An Economical Resistance-Type Controller for Platinum-Wound Furnaces

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This note, a communication from the Development Laboratory of Johnson, Matthey & Co., Limited, describes a temperature controller for resistance furnaces with platinum alloy windings. The control signal is obtained by monitoring the resistance of the winding, so that no separate temperature-sensing element is required. Provision is made for control of the initial heating rate to avoid thermal shock.

In cases where the expense of a pyrometer controller is not warranted, and where the required long-term accuracy is no greater than say ±20°C. it has been customary to use an energy regulator which, of course, does not take direct cognisance of furnace temperature. It has, however, the advantage that the energy input may be set to a low level to bring the furnace temperature slowly up to say 600°C. When reset to the energy input required for the working temperature, it is necessary either to wait for several hours until the temperature has stabilised, or to overset initially and then to arrive at the required temperature by the tedious process of successive approximations. The arrangement to be described provides facilities for slow run-up, and also gives sufficiently close temperature control for most routine laboratory work.

The basic circuit diagram for temperature control is shown in Fig. 1. A "raw" rectified D.C. voltage is obtained from a current transformer in the furnace circuit. A voltage having a similar mean value is obtained from the A.C. mains through a further rectifier. These two voltages are connected in series opposition, and the circuit closed through the

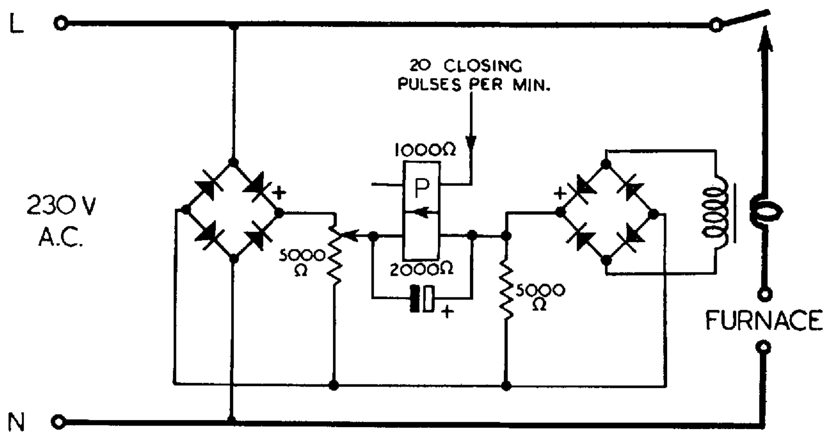

Fig. 1—Basic circuit diagram for temperature controller

coil of a sensitive polarised relay. A large capacitor shunts the relay coil to carry unbalanced ripple current. The relay is polarised so that it is operated whenever the voltage derived from the furnace current is higher than the reference voltage. At this time a contact maintains power to the furnace. When the furnace current falls sufficiently to equalise the voltages the relay will drop out. Since there is now no furnace current this would be the end of the sequence but for the existence of a restoring circuit consisting of a neon tube, resistor and capacitor. The neon discharge closes the polarised relay for a short period after a few seconds, and if the temperature is too low the relay remains closed until balance is again achieved between the voltages.

The relay voltage is not fully smoothed by its shunt capacitor, and the residual ripple serves to keep the relay "wetted". With the particular relay used the discrimination between "open" and "closed" conditions of the relay contacts is about .05 volt. The differential for relay operation is about 2 degrees at 1500°C. and is less at lower temperatures.

The "on" time is dictated by the thermal mass of the windings and adjacent refractory material, also, of course, by the power input at the temperature in question. In a typical case the furnace may remain "on" for two-second periods at 1000°C., and for twenty-second periods at 1500°C.

Possible Sources of Error

There are appreciable sources of error inherent to the arrangement, and these will be discussed in conjunction with the full circuit shown in Fig. 2. Switch positions 1 and 2 are used respectively to run the furnace from cold to about 200°C. in approximately ten minutes, and from 200°C. to 600°C. in approximately twenty minutes, at which time position 3 arranges the circuit for control at a set temperature. The first two positions give "on" pulses of about half a second spaced by ten seconds in the first case and two seconds in the second case. The timing on position 1 is arranged to give an idling temperature of about 600°C. if the furnace is left to stand-by on this setting.

The third position closes the sensitive relay (if it should be found open) every four seconds, when the balance condition found dictates whether or not it will remain closed. The sensitive relay R operates a slave relay C which is fairly slow to fall out. When balance is near relay R will tend to "dither", and its mark-to-space ratio will slowly fall until insufficient mean power is supplied to hold C which will release. When the furnace power is interrupted the voltage from the current transformer disappears, firmly opening relay R. In order to limit the relay de-energising current which flows in absence of furnace current a small rectifier is connected across the main coil of R. Also in parallel with the 2000 ohm coil of R is a thermistor whose purpose is to prevent excessive dissipation in the coil while running up to a high temperature, during which time there is a large "bridge" unbalance holding R closed.

The factors militating against accuracy of temperature control are as follows :

A. The current transformer uses a core of grain-oriented silicon steel run at a moderate flux density. There is, however, a small departure from linearity of relationship between furnace current and rectified voltage, which in the present model results in a fall of approximately 1°C. for each volt rise in mains potential.

B. Change in supply waveform will affect calibration in that the reference voltage will rise more rapidly with increase of form factor than will the current transformer output. This is unlikely to be of importance when using the mains supply directly; but the output waveform of

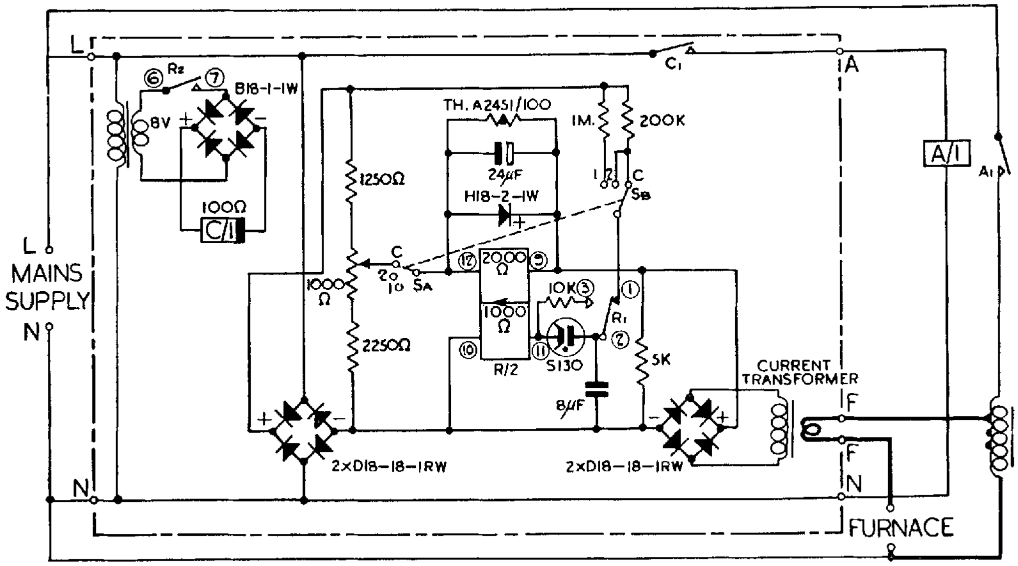

Fig. 2—Complete circuit diagram

certain stabilising transformers varies considerably with load, and can cause appreciable errors of control temperature.

C. A slow drift of calibration will occur as the furnace element wire volatilises during its life. This amounts to no more than about 1°C per 500 hours, and may be neglected since the suggested function of the present instrument is for short-term laboratory work.

D. Change in rectifier characteristics during life may cause a calibration drift of as much as 100°C in a typical case if aged rectifiers were used for one side of the "bridge" and new ones for the other side.

E. The design of tubular muffles is usually such that while they are being heated the rate of temperature rise of the central zone along the axis is more rapid than that of the end zones, although eventually all reach substantially the same temperature. Therefore, if the present controller is set to act at an element temperature of x, "cycling" will commence with the central region at a temperature higher than x and end regions lower than x. The disparity, which in a typical design may be about 20°C, will take several hours to disappear.

It is advisable to allow a little light from, say, a pilot lamp to fall on the neon tube so as to stabilise the breakdown voltage.

Conclusions

This device is cheaper to produce than most orthodox temperature controllers. The accuracy is sufficient for many purposes. The absence of a thermocouple or other sensing element in the hot zone is often advantageous. Occasional temperature checks must, of course, be made with a probe thermocouple, but the life and accuracy of the latter are not impaired by long subjection to high temperature or possibly inimical atmosphere.