A NEW ABSOLUTE NOISE THERMOMETER AT LOW TEMPERATURES[1]

H. J. Fink[2]

ABSTRACT

If three resistors, which are kept at different temperatures, are arranged in form of a π network and if two of the thermal noise voltages appearing across the π network are multiplied together and averaged with respect to time, then under certain conditions the correlation between those voltages can be made zero. This condition is used to calculate the temperature of one noise source provided all the resistance values and the other temperatures are known. A noise thermometer of this kind was constructed which is capable of measuring temperatures below approximately 140° K. The boiling points of liquid oxygen and liquid nitrogen were determined absolutely within 0.2%. Between 1.3° K and 4.2° K the thermometer had to be calibrated due to errors arising in the equipment and the measured temperatures were then accurate within ±1%.

I. INTRODUCTION

This paper deals with the construction of a thermometer which makes use of the thermal fluctuations of voltage across an impedance to measure absolutely temperatures below approximately 140° K. Preliminary investigations were carried out for such a device to measure accurately temperatures in the liquid helium region.

According to Nyquist's (1928) law the mean-square voltage fluctuations arising from the thermal agitation of the electrons across an impedance, Z, are given by:

$$\overline{v^2} = 4kT\,\mathrm{Re}[Z]\,p(f, T)\,df, \quad (1)$$

where k is Boltzmann's constant, T the absolute temperature, $\mathrm{Re}[Z]$ is the real part of the complex impedance, Z, $p(f, T)$ the Planck factor, and df the frequency interval in which the measurements are performed. The above formula can be derived from the equipartition law and the second law of thermodynamics and the available noise power is a universal function of the frequency and the absolute temperature (see also Van der Ziel 1954). Equation (1) has also been proved for models which describe the random motion of the electrons in a conductor (Bernamont 1937; Bakker and Heller 1939; Spenke 1939). Nyquist's theorem can also be proved for the one-dimensional form of black-body radiation (Burgess 1941) which is received by an antenna kept in a sphere at uniform temperature. The thermodynamic method has the merit that it is independent of the mechanism causing the noise.

A number of papers have been published (Lawson and Long 1946; Brown and MacDonald 1946; Gerjuoy and Forrester 1947; Cook, Greenspan, and Wussler 1948) which suggests the possibility of using thermal fluctuations of

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Contribution from the Department of Physics, University of British Columbia, Vancouver, British Columbia.
[2]Present address: The Clarendon Laboratory, Oxford, England.