field is satisfactory for this purpose. The equipotentials measured for this geometry are shown in Fig. 2.

This model is not a precise duplication of the cylinder in a uniform field because the imposed equipotentials were sufficiently close to the cylinder to affect the field distribution in the region of the cylinder. In this case the dielectric constant of the cylinder is 8.3 times the dielectric constant of the surrounding medium. The dots on the curves are measured points. The conformation of the experimentally measured points to smooth curves shows the uniformity of the films. Flow lines for this geometry were determined by measuring the equipotentials for a conjugate model; that is a cylinder with a dielectric constant of unity immersed in a medium with a dielectric constant of 8.3.

Reproducibility of the models is demonstrated by Fig. 3, where data collected from the equipotential and the flow line models are superimposed to make a complete field plot. The perpendicular intersections between the flow lines and the equipotentials, and the regularity of the rectangles formed, is a most striking confirmation of the accuracy of this technique.

ACKNOWLEDGMENTS

The author appreciates the suggestions of R. Lucy and the help of J. Donohoe, F. Clauson, and D. Baker.

THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 36, NUMBER 2 FEBRUARY 1965

Stable Pirani Gauge for Precision Pressure Measurements

E. J. Hughes* and A. D. McQuillan

Department of Physical Metallurgy, University of Birmingham, Edgbaston, Birmingham, England

(Received 13 April 1964)

A modified form of the Pirani gauge has been constructed in which a potential difference between two extra electrodes attached directly to the heated filament is measured rather than the change of resistivity of the whole filament assembly. In this way changes in the long term stability, which are a common feature of most Pirani gauges, can be avoided. The modified instrument may be relied on to maintain its stability after calibration for very long periods, and hence it can be used as a precision gauge for the accurate measurements of pressures in the range 1 to 10^{-3} mm Hg.

In the pressure range 1 to 10^{-3} mm Hg, the Pirani gauge in many ways is an excellent measuring instrument. Since, once calibrated, the gauge allows pressure determinations to be made in terms of simple electrical measurements, it is easier to operate than a McLeod gauge, and allows the coldtrap for the collection of mercury vapor to be eliminated. Furthermore, since it does not depend on the ionization of the gas, the pumping action associated with such gauges is avoided. Normal Pirani gauges consisting of only a heated filament, suspended between current leads and in which the change of resistance of the assembly with gas pressure is effectively determined, are subject not only to slow drifts, but also to sudden, marked, and quite unpredictable changes in calibration. As the heated filament is usually made from tungsten wire, operated at a low temperature, the instability cannot be due to an aging process in the wire. The alterations in calibration can, therefore, only be caused by changes in the contact resistance between the filament and the current leads. The effect of changes in contact resistance can be reduced by increasing the resistance of the filament, but this involves using very long filament wires and complicates the construction of the gauge. It was felt that a more satisfactory way of avoiding these difficulties was to attach two extra potential leads to the filament and to measure the resistance of the filament by a precision potentiometric method.

The practical problem resolves itself into the development of a means of joining potential contacts to the heated filament of a Pirani gauge so that they will be rigidly attached to the filament, and will have sufficiently small dimensions not to conduct excessive amounts of heat away from the filament. It was found that no method involving the use of small tungsten hooks mechanically linked to the filament was capable of yielding a gauge able to withstand mechanical shock without loss of stability. It was essential, therefore, to find some method of welding the potential contacts to the filament.

Although there are undoubtedly many solutions to the problem, in our case the one found to be perfectly successful was to anchor fine nickel wires to a tungsten filament by a very small blob of solder. The filament itself consisted of a helix of thin tungsten wire the ends of which were welded to two rigid current leads so that the filament was stretched tautly between them. The potential leads were, like the current leads, rigid copper rods to the top of which short lengths of nickel wire 0.13 mm in diameter had been

* Present address: Materials Research Corporation, Orangeburg, New York.

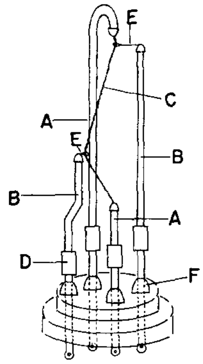

FIG. 1. Schematic drawing of the filament assembly. (A) Current leads, (B) potential leads, (C) tungsten filament, (D) copper sleeves, (E) nickel potential contacts, (F) glass/metal seals.

joined. The nickel wires were tinned with solder and bent into the form of tight hooks. The filament, although already taut, was further extended elastically and hooked around the nickel potential contacts. Once in position with the two potential contacts attached at the extreme ends of the filament, the contacts were anchored by applying a small soldering iron to the point of contact of the nickel and tungsten wires. The final filament assembly is shown in Fig. 1.

In the experimental gauge, the whole filament assembly is attached to a brass disk through which the various electrical connections are brought by means of small glass/metal seals. The disk, in turn, is mounted inside a brass cylindrical envelope 2.5 cm in diameter and 12.7 cm long using a standard O-ring seal. In this way any adjustments and modifications can readily be made to the demountable filament assembly. By using a silicon O-ring, the whole gauge can be effectively degassed by baking before use. The assembled gauge is shown schematically in Fig. 2.

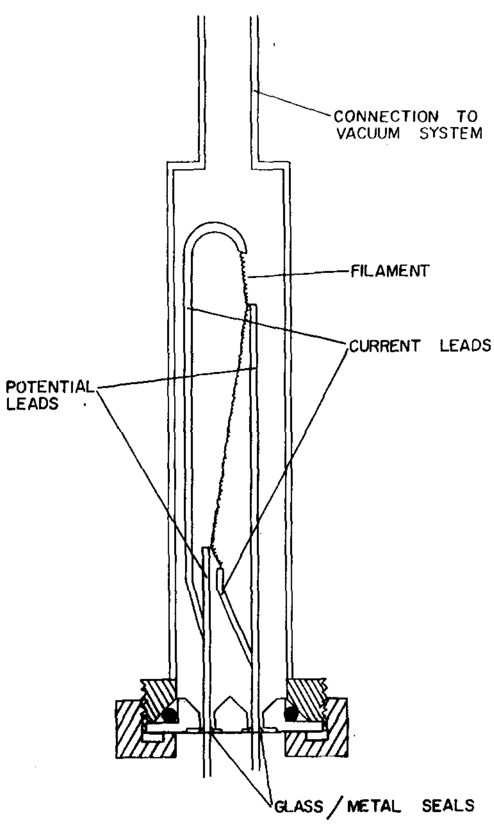

FIG. 2. Cross section of the gauge showing arrangement of the filament assembly.

Since a potentiometric rather than the normal Wheatstone bridge method of measuring changes in filament resistance has been adopted, it is not possible to use a separate pre-evacuated compensating gauge to allow for effects due to changes in ambient temperature on the measuring gauge. Compensating methods are, in any case, not very satisfactory for obtaining accurate measurements of pressure, and it is usually better to enclose the Pirani gauge in a constant temperature enclosure. In our case the enclosure was held at 25.7°C.

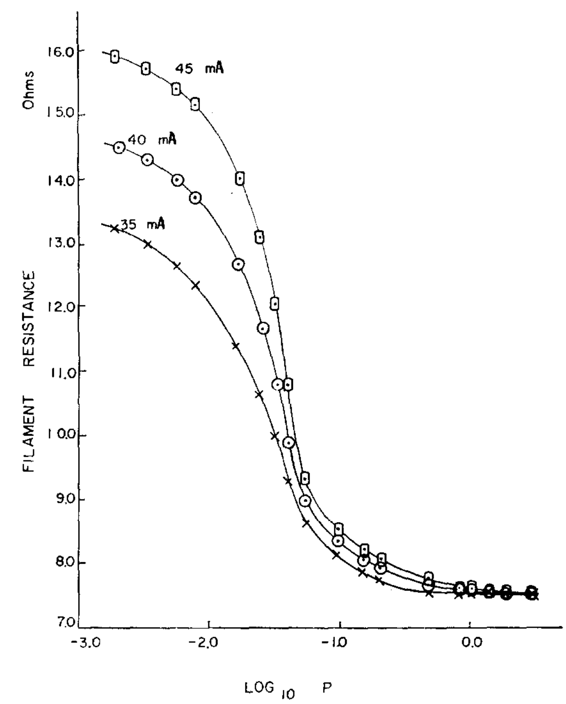

FIG. 3. Calibration curves of the resistance of the filament as a function of gas pressure for hydrogen at three values of the filament current. P in mm Hg.

A typical set of calibration curves for the resistance of the gauge filament as a function of gas pressure using hydrogen is given in Fig. 3. For these measurements the filament current was maintained at a constant value and was checked potentiometrically before each reading. The points on the curves are the aggregate of three separate determinations carried out at different times. In a period of almost continuous operation for three years, the gauge calibration has not changed by a detectable amount.