The 75/7-ohm attenuator is designed in such a way that its time constant, estimated to be less than 10^{-8} sec, is so low that practically no distortion of the current form occurs.

The gap is installed in a $90 \times 90 \times 90$ cm^3 box of hardboard, at one side of which an $f/1\cdot 5$ Leica camera is fixed, allowing the channels to be photographed from a distance of 45 cm.

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Hot Resistivity of Tungsten Wires

WHILE a number of more recent papers have dealt with the variation of electrical resistivity of tungsten with temperature, it remains a not uncommon practice to refer to the tables compiled by Langmuir and Jones[1] for estimating the temperature of a heated filament. These tables, in turn, were taken from earlier work by Zwikker, Worthing and others.

In an investigation into the progress of changes to the electrical parameters of tungsten filaments in thermionic devices, which will be published later, it was soon found that the Langmuir values can lead to errors. For example, at the operating temperature of valve heaters (about 1,100° C), errors of the order of 100° C were common. Furthermore, these errors were not consistent from heater to heater so that, in experiments where heater temperatures were critical, many results could be invalidated by undetermined differences.

Apart from the conventional precautions in measuring resistances, the determination of the resistance of tungsten wires imposes the need to maintain a rigidly controlled temperature, and we have found it necessary to use an a.c. bridge with heating currents not exceeding 1 m.amp on fine wires.

Many expressions have been proposed for relating resistivity with temperature. However, most of these are applicable over but limited temperature ranges, and in our experience, for tungsten, the most useful remains the polynomial of the form:

$$R_T = R_0[1 + \alpha T + \beta T^2 + \gamma T^3]$$

For temperatures up to about 100° C, terms above α can be neglected and γ can be neglected below about 1,200° C, for a precision of about 1 per cent. If Jones and Langmuir's values are plotted, they are found to follow not a smooth curve, but a sequence of short lines, indicating perhaps that a number of the values are interpolated estimations. The 'constants' from their results are roughly:

$$\alpha = 4\cdot 8 \times 10^{-3};\ \beta = 1 \times 10^{-6};\ \gamma = 0\cdot 5 \times 10^{-9}$$

Examining a large number of samples of wire and wire products from a wide range of sources, we have found the values of these parameters to vary: especially α and β seem sensitive to the influential factors of purity and work hardening and α has been found to lie between $3\cdot 9$ and $4\cdot 7 \times 10^{-3}$ and β between $0\cdot 5$ and $2\cdot 0 \times 10^{-6}$: γ has averaged near $-0\cdot 5 \times 10^{-9}$. The room-temperature resistivity, correspondingly, is higher than Langmuir's by about 10 per cent.

This makes it necessary, for really precise work, to determine the characteristics of each sample. But for temperatures up to 1,200° C if a precision close to 1 per cent is adequate, a simplified procedure can be adopted. The resistance at 0° C and 100° C is determined and an average value of $1\cdot 2 \times 10^{-6}$ is taken for β. From this α can be derived and a good approximation up to about 1,200° C can be obtained. Inclusion of the value of γ above permits extension of this range by several hundreds of degrees. It is usually not difficult to determine R_0 and R_{100} even on a completed device, and if there is reason to believe that the characteristics may vary throughout the experiment, rechecks can be made at appropriate intervals. These serve to track changes in state of the wire—for example, by annealing, or contamination—but also to discriminate between such changes and dimensional alterations.

On no samples of fine wire have α's been found as high as Langmuir's $4\cdot 8 \times 10^{-3}$: more commonly α has fallen between $4\cdot 1$ and $4\cdot 3$, and coils tend to have lower values than straight wire.

This lowering of the temperature coefficient is partly due to the consequences of working. While considerable recovery is effected by relatively low-temperature annealing, progressive changes have been observed to continue up to the highest temperatures studied (2,600° C), so that it is not safe to assume that a sample treated, say, at 1,800° C, has been stabilized.

Purity also plays a part: the deliberate addition of trace impurities made to most commercial wires influences the electrical characteristics[2], but the pick up of trace impurities inevitable in the working of materials from ingot to wire is demonstrated in a progressive fall in α (0–100) from the unworked metal (about $4\cdot 7 \times 10^{-3}$) to fine wire (about $4\cdot 4 \times 10^{-3}$ fully annealed). As may be expected, some increase in α is obtained if wire is heavily etched before annealing, illustrating the superficial nature of the contamination.

It is the interplay of these factors which makes imperative the actual measurement of the electrical characteristics of tungsten wire components for critical work, and this applies especially to temperature determinations.

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