A Rapid Temperature Recording Method

G. E. McIntosh and J. E. Brock, Purdue University

At the outset the general problem of this research was that of determining the thermal diffusivities of a number of metals. Of the several available methods the one selected was the periodic unsteady-state procedure as applied to one-dimensional heat flow down a slender rod.

Experimentally this method (Fig. 1) involves taking continuous temperature-time data at two points on a metal rod, one end of which is subjected to some arbitrary periodic temperature wave or pulse. The length of the time period and the distance between the two temperature measuring points are additional factors that must be accurately determined. With this data the phase lag of the temperature wave between the two points can be calculated and from this the thermal diffusivity is computed.

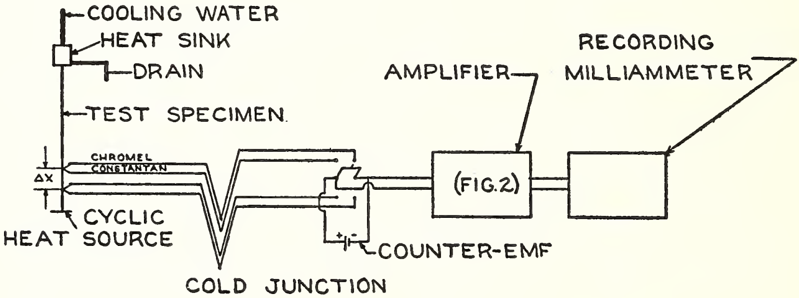

FIGURE 1
THERMAL DIFFUSIVITY TEST APPARATUS

With these considerations known it was immediately evident that at least two elements would be necessary for the measuring circuit; these components being a temperature-sensitive element and some kind of recording device. The thermocouple properties of low heat loss, quick response, durability, and low cost effectively dictated their use. In practice No. 36 chromel-constantan thermocouples were used. Selection of the recording device was considerably influenced by the availability of various types of meters. After investigating all the factors that were then known about the method to be employed, an Esterline-Angus Recording Milliammeter with 0-5 ma. scale was selected to do the recording.

Having determined the end points by selecting the thermal element and recording meter the next task, and actually the crux of the measuring problem, was to join the two components in a manner capable of giving satisfactory results. For this purpose an amplifier was introduced to magnify the thermocouple signal so that its power might be great enough to actuate the recording milliameter. Because of the uncertainty of dc. amplifiers it was decided to "chop" the input signal and use a conventional 60 cycle amplifier. Following an appreciable developmental period the amplifier circuit shown in Figure 2 was built and found to be satisfactory.

The functioning of the thermocouple amplifier is as follows: The emf. from the thermocouple is led to the Brown Converter which is actuated from the 6.3 volt filament tap as shown in Figure 2. The "chopped" 60 cycle alternating signal is transferred to the 6SJ7 tube by the 1:15 shielded input transformer. After the two stages of R-C coupled amplification the current is boosted by the 6L6 power tube and then rectified by the 6X5. This resultant dc. current is recorded by the recording milliammeter. (Values of the components are given in Table I.)

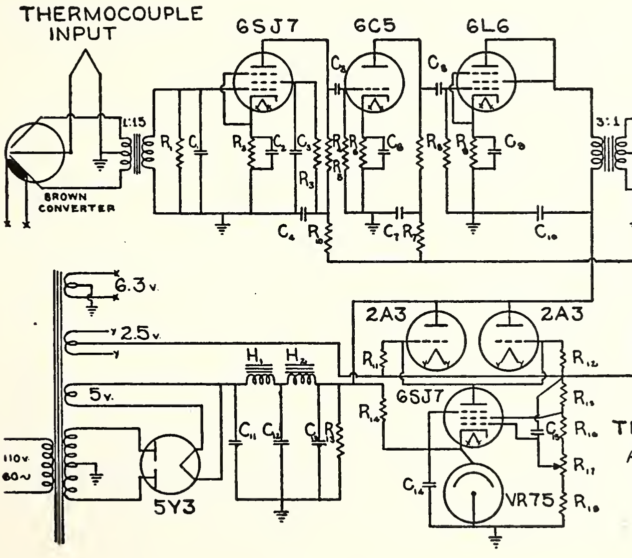

FIGURE 2
THERMOCOUPLE AMPLIFIER CIRCUIT

Due to the small input signal and gain factor of approximately 10^4 some difficulty was experienced in obtaining a stable output and low noise level. The output was successfully stabilized by installing a voltage regulator[1] in conjunction with the power supply. It should be noted that the voltage regulator feeds only the two amplifier stages because it was found that the 6L6 caused the output voltage to be lower than was desired. The noise level was reduced considerably by heavily

[1] Radio Amateurs Handbook, 25th ed., 1948, p. 244

TABLE I. List of component parts for the amplifier.

R_1, R_4, R_8, R_{14}	100 K	ohms
R_2	600	ohms
R_3, R_{11}, R_{12}	500 K	ohms
R_5	250 K	ohms
R_6	4000	ohms
R_7, R_{10}, R_{18}	5000	ohms
R_9	250	ohms
R_{13}	15 K	ohms
R_{15}, R_{17}	10 K	ohms
R_{10}	24 K	ohms
C_1	0.02	microfarad
C_2, C_6, C_9	10.	microfarad
C_3, C_5, C_8, C_{14}, C_{15}	.1	microfarad
C_4, C_7, C_{10}	20.	microfarad
C_{11}, C_{12}	8.	microfarad
C_{13}	40.	microfarad
H_1, H_2	10.0	henrys

shielding the "chopper" with a steel box and by installing a well-shielded input transformer.

Using this amplifier an input of 0.3 mv. gives full-scale output of 5 ma. on the milliammeter which corresponds to approximately 7.5° F. for chromel-constantan thermocouples. The output characteristic of the amplifier is linear up to 4.5 ma. Due to the limited range of the amplifier-recorder combination some source of bucking emf. is supplied at the input so that the unit actually operates over a 7.5° F. temperature range above any predetermined datum. In practice a potentiometer is used to provide the bucking emf. Work on the project is continuing and a new amplifier is being built which should show an appreciable improvement over the present model.

In a number of instances good data has been obtained using the arrangement as shown in Figure 1. It is expected that the experimental procedure will be much simplified and the results more reliable when two amplifiers are available for recording the temperature curves for both thermocouples simultaneously instead of averaging groups of readings for each couple, as is necessary with only one unit.