The Cooling System for BteV Pixels

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Abstract

The cooling system we have designed for the pixels at BteV, located at Fermi National Laboratory, is made to cool at cryogenic temperatures. Nitrogen gas is cooled and allowed to flow over the pixel chips via Copper lines. The benefits of using this type of system included less noise, which leads to a better signal, a mechanically easy design, cooling directly on the chip, rather than next to it, and cryogenically the detector acts like a vacuum pump.

Introduction

The pixel chip, which is the central part of the detector, gathers information from the particle collisions and sends it to a computer. During these collisions the chip is bombarded with radiation and experiences heat generated by readout electronics. If we can get the chip to a temperature of –10 ^{o}C or lower we can hope to remove the heat created by the electronics and obtain radiation tolerance, or more immunity to the radiation. Noise will be prevented and a better signal achieved. We intend to use cryogenic temperatures to do so.

Design

Our design is based around a device called the Cryorefridgerator, by Cryomech, Inc. It consists of Cryomech's model AL10 Cryogenic Refridgerator and a CP510 Compressor System. The Cryorefridgerator is a system that includes a Coldhead (fig. 1), an expansion device that is capable of reaching cryogenic temperatures and a compressor system, in which the working fluid, Helium, is compressed and purified for use in the Coldhead.

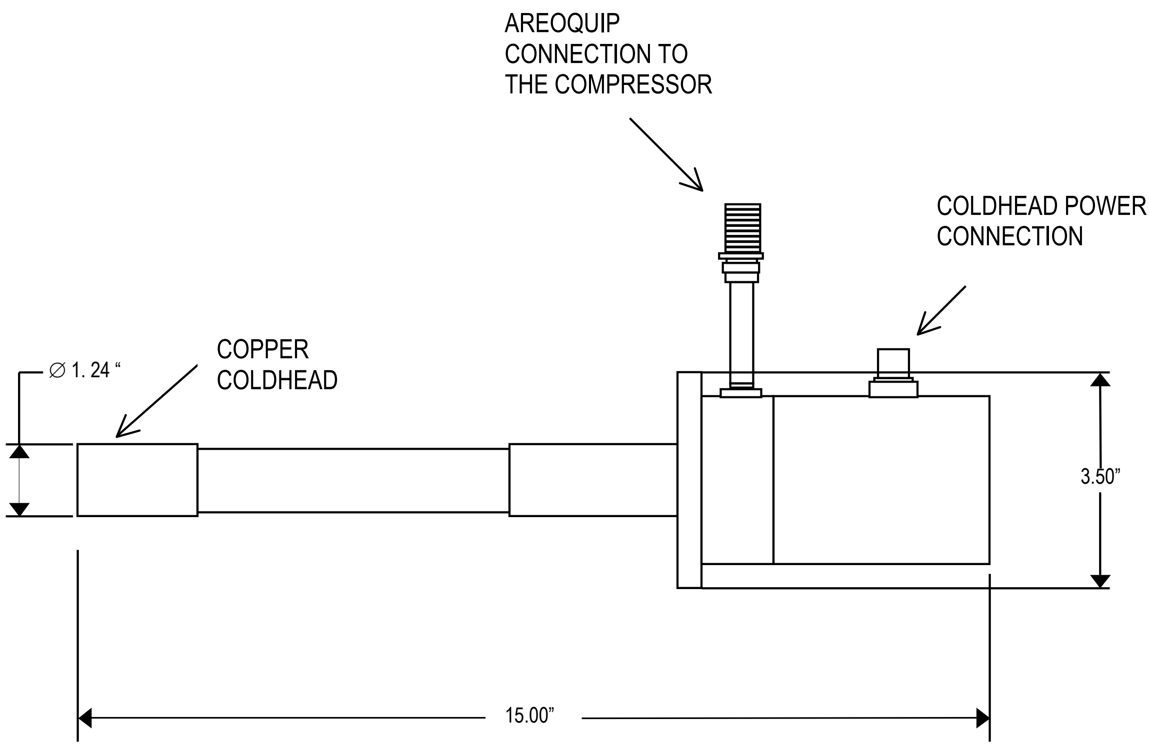

FIGURE 1. CRYOMECH Coldhead

Knowing what we were using for cooling lead to the question of how we were going to take away the heat from our test pixel board using the Cryorefridgerator system. Nitrogen was chosen and the rest of the design would be based around its use.

Using the Coldhead the gas can be cooled to liquid temperatures. A well of some kind would be necessary to hold the liquid. From there we wanted the liquid to flow out and over the test board. In a system such as this additional considerations such as condensation, pressure, temperature control, and flow rate of the liquid Nitrogen were concerns during the design and construction processes.

<u>The Hockey Puck</u>

We needed something to act as a well for the Nitrogen and also connect to the Copper Coldhead of the Cryorefridgerator, and because of its physical appearance we dubbed it the "hockey puck".

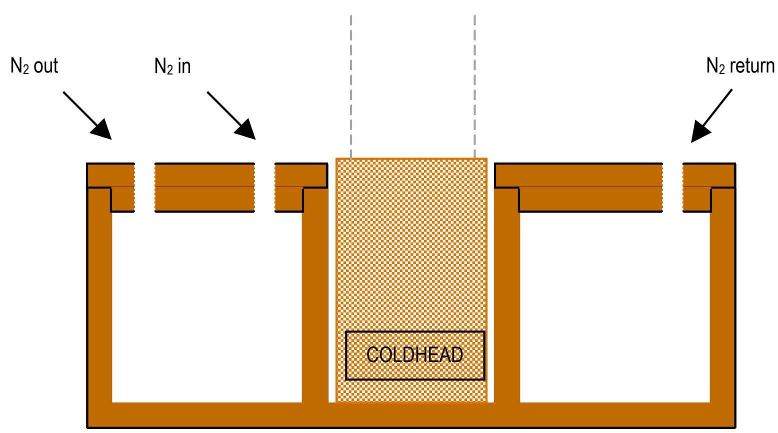

FIGURE 2. The Hockey Puck with the Coldhead Enclosed

The choice of the material for the puck was Copper, because we wanted the thermal conductive properties of the both the puck and the Coldhead to be very similar. The other consideration was the volume it would hold. In order to cool the10 watts of heat that was going to be applied to the G10 board (our test pixel board) I found using

$$Q = c\rho V \Delta T$$

and solving for V that the minimum volume needed to be approximately 20cm^3. The dimensions of the puck ended up being 4” in diameter and 2” in height. A heater is placed on the bottom of the puck to allow for more precise control of the temperature of the Nitrogen.

Preventing Condensation

The Coldhead, as stated earlier, is a device that becomes very cold, cryogenically cold. In a normal environment condensation becomes a big problem. For us to prevent condensation the Coldhead, Copper puck, and the copper lines needed to be enclosed in a Helium or vacuum environment. We simply decided to enclose the Coldhead and the puck in a vacuum tight box made of polycarbonate. A pump is used to create vacuum inside. This was also done to the G10 board since the copper lines are laying on it. Any exterior Copper lines are covered with an insulating tape.

Dealing with Pressure

From the simple relation

$$PV = nRT$$

we know that at a constant volume an increase in temperature will cause an increase in pressure. Both parameters must be controlled. The temperature of the Nitrogen is controlled using a heater and monitored with a sensor through a temperature-controlling device. To have some type of control of the pressure an over pressure value is needed in the system.

The Cooling System (FIG. 3)

Nitrogen gas flows in to the Copper puck. It's interior is hollowed out, so it acts as a well for the Nitrogen. The Coldhead then cools the gas to liquid temperatures. Having a heater placed at the bottom of the puck allows for control of these temperatures. A temperature sensor placed on the puck allows us to monitor the temperature using the controller, which is also the device supplying the power to the heater. This system allows for very precise control of the temperature of the environment.

Once liquid Nitrogen forms gravity allows it to flow out of the puck, through the Copper lines, and over the G10 board. The board has 10 watts of power being applied to it via another heater. A temperature sensor is placed on the board to monitor the temperature. Most of the Nitrogen will vaporize as it cools the board. Any additional liquid will flow back into the puck, creating a closed system.

Conclusion

Mechanically this design is very simple. However, the cooling system is very complex. There is also some uncertainty of how well it will work at

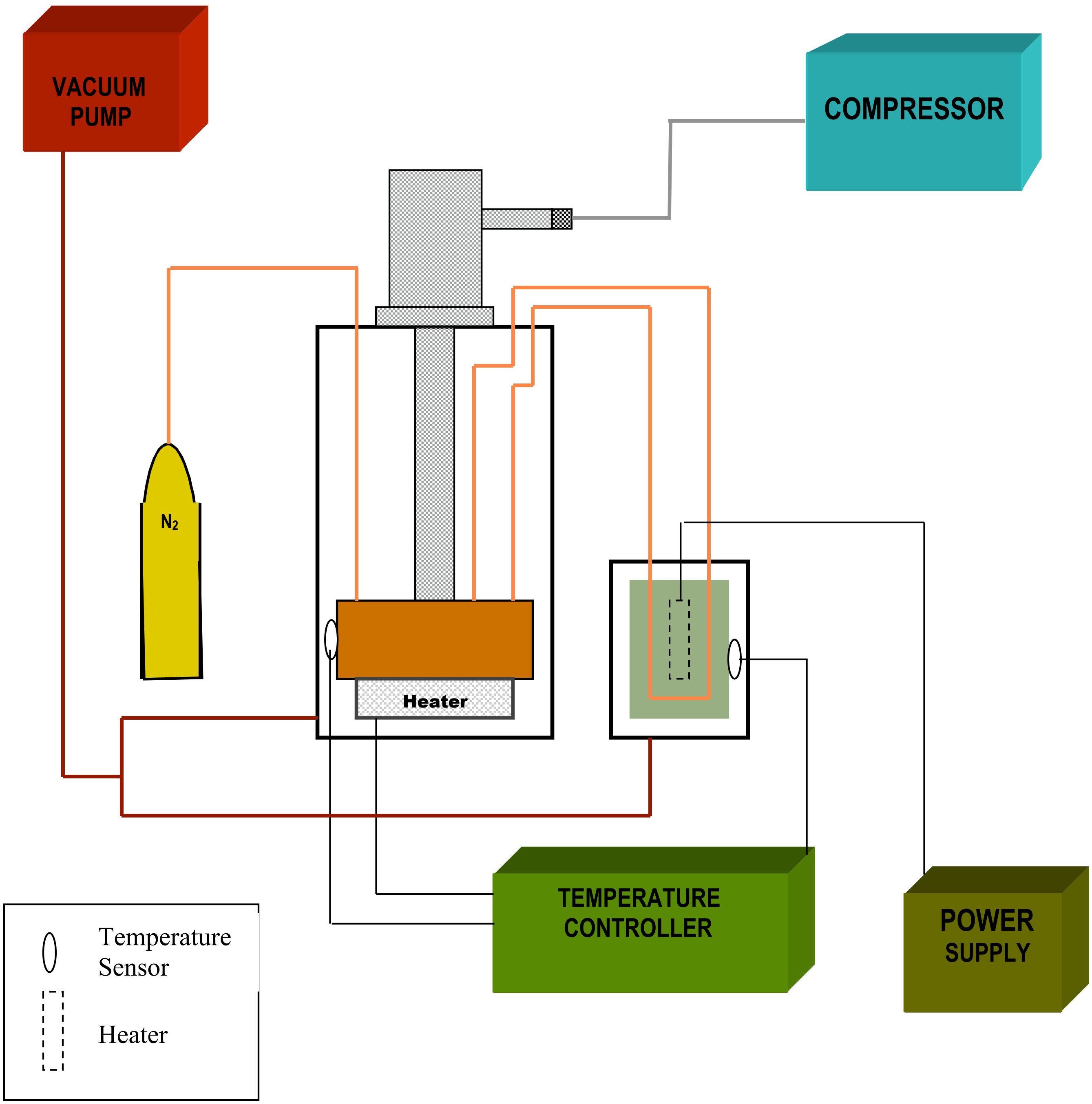

FIGURE 3. Diagram of the System

cryogenic temperatures. The next step in this project is to test it using our dummy heat load and see how well the system will cool the applied heat.

Acknowledgements

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