Methods for Controlling a Constant Temperature Bath

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In the course of some studies on the thermal conductivity of liquids, it was necessary to construct constant temperature baths. Although the basic principles of these control devices are not new, it was thought that a description of our arrangements might be of interest to others.

Consider a thermo-sensitive element made of a long copper coil (44 feet of ½ inch tubing) filled with a low viscosity oil (Stanolex Transformer Oil). The thermal expansion of the oil provides the principle for control of the bath. Oil was chosen for the temperature sensitive element because of its large thermal coefficient of volumetric expansion. A long length of copper tubing was used in order to present as great an area as possible for heat flow between the bath and sensitive element. The copper coil terminated in a mercury filled reservoir so that the change in volume of oil was registered by a change

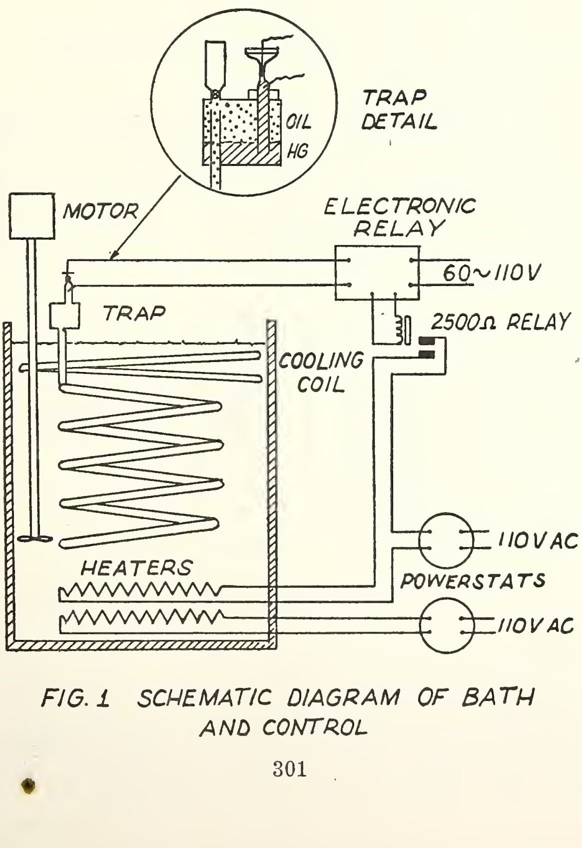

FIG. 1 SCHEMATIC DIAGRAM OF BATH AND CONTROL

in the mercury level in a vertical capillary tube. A trap was necessary to prevent seepage of the oil past the mercury, since mercury does not wet glass walls. Traps made either of glass or steel worked equally well. An ordinary darning needle served as a contact point, so that as the mercury would rise in the capillary tube it would contact the needle, closing the electric circuit to actuate the relay and shut off the heating current as shown in Figure 1. The surface of the mercury in the capillary should be protected from the atmosphere. Methyl salicylate was used for this purpose as recommended by Eastern Industries, Inc. (2). The bath consisted of about 20 gallons of the same light transformer oil that was used in the regulator coil.

If any considerable arcing occurs at the needle to mercury contact it will cause contamination of the mercury surface and reduce the sensitivity. It was necessary, therefore, to devise a relay that could be actuated by a very small current while switching very large amounts of power from the 110 volt a.c. lines. Such a circuit (3) is shown in Figure 2. When mercury is not in contact with the needle, the grid of the 6F6 tube has zero bias through the one meg ohm resistor and the

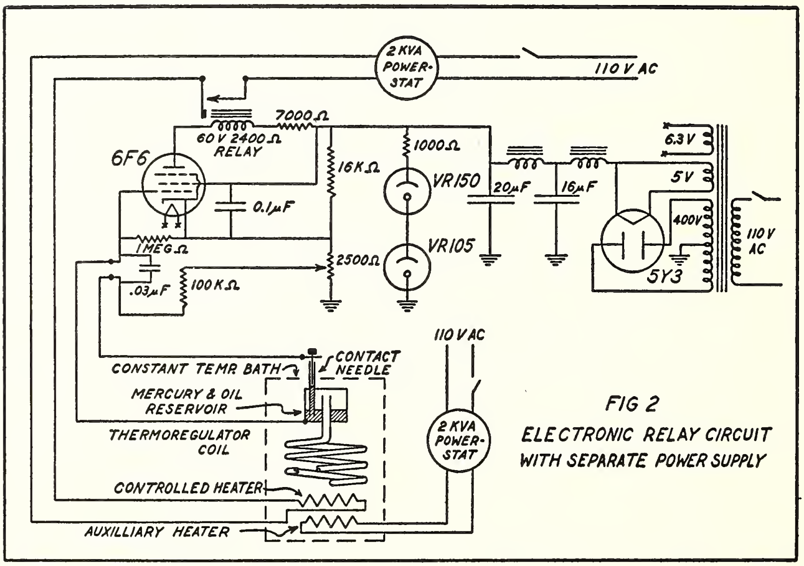

FIG 2
ELECTRONIC RELAY CIRCUIT WITH SEPARATE POWER SUPPLY

relay closes. As the temperature increases the mercury contacts the needle and the grid circuit is completed through the 2500 ohm variable bias resistor set to the correct value for "cut off," the tube blocks, and the relay opens and cuts off the heating current. The small condenser across the thermoswitch reduces relay chatter due to vibrations. This relay is quite stable and remains in operation for long periods without re-adjustment. Since the contact points are in the grid circuit of an electron tube circuit, the current at "make and break" is of the order of a few microamperes. This regulator circuit controlled the temperature of the bath to approximately ±0.02°F over the range 77°F to 145°F. The period of the heating cycle varied from 2-8 minutes and the best control was obtained with the longer periods.

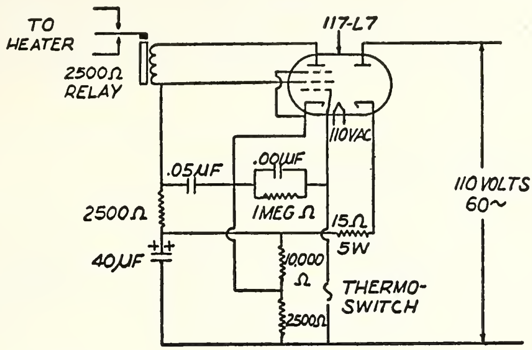

FIG. 3 SINGLE TUBE ELECTRONIC RELAY

A much simpler control circuit is shown in Figure 3. The rectified power for operation of the circuit is supplied from the diode section of the 117L7 tube and the pentode section of the tube serves the same purpose as the 6F6 tube in Figure 1. As before, the thermoswitch is in the grid circuit and the relay in the plate circuit of a power tube and the operation is the same as previously described. This circuit is unique in that a single tube, operating wholly from the 110 volt a.c. line, gives as good control as the more complex arrangement of Figure 1.

In checking the sensitivity of the relay control circuits described in the preceding paragraphs, one method used employed a Western Electric, type 14-B, thermistor (1) in conjunction with a 5-dial wheatstone bridge and a Leeds/Northrup, type 2500-a, galvanometer. A 2 cm. deflection of the light beam (1 meter from scale to galvanometer) on the scale corresponded to 0.04°F temperature change. This observation suggested the use of a photo cell relay circuit, activated by the galvanometer light beam in conjunction with a thermistor, as the temperature control element for a constant temperature bath. Since the thermistor has a negative thermal coefficient of resistivity of about 2% per degree Fahrenheit over the range of temperatures contemplated in the experiment, it makes a very sensitive control device. Another advantage of the thermistor as a control device is its very small thermal capacity.

The direct coupled amplifier circuit for the thermistor temperature control is shown in Figure 4, and was designed and constructed by the Campus Electronics Service at Purdue University. When light strikes the photocell, the grid of the first section of 6SN7 tube becomes less negative and the conduction of the section increases. At the same time the conductance of the second section of the 6SN7 tube decreases and the relay opens the heater circuit. When the light moves off the photocell the effect is reversed and heater power is restored. The schematic bridge circuit arrangement for the thermistor and galvanometer is shown in Figure 4-a. In order to make the system the most sensitive the light beam was directed on the edge of a mirror as shown in Figure 4-b. The light source was a 21 c.p. lamp mounted in a Leeds/Northrup lamp and scale reading device from which the scale had been removed.

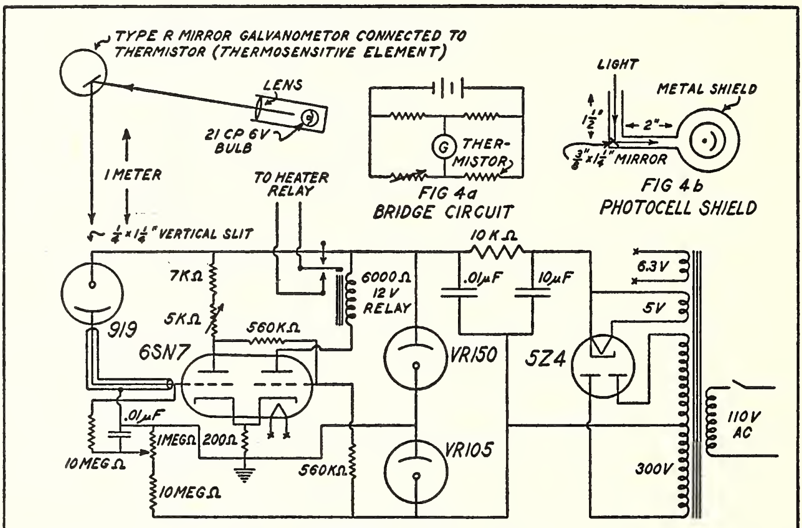

FIG 4 PHOTOCELL RELAY CIRCUIT

The optical system in Figure 4-b consisted of a metal cover for the photocell with a ¼″ x 1¼″ vertical slit for illumination. A ¼″ x 1¼″ x 2″ tube shielded the slit, with a ⅜″ x 1¼″ mirror set at 45° in the end of the tube. Another tube at right angles to the first completed the arrangement. The inside of the shield was covered with carbon black.

Tests employing this photocell relay control showed that the light deviated only about ±1 mm. from the zero point for "off" and "on" control, which is equivalent to a control of about ±0.002°F. The system is stable and operates with a minimum of attention.

Literature Cited

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