85, 211-216 (2011).