NOISE THERMOMETRY FOR VERY HIGH PRESSURE USE

Ikuya FUJISHIRO, Hisao MII and Masafumi SENOWO

Nagoya University, Nagoya (Japan)

ABSTRACT

The present paper describes a new method of balancing the Johnson noise of a sensing resistor with that of a reference resistor in the noise thermometry. In place of the conventional technique which measures the mean square voltage of the thermal noise, the present method is substantially to count the number of pulses exceeding an established constant gate voltage for a unit duration of time.

When an appropriate constant value was chosen as the gate voltage, an improved sensitivity in balancing both the noise voltages was obtained. The accuracy of this thermometry is such that 0.1 % at room temperature and 0.3 % at 900 K both at an atmospheric pressure.

The new method was applied to correct the output of the thermocouple imbedded in a girdle-type high pressure cell.

RÉSUMÉ

Nous décrivons ici une méthode thermométrique nouvelle consistant à équilibrer le bruit de Johnson d'une résistance détectrice à celui d'une résistance de référence. Au lieu de mesurer suivant les techniques conventionnelles le carré moyen de la tension du bruit thermique, la méthode que nous proposons revient à compter le nombre d'impulsions qui dépassent un seuil déterminé, au cours de l'unité de temps.

Après avoir choisi une valeur convenable du seuil, la sensibilité a été améliorée en équilibrant les deux bruits de fond. La précision de cette technique de thermométrie est voisine de 0,1 % à la température ambiante, 0,3 % à 900 K, sous la pression normale. Nous avons utilisé ce procédé pour corriger le signal du thermocouple introduit dans la cellule haute pression frettée.

1. Introduction

It is well known that the output of a noise thermometer is independent of pressure and free from any contamination of a sensing resistor within a high pressure and high temperature environment. Several authors have made experimental investigations of the noise thermometer [1-4].

The present paper describes a new method of balancing the Johnson noise of a sensing resistor with that of a reference resistor. The balancing point of the Johnson noises in the sensing and the reference resistors was detected by counting the rate of pulses surpassing a constant gate voltage. By means of this method, pressure correction was made to the outputs of thermocouples embedded in a girdle type high pressure cell.

2. Experiment

The absolute temperature T_s of a sensing resistor (the real part of an impedance : Re (Z_s)) is determined by means of equalizing a mean square voltage $\overline{v_s^2}$ of the sensing resistor with that $\overline{v_r^2}$ of a reference resistor Re (Z_r). The sensing resistor is expressed in a parallel combination of resistance R_s and capacitance C_s.

According to Nyquist's law, $\overline{v_s^2}$ is given by

$$\overline{v}_s^2 = \int_{f_1}^{f_2} 4kT_sR_s/(1 + (2\pi f C_s R_s)^2)\, df\,, \qquad (1)$$

where k is Boltzmann's constant, f_1 and f_2 lower and upper frequency limits of the channel, and f the frequency of the measurement. If $\overline{v_s^2} = \overline{v_r^2}$, T_s is written as

$$T_s = \frac{\int_{f_1}^{f_2} R_s/(1+2\pi f R_s C_s)^2)\, df}{\int_{f_1}^{f_2} R_r/(1+2\pi f R_r C_r)^2)\, df}\, T_r \qquad (2)$$

If the two channels of measurement are equivalent, and the time constants R_sC_s and R_rC_r are made equal, T_s is expressed as T_rR_r/R_s.

2.1. *Balancing of the noise signal.*

The following method was adopted to detect the balance between $\overline{v_s^2}$ and $\overline{v_r^2}$. The thermal noise was amplified by a low noise preamplifier with double triode (7308) cascode circuits, and was discriminated so as to pass the pulses exceeding an established constant gate voltage v_g by means of the Schmitt circuit. $\overline{v_s^2}$ was balanced to $\overline{v_r^2}$ by integrating the pulse counts for a unit duration of time for both the discriminated noise pulses of $\mathrm{Re}(Z_s)$ and $\mathrm{Re}(Z_r)$. Since the thermal noise is a white one, the number N of pulses, exceeding the gate voltage v_g for a unit time, is expressed as follows [5].

$$N = \sqrt{\frac{1}{3}(f_1^2 + f_1 f_2 + f_2^2)}\, \exp\left(-\frac{v_g^2}{2\overline{v_s^2}}\right) \qquad (3)$$

This relation is shown by the broken line in Fig. 1 in which f_1 and f_2 are assumed to be 20 kHz and 300 kHz respectively, and C_s is to be 200 pF. If we take about 700 Ω as the equivalent noise resistance of the preamplifier used, the observed value agrees to the theoretical one.

The relative error $\Delta R/R$ of the observed values is estimated from the statistical error of the fluctuation of N. This relation serves to find the appropriate range for the sensing resistance.

Care must be taken to ensure that both the amplification and detection of the two noise signals are identical. This was accomplished by employing the same channel, which carried the two signals in time separation. In this pulse-counting method, the accuracy of the contact times (the duration of the integrating time) governs the total accuracy of the thermometry. The solid state switching circuit employed here is controlled by the crystal clock with the relative error of 2×10^{-5}.

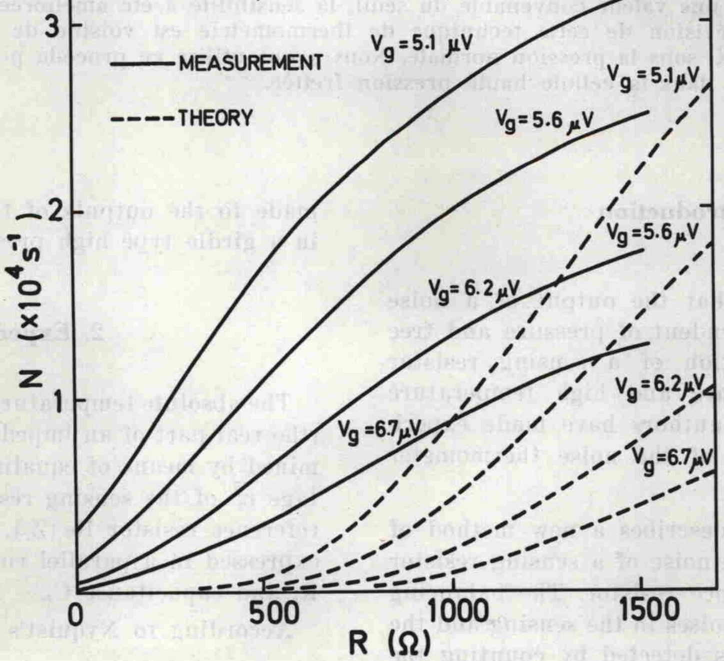

Fig. 1
Relationship between input resistance and pulse count rate.