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# Evaluation of the Temperature Stability of the User Cooling Water

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## Introduction

The increased demand for thermally and mechanically stable optics and components has caused the temperature stability of the user water to be questioned. The user water system was set up when the Aladdin building was built and has been functioning well for most applications, however, it appeared that there was no data concerning the temperature stability of the system in operation. To remedy this problem, a program was started to measure the temperature variations of the user water and determine its temperature stability. Two temperature sensors were ordered and electronic modules were designed and constructed for continuous monitoring of liquids. These were then used to observe the temperature variation of the user cooling water.

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pipe fitting for connection to water or other liquid systems. The #44018 sensor consists of two thermistors packaged in a single module to produce a linear device. The module is able to produce a resistance varying linearly with temperature between -30 and 100 °C. Tom Baraniak designed and constructed a circuit to monitor the sensor and produce voltage proportional to temperature. The circuit is designed to produce a 0 to 10 volt signal between 0 and 100 °C. Use of a 9 volt power supply limits the highest output voltage to slightly less than 9 volts. This also limits the temperature range to values some what lower than 90 degrees. The circuit is documented on SRC drawing # 2644B003 and in appendix A. The circuit can be powered by an internal 9 volt battery, or by an external 9 volt supply (Radio Shack Cat No. 273-1455D)[2]. The battery is functional for several hours; however, for testing over a several day period, the external supply is required. The external supply was used for all of these tests.

**Initial Tests**

The temperature measurements were performed at the end of the 10 meter TGM beamline (port 123). The 10 m TGM was chosen because of space availability and because it is representative of the SRC beamlines. The temperature sensor was mounted in a tee and nipple in a 1 gal/min flow of cooling water. It was connected in a loop at the end of the beamline in the same manner that a user might connect a device requiring cooling. There was no heat source in the cooling loop so any temperature variation should indicate typical temperature variation in the cooling water itself. The output was monitored with a chart recorder moving at 10 mm/hr. An offset voltage was used to expand the chart scale for better observation of temperature variation. Figure 1 shows a representative section of the chart. There are small oscillations in the signal with a period of about 14 minutes. In addition to these small regular variations there are longer term temperature drifts with periods of a couple of hours. Figure
Figure 1: Representative chart recording of the user cooling water temperature variation at the 10 meter TGM beamline.

Figure 2: Representative chart recording of the user cooling water temperature variation at the 10 meter TGM beamline.
2 shows a longer section of the chart. The far right section of the chart shows an even larger temperature increase over a four hour period. It is of interest to note that there is no evidence of a control system responding to changes in temperature. At no point in the measurements was anything observed that resembled the corrective response of a servo like control system.

**Long Term Testing**

In an attempt to establish the long term performance of the system, the probe and recorder were allowed to run continuously for 25 days. During this time, the temperature of the probe was periodically measured with a digital voltmeter and recorded on the chart. At the end of the run, the temperature was manually determined every half hour in chart paper units. The chart paper units were also recorded for each of the voltage measurements made over the 25 day period. The resulting values of chart paper units versus temperature were fit to a straight line as illustrated in figure 3. The resulting fit was used to convert the chart units to temperature. The fact that all of the points fit the line indicates that there were no accidental scale changes during the experiment. The resulting plot of temperature versus time is shown in figure 4. This figure dramatically illustrates the random excursions in temperature that occur frequently in the system. Attempts were made to relate the changes in temperature to periodic events like injection or line voltage. Unfortunately, no correlation was found. The temperature anomalies tend to be increases; however, temperature decreases were also observed. The sigma value for the temperature values in this data set is 0.24 degrees; however, the variation of temperature does not appear to be Gaussian in nature. It is probably more valid to specify the error in terms of range of the values. The high and low values in this data set are 22.92 and 21.64 indicating a range of 1.28 degrees. It is probably more valid to note that at apparently random intervals the cooling water temperature was observed to increase or decrease by up to 0.65 degrees for
Figure 3: Temperature versus chart unit data used to calibrate the thermistor measurement system.

3-5 hours.

The theory that best fits the data is that the temperature of the cooling water is primarily determined by the flow patterns and the ambient heating or cooling of pipes delivering the cooling water to the user. It is not affected in a major way by the cooling water temperature control system. Examination of the cooling water system reveals that the major volume of the system is in the piping to the users. The system is cooled by well water and the volume of water in the cooler is very small. It is likely that the 14 minute oscillations observed in figure 1 are due to the activity of the cooling water control system. It is reasonable to assume that the return water is always slightly above room temperature. The control system cools the water to a temperature below room temperature with well water. In performing this function, the cooling system cycles on and off with a consistent 14 minute period. The water going out of the controller is heated to room temperature in all of the pipes distributing the user cooling.
water around the ring. Since most of the volume of the system is in the piping, it is reasonable to suspect that most of the heat exchange will also be in the piping. Given the relative surface area of pipe in the heat exchanger and that in the delivery system, it is possible that the heating of the water in the piping is a major factor in determining temperature. Ideally the system would have a constant flow and some equilibrium temperature would be established at each location. In actual practice, the flow is disrupted at random intervals when users connect and disconnect equipment. It is likely that whenever there is a change in the flow pattern, the temperature of the water at a particular location will be changed. The large variations in temperature would then be caused by increases or decreases in the flow of cooling water at some point in the system.

It is important to note that no absolute calibration of the temperature probe was performed. The manufacturer lists the probe as providing an accuracy and interchangeability of $\pm 0.15^\circ C$ and a linearity deviation of $\pm 0.216^\circ C$. Our additional circuitry may provide addi-
tional errors if it is not adjusted correctly. It is possible that the absolute value of average temperature measured in this study is in error by as much as half a degree centigrade. In contrast, the relative variation, or the deviations from the average should be more accurate.

Conclusions

The average cooling water temperature is about 22 degrees Centigrade or slightly above room temperature. The cooling water temperature is not particularly well regulated and shows apparently random increases and decreases of up to 0.65 degrees Centigrade lasting for several hours. These temperature excursions do not correlate with injection or other daily activities and are probably driven by changes in the system flow pattern as equipment is added and removed from the system. The cooling water functions well for many applications. It is certainly adequate to cool pumps and sublimators. The user cooling water is not appropriate for cooling critical optics and other items requiring temperature stability of better than 0.65° C. In conclusion, the user water temperature is $22.2 \pm 0.65$ degrees.

Acknowledgment

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References

[1] Omega Engineering, Inc. PO Box 4047, Stamford, Ct 06907-0047.

[2] Radio Shack, 100 Throckmorton Street, Suite 1800, Fort Worth, Texas 76102 a division of Tandy Corporation.
A Appendix—Thermistor Schematic

Figure 5: Thermistor circuit schematic.