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design and implementation***

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# RHIC 12×150A CURRENT LEAD TEMPERATURE CONTROLLER: DESIGN AND IMPLEMENTATION\*

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## Abstract

There are 60 12×150A current leads distributed in six RHIC service buildings; each lead delivers power supply current from room temperature to cryogenic temperature in RHIC. Due to the humid environment, condensation occurs frequently and ice forms quickly during operation, especially during an extensive storage period. These conditions generate warnings and alarms to which personnel must respond and establish temporary solutions to keep the machine operating. In here, we designed a temperature control system to avoid such situations. This paper discusses its design, implementation, and some results.

## INTRODUCTION

There are six service buildings in the RHIC complex [1]; each building has two valve boxes that transfer room-temperature current cables from the power supplies into superconducting leads, and then transport them into the RHIC tunnel. In there, the transition between the room-temperature lead into superconducting lead is critical and essential; smooth running during the physics store is crucial for the machine's continuing operation. One of the problems that often occurred previously was the icing of these current leads that could result in a potential leakage current onto ground, thereby preventing a continuous supply of physics store. Fig. 1 illustrates a typical example on a power lead.

Among the modifications of the design of the valve box, we list below the new requirements for designing the temperature controller to prevent icing occurring:

- Remotely control, monitor, and record each current lead's temperature in real time. Prevent icing or overheating of a power lead.
- Include a temperature alarm for the high/low level threshold.

In this paper we discuss the design, implementation, upgrades to, and operation of this new system.

## DESIGN & IMPLEMENTATION

The modification of the valve box's power lead design, shown in later in Fig. 5(1), is the replacement of the previous power lead assembly (Fig. 1). Our new design encompasses many innovative constructions to assure smooth operation in the future. Temperature controlled



Figure 1: Icing Problem in a 12×150A Power Lead

heater is one of these novel features. Fig. 5(1) (3), depicts the two flanges used in this assembly: Top square flange and bottom clamp flange. In each flange we installed two 100W cartridge heaters. We proved experimentally that 4 100W cartridge heaters are needed to supply enough heat to maintain the proper operational temperature based on the helium flow rate. We attached a thermocouple to every flange; the controller monitored the temperature and controlled the heaters of the power lead. Our prior experience showed that the ice always formed from the bottom to the top (cold side). Due to the rapid thermal transition and helium flow in the bottom section of the power lead assembly. Consequently, we decided to use the bottom thermocouple as a controller transducer, and the top thermocouple as a secondary/redundant monitoring sensor.

### Initial Design & Implementation

The initial concept design started at the end of RHIC Run 9 (from 1/2009 to 7/2009). We investigated several controllers from various companies, based on our prior experience and communication. We eventually chose iSeries<sup>®</sup> controller [2] from Omega Engineering<sup>®</sup>. Therein, temperature control is realized by using either the ON/OFF or PID (Proportional Integral Derivative) Heat/Cool approaches. An auto-tune feature is also available to the users. The standard features of this product include dual outputs. We chose SSR (solid state relay) and relay outputs for our application. The SSR

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output directly drives a 3 to 32V solid state relay input that is in series with AC power and a cartridge heater.

Because of our existing environment, having a reliable, accurate thermocouple sensor is critical. We used "Bolt-On Washer Thermocouple Assemblies" [2] for all of our temperature measurements. This versatile thermocouple assembly enabled us to mount it easily on to a variety of surfaces, offered us an excellent solution that suitable for our environment. Fig. 5(1) (3) shows the installed view.

Fig. 2 is a simplified diagram of a single channel. As a proof of concept, we installed a single set of this system during the end period of Run 9. During the 2 weeks period, we proved that this system could maintain temperature around the power lead, thus preventing ice forming. Afterwards, we began the Phase 1 design, constructed it, tested and installed it before RHIC Run 10 (from 12/2009 to 6/2010) started. Instead of using the ON/OFF control initially, we implemented a PID control scheme that allowed us to maintain the target temperature closer to the setpoint temperature. The response time on reacting to the power lead's temperature variation has decreased significantly as well.

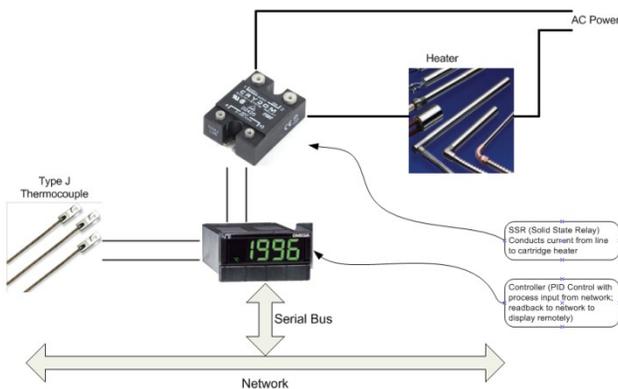


Figure 2: Simplified Diagram of Single Channel Power Lead Temperature Controller

### Phase 2 Modification and Upgrade

To keep system reliable and that it is fail-safe. We enhanced the Phase 1 designed system with additional mechanical relay to provide this feature. The relay used the second output of the Omega<sup>®</sup> controller. This output basically is a relay, and depending on its internal logic, the state of relay changes. The setpoint of output 2 is at temperature below our safety level (120 °F). Ideally, the temperature should never reach this level because the software alarm is set lower than this point. However, if an unexpected event occurs; the second output of controller will open up to prevent any damage to our equipment. Fig. 3 shows the complete temperature controller chassis wiring diagram with redundant fail-safe features.

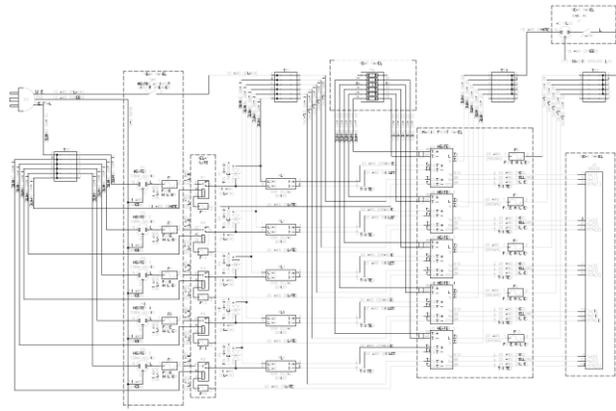


Figure 3: Temperature Controller Wiring Diagram with Redundant Fail Safe Feature

## OPERATION & RESULTS

### Functional Testing

The testing of the controller chassis was completed on a dummy load. We constructed a special fixture for the initial test that gave us a convenient means functionally to check the chassis wirings before installing it in a service building.

### Operation & Results



Figure 4: Installed Temperature Controller Rack System in a RHIC Service Building

Fig. 4 shows a fully installed and operational chassis in one of our service buildings. This system was used in Run 10; the current Run 11 (from 01/2011 to 6/2011) is the second run for this system. The entire system has a number of major parts: 2 temperature controller chassis, a secondary monitoring panel (shown on the top), an UPS

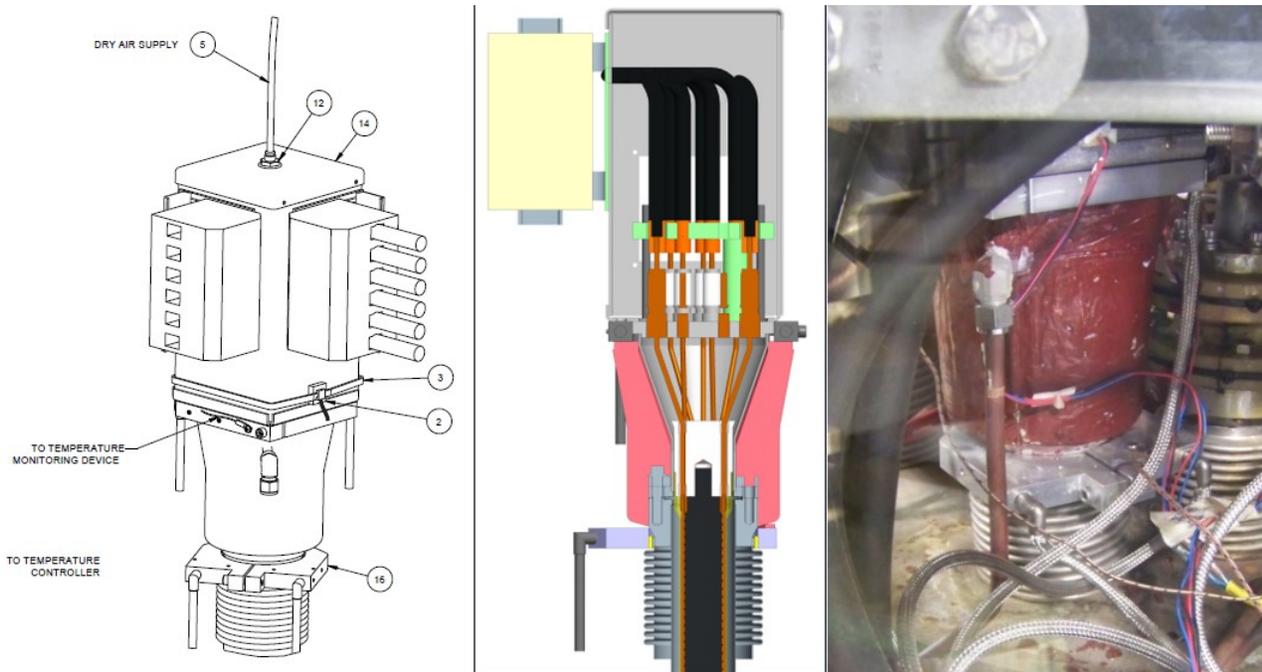


Figure 5: Valve Box Power Lead Assembly (1) 3D Drawing (2) Rendering View with Internal Power Lead (3) Installed Bolt-on Washer Thermocouple on Square Flange with Cartridge Heater

(shown in the bottom) and a communication/network module. The sensing and the heater part of the system are located on top of each valve box (Fig. 5 for an example). Each rack is in charge of controlling two valve boxes – a total of 10 12×150A current leads.

To remotely control and monitor the temperature of these leads, our control group developed new software to interface with them. As described previously, the top thermocouple is used only for monitoring and the bottom sensor used for both monitoring and control. There are 12 devices, 2 monitors and 10 controllers, communicating with control system through the network. Users can remotely monitor each temperature sensor; assign a low/high level warning setpoint, and adjust controller’s parameters easily through an user interface. Although the controller system encompasses a hardware fail-safe feature, software alarms are used first as fault indications to the users.

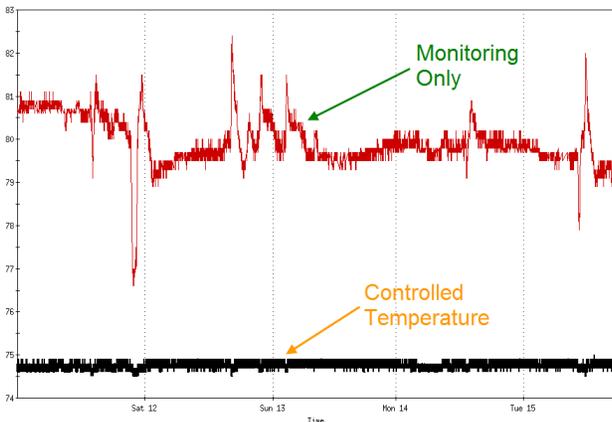


Figure 6: Temperature Measurement of a Power Lead Both Top Monitoring and Bottom Sensing Readback

Fig. 6 plots an example of a typical temperature profile of a 12×150A current lead (Fig. 6) over a period 5 days, showing the required lead temperature has maintained satisfactory. The black trace shows stable temperature readback from this lead.

## CONCLUSION

We describe the configuration and establishment of a 12×150A current lead temperature controller system we recently designed; sub-systems have been installed throughout the RHIC complex. The system currently is operating 24 hours and 7 days a week, with minimum maintenance.

## ACKNOWLEDGEMENT

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## REFERENCE

- [1] RHIC Design Manual, [www.agsrhicome.bnl.gov/NT-share/rhicdm/00\\_toc1i.htm](http://www.agsrhicome.bnl.gov/NT-share/rhicdm/00_toc1i.htm)
- [2] The Omega Temperature Measurement Handbook® and Encyclopedia, Vol. MMXIV™ 7<sup>th</sup> Edition, <http://www.omega.com/literature/6thedition/>