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A SYSTEM FOR ACCURATE TEMPERATURE CONTROL OF SMALL FLUID BATHS

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ABSTRACT. A temperature controller is described which uses a thermistor sensor and electrical heating to maintain the temperature of a small bath of fluid to within a few millidegrees.

RÉSUMÉ. *Un système de contrôle précis de la température de petits bains liquides.* On décrit un appareil de contrôle de la température qui utilise un capteur à thermistor et un chauffage électrique pour maintenir la température d'un bain fluide dans une fenêtre de quelques millièmes de degré.

ZUSAMMENFASSUNG. *Ein System zu genauen Temperaturkontrolle von kleinen Flüssigkeitsbädern.* Es wird ein Temperaturregler beschrieben der einen Thermistor-Fühler und elektrische Heizung benützt, um die Temperatur eines Flüssigkeitsbades auf wenige Milligrad konstant zu halten.

INTRODUCTION

The flow parameters of ice are very temperature sensitive particularly as the temperature approaches 0°C (e.g. Mellor and Testa, 1969) therefore, in order to make reliable ice-flow measurements it is necessary to control the specimen temperature to within close limits. If the ice sample is immersed in a fluid (usually kerosene) to prevent ablation it is convenient to control the temperature of this fluid. The controller uses a thermistor bridge and amplifier to switch a heater in the fluid on and off. Temperature accuracy is maintained by having a high loop gain in the sensor-to-heater system and low offset drifts in the bridge and amplifier.

PERFORMANCE

The ability of the system to maintain accurate control depends on a number of factors, e.g. the stability of the surrounding cold box, the insulation around the controlled bath, and the heat input from experiment sensors, etc. Typically it is not difficult to set up a bath which has a short period (*c.* 10 s) thermal noise of *c.* 0.01 deg peak to peak which, if smoothed by a time constant of several minutes, leaves a residual variation of about 0.003 deg. The long-term drift is less accurately known but over a period of several weeks no variation of the mean temperature is detectable above the noise. The extreme temperature variation from the centre to the edge of a suitably stirred and insulated bath is less than 0.01 deg. Within the central zone variations are much less.

APPARATUS

A typical arrangement will have the insulated container of fluid (in which the ice specimen is immersed) in a cold room or small freezer box which is run at a temperature about 10 deg below that required for the controlled bath. 2 cm of foam insulation provides enough heat flux out of the system and sufficient damping of variations in the freezer temperature.

A small electric motor drawing 100 mA at 4 V turns a propellor which stirs the fluid. It is most important that the fluid is well mixed throughout the bath and that it has sufficient velocity past the thermistor sensor to reduce the effect of self heating. Excessive stirring however can cause significant ablation of an ice sample over a period of six months when kerosene is used. Low-viscosity silicone oil will prevent this for longer experiments but is much more expensive.

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The heater consists of a lattice of resistance wire wound on an open frame which occupies a large section of the bath. This gives better control than a more localized heater by preventing temperature overshoots from heat storage and delays in heat transfer. The length of resistance wire is selected to give the appropriate resistance and hence heater power.

Electronics

The thermistor sensor (R_{th} in the circuit diagram, Fig. 1) is an STC type F23 which has a very small bead of resistance material encapsulated in glass. These have been found to be stable and to give a rapid response to temperature changes. The resistance of 4 kΩ at 0°C gives a power dissipation of 90 μW and the resultant self heating is 0.03 deg in still water. It is therefore important that the thermistor be located in a well-stirred position in the bath to minimize and help keep constant this effect.

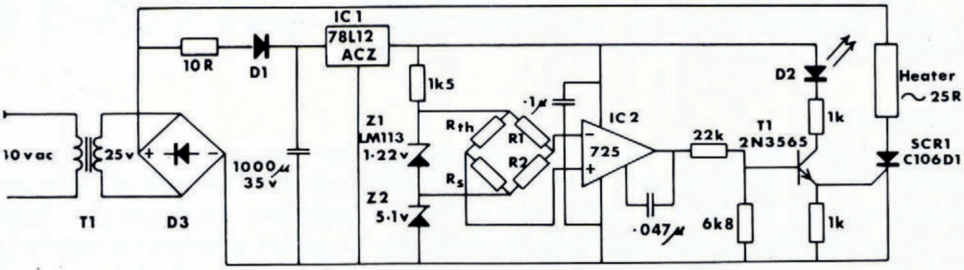

Fig. 1. The electronic circuit.

The thermistor bridge voltage V_B is maintained at 1.22 V by a LM113 precision zener diode Z_1. The criteria of Narod (1976) which equalize the effects of self heating and detector noise to give optimum resolution of a thermistor bridge as a thermometer suggest a lower voltage (*c.* 0.4 V); but for a controller where self heating remains substantially constant it is reasonable to use a larger voltage to increase sensitivity and immunity from temperature drift due to changes in the amplifier input offset voltage.

Using $V_B = 1.22$ V and with a thermistor coefficient $\alpha = 0.03$/deg the differential output is 10 mV/deg. The LM725 or μA725 amplifier has an input offset voltage drift of less than 2 μV/deg so a temperature fluctuation of 10 deg at the amplifier gives an equivalent temperature shift at the sensor of only 2 mdeg.

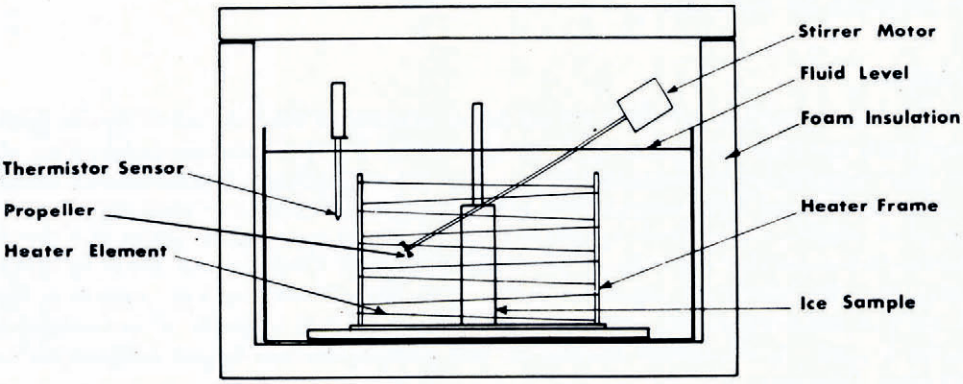

Fig. 2. A typical configuration of heater, stirrer, and sensor, which gives good temperature stability.

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The resistors in the bridge (R_1, R_2, R_s) should be high-stability types, e.g. metal film. R_1 and R_2 are of equal value approximately equal to that of the thermistor (3.9 kΩ). R_s is varied to set the required temperature and is composed of switched fixed resistors (1 kΩ) in series with a multi-term variable resistor with a turns-counting dial.

The power transformer T1 and the bridge rectifier D3 must be capable of supplying the heater current, which may be up to 2 A.

Setting up

If the bath temperature is measured for a number of different settings of R_s, a calibration graph can be produced which allows any temperature to be set fairly accurately. Over a small range the relation between R_s and temperature is very close to linear. The light-emitting diode D2 indicates when the heater is on, and cycling of the light indicates control of the temperature. The best performance is obtained with a cycle time of about 10 s or less and approximately equal times on and off. The heater power and the configuration of the heater, stirrer, and sensor can be adjusted for this. A small well-insulated bath of capacity *c.* 0.5 l uses 5 W of heater power. A larger bath of 20 l with the top uninsulated requires 90 W.

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REFERENCES

Mellor, M., *and* Testa, R. 1969. Effect of temperature on the creep of ice. *Journal of Glaciology*, Vol. 8, No. 52, p. 131–45.
Narod, B. B. 1976. Bridge optimization for thermistor measurements. *Journal of Glaciology*, Vol. 16, No. 74, p. 269–75.