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Wide-Range Thermal Convection Manometer

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A pressure gauge covering both the Pirani and liquid manometer ranges, easily adaptable for continuous recording, has been devised and successfully operated. In the pressure range of the Pirani gauge, the working principle is that of the thermal conductivity at low pressures; at higher pressures, on the contrary, a convection stream takes place, which depends on pressure and determines temperature variations in the filament. Experimental results give maximum sensitivity in the range 0.5–5 torr and a reasonable sensitivity for pressures up to one atmosphere.

INTRODUCTION

THE upper limit of the pressure range covered by the conventional Pirani gauge depends on the ratio of the gap-space between the hot wire and the cold wall to the mean free path of the molecules. Common designs cover a range extending from 10^{-4} to 1 torr.

Rittner[1] described a gauge in which the upper limit attained was 15 torr, with a gap-space of 1 mm. Leck and Martin[2] proposed a gauge working up to 10 torr.

At higher pressures, the Pirani gauge loses its sensitivity, because thermal conductivity does not depend on pressure. The temperature of the wire is, in conventional designs, *ca* 200°C, and the heat transfer due to convection is negligible, the temperature of the wire remaining unaltered by pressure changes.

If, however, the influence of convection is increased, e.g., by increasing the temperature of the wire, it will become sensitive to pressure changes, even for high values of the latter.

Johnson[3] has proposed recently a manometric device which operates on this basis, the heating element being a horizontal wire placed between two differential thermocouples. The author reports good sensitivity for pressures above 20 torr.

Although the theory of the phenomenon is rather complex, many papers have appeared dealing with the case in which both the convection and the temperature gradient have the same direction. Langmuir[4] and Brody and Körözy[5] have studied the case of a horizontal hot filament at pressures up to 1 atmos.

[1] R. Rittner, Rev. Sci. Instr. 17, 113 (1946).
[2] J. H. Leck and C. S. Martin, J. Sci. Instr. 33, 181 (1956).
[3] J. B. Johnson, Rev. Sci. Instr. 27, 303 (1956).
[4] I. Langmuir, J. Am. Chem. Soc. 37, 417 (1915).
[5] I. Brody and F. Körözy, J. Appl. Phys. 10, 584 (1939).

We have resorted to convection to extend the range of sensitivity of a Pirani gauge, but in our case, the convection is normal to the temperature gradient, having obtained a manometer covering the Pirani range, being also sensitive for higher pressures.

EXPERIMENTAL RESULTS

Figure 1 shows the construction of the gauge. It differs from the conventional Pirani in the intermediate jacket J, which serves to assure the formation of a couple of streams thermally isolated. Since the tempera-

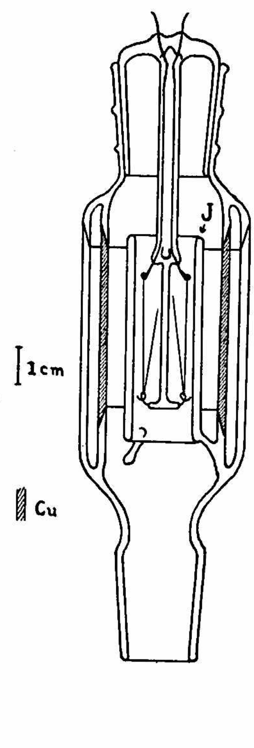

FIG. 1. Schematic design of the convective manometer.

ture of the filament is usually *ca* 1000°C, water cooling is not essential. Nevertheless, it seems advisable to add an external glass wall that protects the cold wall from sudden changes in temperature.

If glass is also used for the cold wall, the device exhibits a delay time of response of one minute or even more. If, on the contrary, a metallic cold wall is used, the delay time is reduced to a few seconds.

The resistance of the filament, and consequently its temperature, was estimated by measuring the current passing at constant emf, with a sensitive ammeter. The sensitivity obviously increases with the emf, as well as the range in which it fulfills practical requirements.

Tungsten was mostly used for the filament as it has a high-resistivity coefficient, but it should be noted that it is readily oxidized by air when heated at intermediate pressures; hence, platinum is preferable since it remains unaltered when heated, although its resistivity coefficient is not so high.

The gauge was calibrated against an absolute McLeod manometer, with air and hydrogen. Figure 2 shows the variation of the resistance of the filament with pressure, for both gases. The marked difference is presumably due to both the great difference in thermal conductivity and in viscosity between air and hydrogen. In any case, the instrument should be calibrated with the gas whose pressure is to be measured.

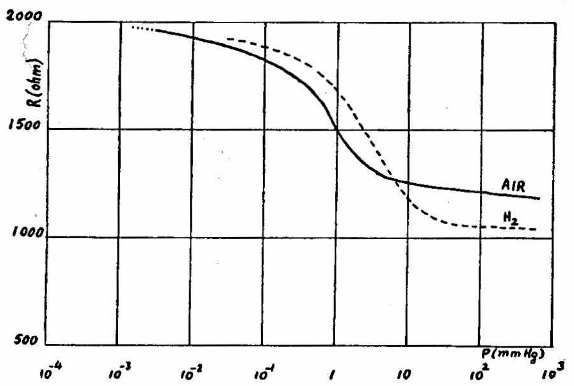

FIG. 2. Variation of the filament resistance with pressure for air and hydrogen.

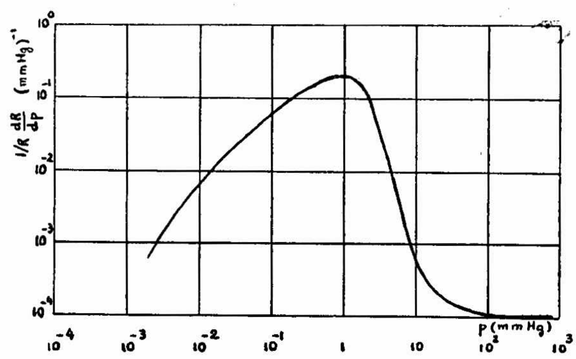

FIG. 3. Variation of the sensitivity, expressed as $(1/R) \times (dR/dp)$, as a function of pressure for air.

The sensitivity for air for a filament of 345 ohm of cold resistance, was found to be

200	ohm/torr	at	1 torr
10	ohm/torr	at	5 torr
0.07	ohm/torr	at	700 torr

Figure 3 gives an account of these results.

Finally, it should be noted that this device is sensitive to position of the axis with respect to the vertical line. Maximum sensitivity is obtained when the device is vertical, but the sensitivity does not appreciably vary for an angle of deviation less than *ca* 5°. Notwithstanding, if this angle is increased, the sensitivity rapidly falls down to a minimum value. It is then important to place the manometer as vertical as possible, but a visual estimation is normally sufficient.