A PRECISION AUTOMATIC TEMPERATURE CONTROL DEVICE IN THE RANGE 4.2 TO 300 °K

By

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Abstract :

The design of a simple automatic temperature controller with a fast response time using a resistance bridge and readily available integrated amplifier is described.

Introduction :

One of the technical low temperature problems is making studies over a wide temperature range from room temperature to liquid helium temperature ; there is insufficient literatures on obtaining intermediate temperatures and carrying out experiments at these temperatures. In few of the previous work some apparatus was used to maintain the temperature in the experimental chamber, but these are complicated and inconvenient to use. (1,3-6)

The aim of the present paper was to device a simple precision automatic temperature controller to achieve temperatures from 4.2 to 300 °K with stabilization of the temperature. This controller is capable of providing temperature control within 0.1 °K for long period.

The most convenient way of regulating the temperature of the cryogenic bath is to dissipate a small amount of power in a heater placed near the bottom of the dewer. A very good regulation can be achieved by incorporating the heater and a suitable temperature sensing element in a feed-back system, so that the heater power is controlled automatically.

Temperature Control Circuit and Sensors :

The circuit of the temperature controller is shown in fig. 1 and consists of a power supply regulator and an operational amplifier 709 μ A. This model features low offset high input impedance, large input common mode range and low power consumption. One of the

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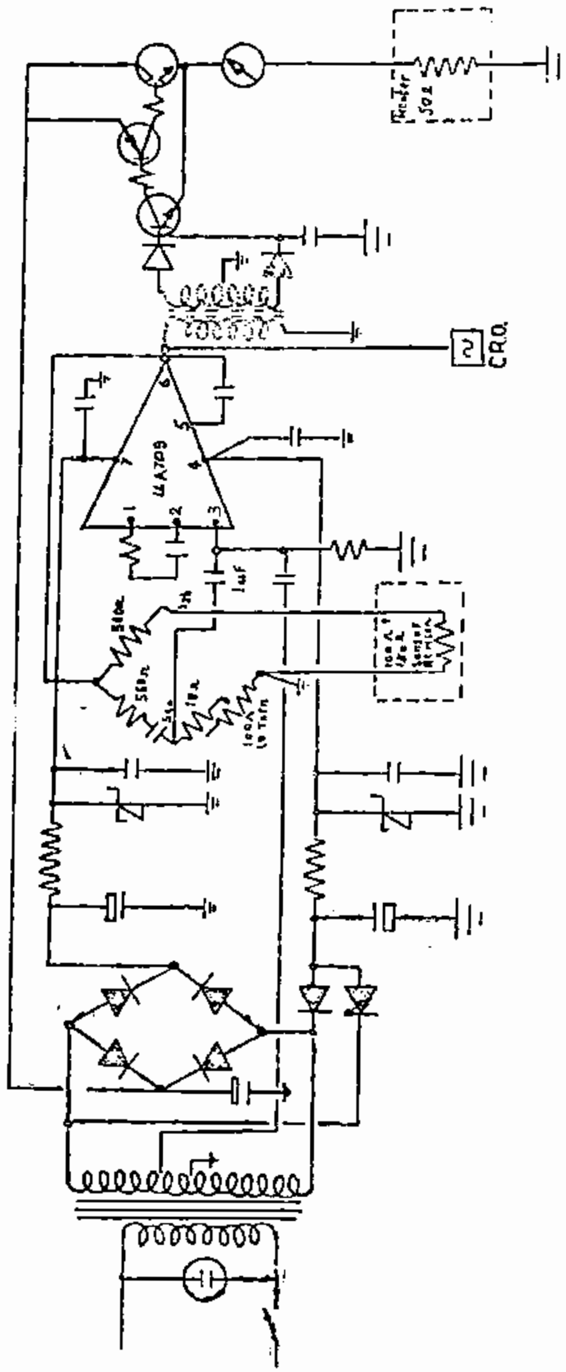

Fig. (1)

arms of the a.c. Wheatstone bridge acts as a sensor and the other arm is replaced by a 10 turn helipot which is used to balance the output power. A three stage d.c. amplifier is used to provide power for the heater of the cryogenic chamber.

The bridge circuit is a modified Wien bridge oscillator with the addition of a four pole switch for selection of two separate sensors fig. 2. This switch also has reversing contacts, associated with the secondary winding of the shield isolating transformer.

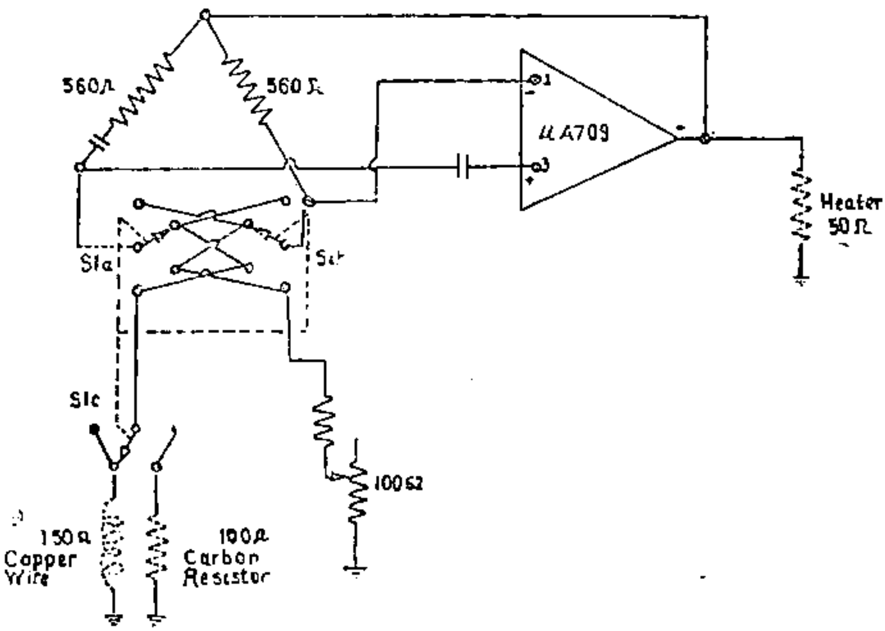

Fig. (2)

One of the sensors used is a copper resistance wire of 48 s.w.g. It is wound noninductively on a brass rod. The sensor has high sensitivity in the range 50 °K up to 300 °K with a positive temperature coefficient. The characteristic of this wire resistance - fig. 3 - has been shown to be reporducible and was used as a relaible resistance thermometer (2). The variation of R / R_o ratio with temperature is quite remarkable between liquid nitrogen and room temperatures. Since due to the electrical conductivity of the element of the wire, the temperature control in the range between room temperture and liquid nitrogen temperature, the contorl of the temperature was better than 0.05 °K, as the control period was more than 5 hours. The heating effect due to the sensor was much less than that due to the heater (50 ohm constantan wire).

The other sensor, to be used in the liquid helium range, was an Alan Bradley carbon resistance. This sensor is calibrated in the range 4.2 to 50 °K by using a digital multimeter type 3800A. The carbon sensor has a negative temperature coefficient resistance as shown in fig. 4. The control sensitivity below 50 °K was less than 0.1 °K.

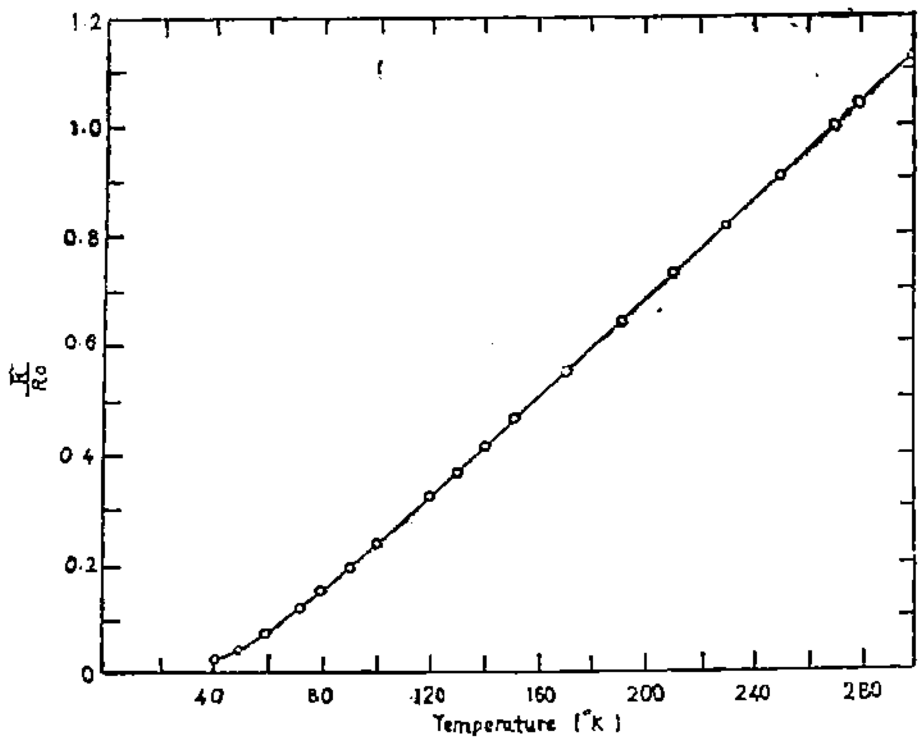

Fig. (3)

Operation of the controller :

The temperature is sensed by a suitable resistance thermometer which is incorporated in the a.c. bridge circuit. Its output after amplification is used to control the power supplied to the heater attatched to the specimen and also to feed back to the bridge, so as to maintain the oscillation automatically. If R_s' is the value of the sensor R_s resistance, corrosponding to a balance, then for $R_s > R_s'$ the feed-back is positive causing an a.c. voltage to appear at the output with continuous oscillation. On the other hand if $R_s < R_s'$ the feed-back negative and the output stays at or close to zero. The frequency of the output is determined by

$$2 \pi f = (R_4 C_1 C_2 R_2 R_3 / (R_2 + R_3) ^{1/2}$$

In the constructed temperature controller $R_4 = 1$ ohm , $R_2 = 560$ ohm , $C_2 = 0.033\ \mu$ F and R_3 is the variable resistance of the helipot.

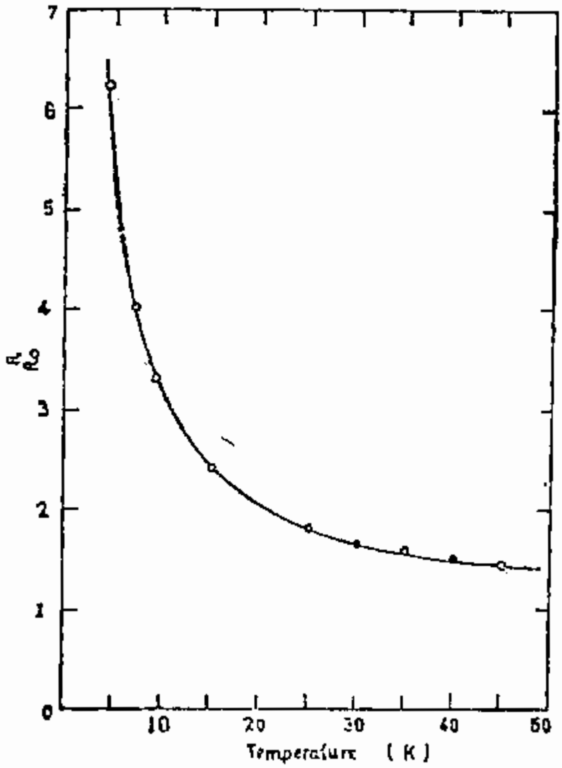

Fig. (4)

For small disturbance the out of balance voltage output varies linearly with the output current through the heater. The output singal can be seen on the cathode ray oscilloscope, as an a.c. wave singal and square wave singal, wider maximum positive feed back providing maximum heating power.

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