[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA]

A NEW DIFFERENTIAL PRESSURE GAGE

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In a recent investigation we found it necessary to follow the speed of a very slow gas reaction by means of the pressure change produced in the reacting mixture. In this investigation it was desirable to work at about atmospheric pressure. The differential gage devised by Frank,[1] in which he combined the circuit developed by Gunn[2] with a condenser, one plate of which was mounted on the thin glass diaphragm of a reaction chamber, would have been satisfactory. This circuit, however, is complicated and very sensitive to small battery variations, since it depends upon current measurements.

Within the past ten years piezo-electric quartz crystals have been introduced into radio circuits to hold the frequency constant.[3] By combining such a crystal-controlled oscillator with a resonance circuit which utilized a condenser mounted on a glass diaphragm, we were able to construct a gage which combined the advantages of simplicity and accuracy.

The wiring diagram of the oscillation and resonance circuits[4] is shown in Fig. 1. We used a 301 A Cunningham tube operated with a 6-volt filament battery and a 150-volt plate battery. Q is quartz plate which has frequencies of 1080 and 1211 K. C. The inductance L_1 has 25 turns of No. 14 copper wire wound on an 11-cm. bakelite cylinder. L_2 in the resonance circuit consists of 80 turns of No. 16 wire wound on an 8.5-cm. bakelite cylinder. It is tapped at every turn to facilitate adjustment. C_1 is a standard $1500\mu\mu$ variable condenser; C_2 is a small parallel plate condenser which is shown in detail in Fig. 2. The diaphragm D is a No. 0 cover glass about two inches in diameter, to which the lower condenser plate is attached by shellac. The cover glass was attached to the tube by sealing wax. In case an all-glass system is needed, the diaphragm can be blown from the tube itself. The upper plate is rigidly fixed to the top of the gage by an adjusting screw. The distance between plates is about 0.3 mm.

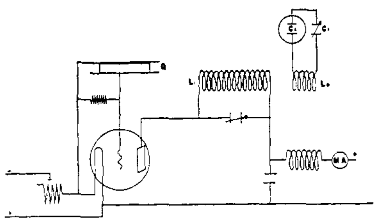

Fig. 1.

When circuit is oscillating, the plate current is about 15 m.a., as shown by the meter MA, Fig. 1. When resonance is established in the gage circuit, the plate current increases very sharply by about 10 m.a. To adjust the apparatus, the oscillator is set going, C_1 is fixed at a rather large value ($1000\mu\mu$ to $2000\mu\mu$) and L_2 is varied until resonance is obtained. No further adjustments are necessary. For accurate work

[1] H. S. Frank, unpublished Thesis, University of California.

[2] Gunn, *Phil. Mag.*, **48**, 224 (1924).

[3] W. G. Cady, *Proc. Inst. Radio Eng.*, **10**, 83 (1922); G. W. Pierce, *ibid.*, **15**, 9 (1927).

[4] See Catalog E, General Radio Co., Cambridge, Mass.

it is desirable to thermostat the whole circuit to prevent capacity changes, etc., during the measurements.

To use the gage, fill one side with the reacting mixture, and the other side with an inert gas. A small leveling bulb will help to adjust the pressure until the diaphragm is in its undisplaced position. Then start the oscillator and increase C_1 until the sharp increase in the plate current is obtained. Decrease C_1 again until oscillation is restored and repeat the operation. Since the frequency of the oscillator is constant and since the inductances L_1 and L_2 are fixed, the total capacity in the resonance circuit is fixed. But $1/C = 1/C_1 + 1/C_2$ = a constant. Therefore $dC_1/dC_2 = -C_1^2/C_2^2$, or the ratio of the changes of capacity is directly proportional to the square of the ratio of their absolute values. For the condition as outlined above, a small change in C_2 corresponds to a large change in C_1. In our work the gage was reproducible to one division of our standard condenser, which corresponded to 3×10^{-4} mm. mercury pressure. This does not represent the limit of reproducibility of the electrical circuit, for when C_2 was replaced by a small fixed condenser, C_1 readings checked within such limits that we could estimate fractions of a subdivision, *i. e.*, tenths of a division.

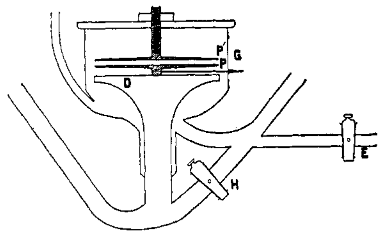

Fig. 2.

To calibrate the apparatus various methods can be used. Thus both sides can be filled with an inert gas and then the pressure on one side can be changed a given amount by changing the leveling bulb, or the whole apparatus may be evacuated and a liquid with a known pressure introduced on one side. The details of such a calibration can be seen from the following data

Press. above D, cm. of Hg	24.5	24.5	17.1×10^{-3}	17.1×10^{-3}	17.1×10^{-3}	17.1×10^{-3}
Press. below D, cm. of Hg	24.5	24.5	17.1×10^{-3}	17.1×10^{-3}	14.6×10^{-3}	14.6×10^{-3}
C_1	1026.8	1026.9	1028.8	1028.8	1007.7	1007.8

A change of pressure on both sides of D from 24.5 cm. to 2×10^{-3} cm. produced a change in C_1 of only two divisions. If the pressure on one side is kept constant, and the pressure on the other side of D is changed, C_1 changes approximately one division for each thousandth millimeter change of pressure. If C_1 were adjusted so as to resonate at $2000\mu\mu$, the change in C_1 would be about four times as much.

Summary

A new simple and accurate differential pressure gage has been devised which will permit the study of very slow reactions at any pressure even when an all-glass gage is needed.

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