Design and fabrication of a water based cooling system for the CBM Muon Chamber

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Introduction

Triple GEM detectors will be used to instrument the CBM (Compressed Baryonic Matter) muon chamber (MUCH) at the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany [1–3]. The CBM Muon Chambers consist of alternating layers of six absorbers and detector stations. For each full size GEM module 32 front-end electronic (FEE) boards are required. Each full size GEM module uses 32 front end electronics (FEE) boards to collect the signals from the detector. These boards are sensitive to temperature, the operating range being 25-30^{o}C. The heat dissipated by FEE boards is estimated to be $\sim$ 90 W per GEM module. This heat is to be continuously dissipated out to keep the ambient temperature within the desirable range. We have designed a water based cooling system to achieve this [4]. FEE boards are connected using a wire bond technique therefore air cooling is not suitable for this purpose. Using a small prototype as shown in Fig.1 we already tested and verified the proof-of-concept. This document describes in detail the building process of the cooling system and the results obtained from the laboratory tests.

Prototype Cooling Setup

A picture of the experimental setup is shown in FIG. 1. The heat load here is simulated by using seven power resistors as heating elements, each of 4 W heat dissipation (total dissipation 28 W). A bucket full of water with ice in it is used as the cold reservoir (heat sink). The pump is submersed inside the bucket. The heating elements are directly soldered to a copper board, which is the base-plate for this experiment as shown in the figure. Copper pipes of diameter 6 mm, used as cooling pipes, are also soldered directly on the board for better heat dissipation.

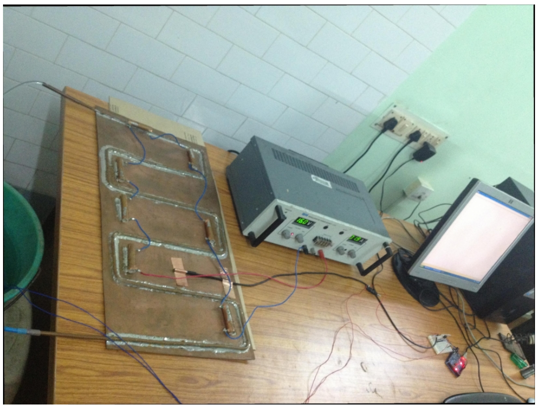

FIG. 1: Experimental set-up of the cooling system.

Working Principle

A microcontroller based control system, AVR microcontroller ATMEGA328p [5], is introduced here to keep the temperature of the base-plate at the desired level. A closed loop negative feedback PID system is used for the flow control mechanism [6]. The controller runs at 5 V external power supply and is supported by a 16 Mhz crystal oscillator. The temperature is sensed using the digital temperature sensor DS18B20, which interfaces with the microcontroller via the I^2C protocol. The Microcontroller board is connected

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via USB with a computer for various purposes such as (a) to programme the controller, (b) to monitor temperature and motor speed, and (c) also for debugging purposes [7]. A DC power supply of 16 V has been used to power the heating elements, which rises the temperature of the copper plate upto 38^{o}C without any cooling. The motor is powered by a 12 V, 1 A external power supply.

Results

The plate was heated and then the cooling system is turned on. Data are collected for various target temperature values (set points). The cooling system brings the temperature of the copper plate down to the desired temperature quite fast and efficiently. Initially five different set-points were taken and the corresponding data were recorded. Plot of such two typical set points are shown in FIG. 2 and FIG. 3.

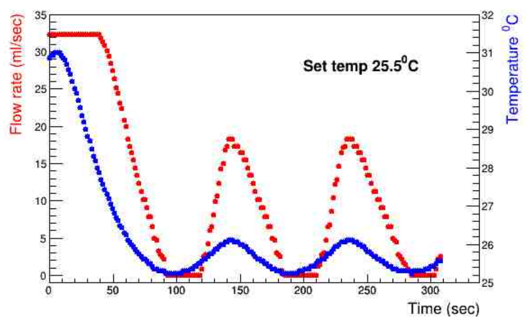

FIG. 2: Variation of temperature and flow rate with time.

From the first graph it is quite clear that the initial temperature was around $\sim 31^o$C, which, after turning the device on, went oscillating about the set point of 25.5^{o}C. On the second curve, the temperature oscillates around $\sim 30^o$C. The range of the oscillation can further be narrowed down by properly tuning the PID parameters used in the programming.

Future Plans

The Controlling algorithm can be improved for more robust control. From the current results we can see that the temperature varies

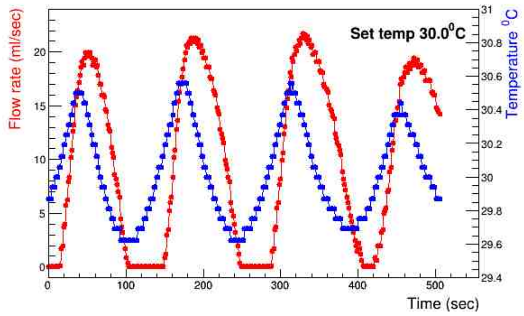

FIG. 3: Variation of temperature and flow rate with time.

back and forth over the set point. By precise tuning of the PID parameters, one can implement more robust control. A realistic sized prototype (cooling plate) is being built at VECC, Kolkata, using a 10 mm thick aluminium sheet with water channels grooved inside it. After the completion of the real size prototype, there will be a test in the laboratory and also in a test beam with detectors and full electronics. The ice bucket will be replaced with a chiller module, which will ensure a fixed temperature of the sink. Results obtained with full size prototype will also be presented.

Acknowledgement

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