Performance of an Automated Water Based Cooling System for CBM MuCh

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Outline

- Motivation

- Development of a water based cooling system for CBM MUCH.

- Future plan
Front End Boards (FEBs) dissipate ~ 90 W of heat per MuCh sector (15 FEBs).

The heat is to be continuously taken out to keep ambient temperature within working range (20 to 25°C).

FEBs are connected using wire bonding technique, thus air cooling is not an option, water cooling is preferred.

A controlled water based cooling system is designed for the CBM Muon Chamber (MUCH).

Al-plate (8 – 10 mm thick) with water channels (5 – 6 mm dia) inside it works as both support structure for mounting detector and cooling plate.

FEBs dissipate heat to the cooling plate which is taken out through controlled water flow.
Hardware Details
Basic design of the cooling system

- Two schemes are followed for mechanical design of the cooling plate:
  - **Scheme-I**: 7 mm Grooves are made inside plate and then sealed with 3 mm Al plates.
  - **Scheme-II**: Channels are made inside the plate and Al-pipe is inserted.

- Water channels are drawn closest to the FEBs to maximize the heat transfer.

- Temperature sensors are placed on top of cooling plate for monitoring and control.

- A micro-controller drives the submersible suction pump taking input from the temperature sensor as and when needed.

- Water cooler is used to provide chilled water at low temperature (10 – 15 °C). The submersible pump is placed inside the water cooler.
A 10 mm thick Al sheet was taken, and T-shaped groove was drilled into the sheet. The groove was covered with a 2mm thick Al strip, resulting in a water channel inside the sheet.
Mechanical design

Prepared by Jayant Kumar, VECC
Designing the Cooling plates
Setup in the lab at Bose Institute

Water Chiller (sink)  Al Plate

Inlet
Software and electronics
The Control Mechanism:

- A closed loop *negative feedback PID system* is used for the flow control mechanism.

The Algorithm is based on the formula

\[
OUTPUT = k_p * e(t) + k_i \int e(t) \, dt + k_d * \frac{de(t)}{dt},
\]

where \(k_p, k_d, k_i\) = constants

\(e(t) = (Desired \ temperature - Actual \ temperature)\)

- The Controller is programmed to take the measured temperature as input and control the motor as output.

- Output from controller is 8 bit PWM signal

- Motor is controlled via Power Transistor
PWM pulses depicting various Duty Cycles

Basic control circuitry
Block diagram of the process

- **Computer for monitoring and control**
- **Water Bath (Low temperature water)**
- **Automated water flow controller**
- **Submersible suction pump**
- **Cooling plate**
- **Temperature sensor**
- **Temperature value**
- **Flow control**
- **RS - 232**

Water flow and control connections:
- Water flow from **Water Bath** to **Submersible suction pump**
- Water inlet from **Submersible suction pump** to **Cooling plate**
- Water outlet from **Cooling plate**
- Temperature value from **Temperature sensor**
- Flow control from **Computer for monitoring and control** to **Automated water flow controller**
- **RS - 232** connection between **Computer for monitoring and control** and **Automated water flow controller**
Preliminary tests:

- Preliminary tests were done using copper plate of thickness 2 mm, with copper tubes of diameter 6mm welded on the plate.
- Heat load was simulated using seven heating elements, each of 4W dissipative power.
- Several set-points were set and the corresponding data was recorded.
- Temperature was recorded using DS18B20 sensor, which was later replaced with an analogue sensor LM35.
Preliminary test results

- Water volume flowing against various PWM values were recorded.
- The data was fitted, and the fit parameters were obtained.

\[ \chi^2 / \text{ndf} = \frac{6.298}{7} \]

- \( p0 = -8.787 \pm 1.309 \)
- \( p1 = 0.304 \pm 0.02007 \)
- \( p2 = -0.0005612 \pm 6.551e^{-05} \)
Both the mechanical designs were tested at CERN SPS test beam.

Two different Full sized GEM foils were used, one equipped with complete number of FEB’s and the other partially equipped with FEB’s.
Setup at CERN SPS test beam
Setup at CERN SPS test beam

Controller with PC

Chiller module

Controllers
Data from SPS Test Beam

Different colours represent data at different duration of time

Setpoint: 22°C
Sink Temperature: 12°C
Data from SPS Test Beam

Setpoint: 22°C
Sink Temperature: 12°C
Data from SPS Test Beam - zoomed view

Setpoint: 22°C
Sink Temperature: 12°C
Complete layout for a single sector

- **Computer**
- **Controller**
- **Temperature Sensor Bus**

- **Water Inlet to plate**
- **Water Outlet from plate**
- **PWM signal lines**

- **Sink**

**Notes:**
- Water Flow from the left side entering the system.
- Water Flow on the right side exiting the system.
- Multiple temperature sensors connected to the sensor bus.
Summary

• One micro-controller based Cooling system has been developed.
• The cooling system is successfully used in the test-beam of CBM GEM chamber at CERN-SPS.

Future plan

• To conduct more rigorous tests.
• To equip the system with a leak detection mechanism.
• To develop the system for the real experimental need and to tune the program for less fluctuations.

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Backup slides