THE
REVIEW OF SCIENTIFIC
INSTRUMENTS

*VOLUME 33, NUMBER 8* *AUGUST 1962*

# Vibrating Vane, Absolute Gas Pressure Gauge

H. V. NEHER
*California Institute of Technology, Pasadena, California*

(Received May 15, 1962)

An oscillating rectangular vane suspended by a fine quartz fiber is used to determine the absolute pressure of the gas in which it is located. Aside from being an absolute instrument, the advantages of such a device are (1) simplicity, (2) the fact that it does not change the pressure when an observation is made as do many other types of gauges, and (3) the absence of a heated filament which may decompose the gas under study.

A RECENT article by Beams *et al.*[1] describes an absolute method for determining the pressures of gases when the mean free path of the molecules is greater than the dimensions of the apparatus. The gauge agrees with the usual Alpert ionization gauge down to pressures of $5\times10^{-8}$ mm Hg. The method consists of measuring the decrease in rotational speed of a small magnetically suspended rotor spinning at a very high angular velocity. Aside from the numerous disturbing effects which can affect the result, the system is not very practical because of the complicated auxiliary apparatus.

Other mechanical types of gauges have been described in the literature. In particular, the decrement type of quartz gauge has often been used, especially where the decomposing effect on the molecules of the gas, due to a hot filament, would be serious.[2] None of the gauges of this type, apparently, has sufficiently simple geometry to permit a calculation of the pressure for a given damping, using the simple kinetic theory of gases.

In the process of making an apparatus to measure the pressure of light,[3] it was found that the same device was also useful in determining the gas pressure in a vacuum apparatus.

The details of construction are described in reference 3. For convenience the drawing in that article is reproduced here in Fig. 1. An essential feature is the fact that the torsion constant of the suspension is determined by initially fastening to the moving system a quartz fiber of known mass and dimensions which can later be snipped off. A measurement of the period, with and without this additional piece of quartz, allows both the moment of inertia and the torsion constant to be determined.

The 0.5-$\mu$-thick aluminum vane is fastened to the quartz fiber rectangular frame by means of colloidal graphite. The small quartz mirror allows deflections to be measured easily with a light beam or telescope and scale. All quartz parts are fused together and hence the whole device may be heated to temperatures of 400 to 500°C without damage.

The application of kinetic theory to the problem is quite

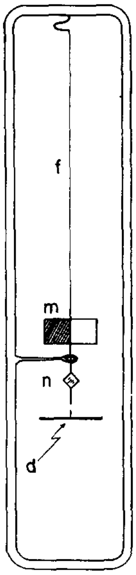

FIG. 1. The oscillating system is mounted in a quartz frame which in turn is contained inside the apparatus where the gas pressure is to be determined. The fiber f is approximately 1 $\mu$ in diameter. The torsion constant is determined from the two periods, (1) when the extra quartz piece d is attached and (2) when it is detached. Because of the simple geometry, the damping in a gas at a given pressure may be calculated and the instrument becomes an absolute pressure gauge.

---

[1] J. W. Beams, D. M. Spitzer, Jr., and J. P. Wade, Jr., Rev. Sci. Instr. **33**, 151 (1962).

[2] For a discussion of various types of decrement gauges, see S. Dushman and J. M. Lafferty, *Scientific Foundations of Vacuum Technique* (John Wiley & Sons, Inc., New York, 1962), 2nd edition.

[3] H. V. Neher, Am. J. Phys. **29**, 666 (1961).

simple, provided the mean free path of the molecules is large compared with the dimensions of the apparatus. For a rectangular vane of width $b$ and length $2l$, vibrating about an axis lying in the plane of the vane as shown in Fig. 1, the logarithmic decrement is given by

$$\lambda = (4/9)\ (nmvbl^3T/I), \tag{1}$$

where $n$ is the number of molecules/cm$^3$, $m$ is the mass of a molecule of the gas, $v$ is the root mean square velocity of the molecules, $T$ is the period of oscillation, and $I$ is the moment of inertia of the system.

For the system in tube No. 3 in reference 3, the pressure for air is given by

$$p = 1.04\times 10^{-4}\lambda \quad \text{mm Hg}.$$

In a particular case, the pressure in a demountable vacuum system, using an ionization gauge, was measured to be $5.0\times 10^{-5}$ mm Hg. The pressure found from Eq. (1), as applied to the enclosed vibrating vane, was $6.8\times 10^{-5}$ mm Hg.

To produce oscillations of the system, a magnet, operated by hand outside the vacuum container, may be used to wind the fiber up several full revolutions. The vane has sufficient magnetic susceptibility to allow this to be done.

To find the lowest pressure which would be practical to determine with such a gauge, consider the following: Let the waiting time be 10 min and let the system originally have an amplitude of 2 revolutions. Then for tube No. 3 (reference 3) the gas pressure for a decrease in amplitude of 1 cm on a scale at a distance of a meter would be $0.8\times 10^{-8}$ mm Hg. Thus, pressures of $10^{-9}$ mm Hg could be detected in a period of 10 min and measured with some accuracy if one is willing to wait for a couple of hours.

There seems to be no indication of damping due to losses in the fiber at pressures down to at least $10^{-8}$ mm Hg.

---

THE REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 33, NUMBER 8 AUGUST 1962

# New Wide-Range Pressure Transducer

JOHN DIMEFF, JAMES W. LANE, AND GRANT W. COON
*National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California*

(Received April 12, 1962; and in final form, June 4, 1962)

A new transducer has been developed that will measure pressure over a wide range by sensing the damping of a vibrating diaphragm immersed in the gas whose pressure is being measured. It is capable of measuring pressures from approximately $10^{-5}$ to 200 mm Hg with an accuracy of about 1% over a large portion of the range. The device overcomes many of the shortcomings characteristic of other gauges; it is small and rugged, with a fast response time at low pressures, and lends itself well to automatic operation.

NEW wind tunnels at NASA's Ames Research Center require pressure instrumentation that will measure vacuum and pressure over an extremely wide range. The range of concern is from about $10^{-5}$ to $10^{3}$ mm Hg and measurements must be made within a time interval of approximately 1 sec.

The transducer developed to meet these needs is shown schematically in Fig. 1 along with its associated electronics. This transducer is basically a modification of Langmuir's quartz fiber gauge. Langmuir's gauge[1] and its modifications by Haber and Kerschbaum,[2] and by Wetterer[3] are typical examples of a type of gauge which senses pressure through the damping effect of the gas. Such gauges, however, have several undesirable characteristics: They are delicate; they are difficult to use; they are limited in their useful range; they are dependent on construction techniques which require a large gauge volume and thereby are characterized by long time lags at low pressures. The new transducer differs in that its sensitive element is a thin metallic diaphragm under radial tension, with the gas whose pressure is to be measured filling a small enclosed space on each side of the diaphragm. This configuration largely avoids the disadvantages of the earlier types of gauges.

A simplified sketch of the transducer is shown in Fig. 2. The diaphragm is driven at the resonant frequency of the system by induced electrostatic forces applied between the diaphragm and a stationary plate in close proximity to one side of the diaphragm. The diaphragm displacement is measured by a capacitance technique using a similar stationary plate in close proximity to the other side of the diaphragm. As the pressure of the gas sample in the spaces between the moving diaphragm and the stationary plates is varied, the work done by the diaphragm in overcoming the losses associated with the motion and compression of the gas also varies. The driving energy required to keep the system oscillating at a fixed amplitude

---

[1] I. Langmuir, J. Am. Chem. Soc. **35**, 105 (1913).

[2] F. Haber and S. Kerschbaum, Z. Elektrochem. **20**, 296 (1914).

[3] G. Wetterer, Z. tech. Physik **20**, 281 (1939).