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The Way to Measure the Surface Temperature through PbS-Photoconductive Cell

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Abstract

A pyrometer which was built for the measurement of comparatively low temperature is described.

The detector of the radiative energy is the recently developed PbS cell, and the amplifier system was specially designed for the purpose.

1. Introduction

As Planck's Law shows, the energy which radiated from a heated object can be represented by the formula

$$J_{\lambda d}=C_1/\lambda^5(e^{C_2/\lambda T}-1) \text{ [1]},$$

so the total energy integrated from 0 to λ is

$$\underset{0\to\lambda}{E}=C_1 T e^{-C_2/\lambda T}(1/\lambda^3\cdots\cdots)/C_2 \text{ [2]}.$$

Consequently when we use two filters which intercept all radiation of waves longer than λ_1 and λ_2 respectively, the response ratio R of the two can be given by the following formula,

$$R=\lambda_1^3 e^{C_2/T}(1/\lambda_1-1/\lambda_2)/\lambda_2^3, \quad \lambda_1<\lambda_2.$$

When the emissivity of this object does not show any large change, around λ_1 and λ_2, the surface temperature can naturally be directly measured by our measuring of R. This value is independent of the distance between the object and its light source, or the exposed time duration.

2. Method of measurement

For the detector we used the PbS cell which was an improved type of infrared detector used in the measurement of precipitable water [3]. This PbS cell is a photoconductive cell which has the largest near infra-red sensitivity, and the sensitive part of which consists of a thin film (about 1 μ thick) of PbS which is oxygenated and heated and consequently takes the form of mixed tiny crystal structure of PbS and PbO. And when an infra-red ray falls on the sensitive part, photon is issued forth and the photo-conduction takes place. The electrode structure is slit-form: and the resistance between the two electrodes is about 0.1~0.5 MΩ and the time constant of the cell is 10^{-5} sec, and if within the audible range this set is used with the alternating current amplification system, its character is always the same within 5db. Its noisiness is one of its weak points, and if with 1 cps of free path band of an amplifier at low frequency it exceeds 10 μV. But at 1000 cps it is within 10 μV.

With the change of temperature the cell changes its resistance like a half conductor. Also in order to prevent the noise the ceil is cooled by dry-ice.

The amplifier here used is illustrated in Fig. 1. The frequency of chopper is

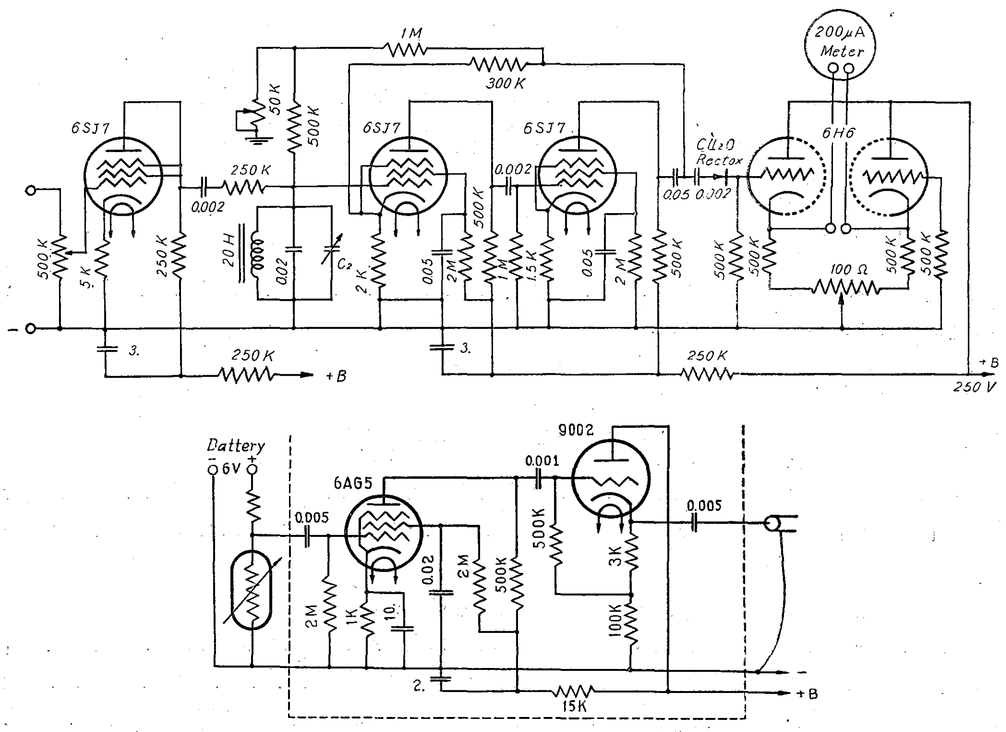

Fig. 1. Amplifier circuit.

360 cps, and of cps of this grade the negative feed back (NFB) type is the best one; but during our measurement the LC type is used, for only one of this type is sufficient for the purpose of avoiding hum. By some adjustment of the NFB type we can lower the free pass band till the degree of 0.5 cps. Including preamplifier the total gain comes to 80~120 db. This structure chiefly follows the Cashman type [4]

and its formation is comparatively simple. Its adjustment was done by one capacity in a simple way, and its character has brought about a rather good results as shown in Fig. 2.

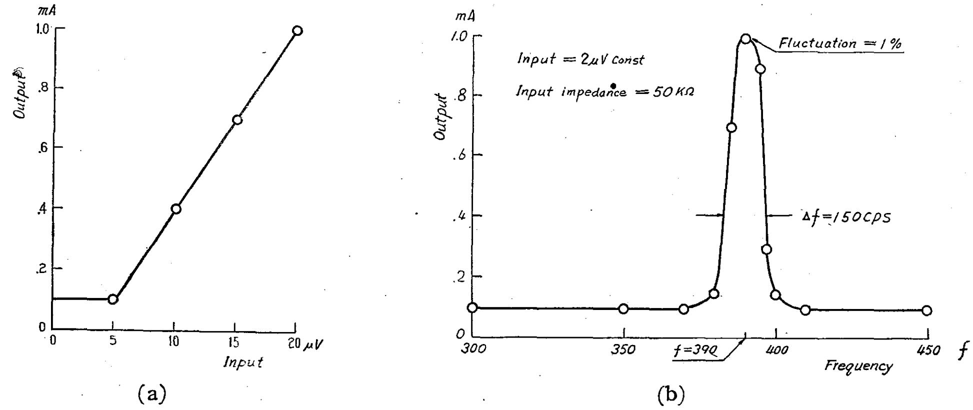

Fig. 2. Characteristic curves.

The heat noise for incoming impedance 1 MΩ (resistance of cell) is 1.3×10^{-1} volt at the time of $\Delta f=1$ cps and $0.4\,\mu$V at the time of 10 cps in proportion to $\sqrt{\Delta f}$ respectively. But it entails a noise level several times as high a noise formed from the vibration effect of frequency f_0 and the hum which is picked up by L. The former can be expelled by the selection of f_0 through D.C. heating of a filament and shield.

Combining this cell with an amplifier at the time of measurement we placed chopper near the subject and a mica filter ($\lambda=2.75\,\mu$) and the Mazda's infra-red filter in front of the cell and thus tried to obtain its signal ratio.

3. Result of the measurement

Our measurements took place in the chamber of carbonization and the heat keeping room and at the surface of the accession pipe of the Tokyo Gas Company. Actually, the temperature in the chamber of carbonization is measured with photo pyrometer, or chromel-alumel thermometer and at the heat keeping room with chromel-alumel thermometer and at the surface of the accession pipe with bolometer. Our equipment singly supersedes the above three. Moreover it has the following two advantages: (1) We need not put the instruments directly on the heated object as it necessary in using the chromel-alumel apparatus; (2) We need not take the solid angles on the surface into consideration as is necessary in using the ordinary photopyrometer.

And the results of the measurement in the chamber of carbonization, the response ratios are

1.02, 1.03, 1.03, 1.08, 1.04/1.04,

so the average temperature is 1090°C. In heat keeping room, the response ratios are as follows:

1.05, 1.05, 1.06, 1.08, 1.08/1.055,

so the average temperature is 7150°C. In the case of the accession pipe the frequency change of signal ratio is large, so if we get temperatures of each item, the results are as follows:

R	T°C
1.61	110
1.41	182
1.50	132
1.48	133
1.52	125

If we compare the change in the heat keeping room with that in the chamber of carbonization, the variance ratio is as follows:

$$F=0.00055/0.0023=2.3913<F^{n_1=4}_{n_2=4}\ (0.05)=6.39,$$

and so although we cannot say there is a significant difference in the heat variation of them both, it must be taken into consideration that the chamber of carbonization had just been changed with coal and was not yet ignited. Therefore the fluctuation of its temperature may be larger than the temperature fluctuation in the heat keeping room.

Again the variety of the surface temperature of the accession pipe was so large (182°~110°C), for the wind blew rather hard and with considerable gustiness from the sea on that day (The place was near Tokyo Bay). And if we compare it with the temperature variation in the heat keeping room by signal ratio,

$$F=0.003125/0.00023=13.589>F^{n_1=4}_{n_2=4}(0.05)=6.39.$$

Then we can find there was a considerable difference. Even considering the effect of the wind variation, the differences are significant at 10% of significant level between the temperature in the chamber of carbonization and in the heat keeping room and at 0.1% of significant level in the accession pipe.

The above is only a test of measuring temperature through PbS-photoconductive cell, but if we contrive this method for each actual case, we shall be able to measure temperature more accurately and more automatically, and the method shall consequently contribute to raise efficiency for heat control.

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References

[1] AMERICAN INSTITUTE OF PHYSICS, 1941 : Temperature, Its Measurement and Control in Science and Industry. New York, p. 19.

[2] GIBSON A.F., 1951 : A Two-colour Infra-red Radiation Pyrometer. Journal of the Scientific Instrument, **28**, p. 153.

[3] KAMIYAMA K., EGUCHI M., YATABE Y. and MORIGUCHI M., 1951 : Determination of Precipitable Water in Air by Near Infra-Red Spectrometry. Geophysical Magazine, **23**, p. 59.

[4] KUIPER G.P., WILSON W. and CASHMAN R.J., 1947 : An Infra-red Stellar Spectrometer. Astrophysical Journal, **106**, p.243.