NEW ACOUSTICAL METHOD OF VACUUM MEASUREMENT

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1. Introduction

In vacuumtechnique pressures to be measured most frequently are in the region a few times 10^2 mmHg to 10^{-5} mmHg. There are several kinds of meters which are capable of measuring the actual pressure in this interval, but none of them can be used in the whole region. The different kinds of meters can be practically devided into two groups, one of them measuring the region above 10^{-3} mmHg, while the other operates below 10^{-3} mmHg.

It is to be noted that instruments belonging to the first group have a limited range of measurement lying between 1 and 10^{-3} mmHg, and there are only a very few of them whose upper limit of measurement can be extended as far as the atmosphere. However it is quite possible to construct meters for the interval 1—760 mmHg e. g. a simple U-type mercury manometer should be used.

Some types of vacuummeters can be regarded as absolute ones, while the rest must be calibrated against an absolute meter. The most common absolute manometer for this purpose is the so-called McLoad gauge.

2. Acoustical method for determining pressures

To explain the method let us place, for the sake of simplicity, a loudspeaker and a microphone in a chamber in which a certain given pressure exists. Connect the loudspeaker to an audio frequency generator set to a proper frequency. Then the loudspeaker will radiate sound energy in the chamber. Let the microphone be connected to a suitable vacuumtube voltmeter, then this will indicate the *ac* voltage generated by the sound energy received by it.

The energy is chiefly transferred from loudspeaker to microphone by the aid of the medium existing in the chamber i. e. by the air molecules (neglecting the conduction through the rigid parts of the system), therefore the voltage output of the microphone will vary with pressure in a definite way, supposing constant loudspeaker input and absence of any other noise in the chamber.

It can be easily seen that by this simple method it is possible to determine pressures to such a low value below atmosphere, at which the radiated energy is comparable to that one picked-up by conduction.

3. A first-order theory of the method

A simple approximate theory will be given for the proposed method. Only the ideal case is treated, supposing a tube with movable membranes on its both ends (Fig. 1) and neglecting any conduction, reflexion (interference) and noise.

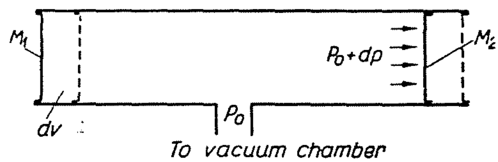

Fig. 1

Let us suppose that in this tube a given pressure p_0 exists, and let the membrane M_1 move to a distance dx so, that the volume v of the tube will be smaller by dv. Then the pressure in the immediate vicinity of the membrane M_1 will increase, and this increase of pressure will extend through the tube till it reaches the other end of the tube, where it will act on the membrane M_2 and causes it to move outwards, resulting in some increase of volume.

Let us suppose that the whole process will be adiabatic, then for ideal gases, and so in good approximation for air, too

$$p_0 \cdot v^{\varkappa} = \text{const}\,.$$

So

$$dp \cdot v^{\varkappa} + \varkappa \cdot p_0 \cdot v^{\varkappa-1} \cdot dv = 0$$

and finally:

$$dp = -\varkappa \cdot p_0 \cdot dv/v\,.$$

It can be seen, that with constant loudspeaker input (i. e. $dv = \text{const.}$) the change of pressure at the microphone, dp, will linearly vary with the existing pressure p_0, that is the instrument will have a linear scale.

It must be emphasized that this simple explanation is only a very first-order theory, neglecting for example, reflections from the walls of the tube, which result in a strange response regarding the applied frequency, because of the possibility of interference. The applied frequency should not be too low, because noises are always present.

As is mentioned above there is energy transfer, not only by radiation, but also by the aid of conduction. This will determine practically the lower end of the measurable region.

4. Experimental results and remarks

Several measurements were made and the mentioned linearity was found through a region ranging from atmosphere to a few times 10^{-2} mmHg. In these measurements carried out a various pressure, care was taken, to the change in acoustical impedance of the loudspeaker and microphone.

The measurements were made by crystal loudspeakers and microphones and also in some cases with dynamic loudspeakers. The applied frequency varied from 500—10 000 c/s, and sometimes a highpass filter was used at the microphone-end to prevent of undesirable response caused by noises.

It was found, that in all cases this simple measuring arrangement could be used for pressure measurements from atmosphere till $5 \cdot 10^{-2}$ mmHg. However, it is possible to extend the lower end by diminishing conduction with the aid of suitable acoustically damping materials.

An instrument based on this principle can be regarded as an absolute meter, or at least as a semi-absolute one, having a linear scale and can be calibrated at atmospheric pressure.

An absolute meter, however, should not need any calibration, as its geometrical dimensions are quite enough to calculate the pressure. The discribed method above gives a linear relation which enables us to calculate the scale till a numerical factor which is to be determined by calibration for example at atmospheric pressure.

For a more accurate treament of the theory of this method as well as for the realization of the instrument including the possibility of the application of pulsed sources to prevent conduction we refer to our next article to be published in the near future.

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Summary

A new acoustical method is presented for measuring pressures lower, than atmosphere. Based on this principle it is possible to construct an absolute vacuumeter, the usuable range of measurement of which extends from atmosphere, to below the micron-mercury region. Some practical remarks are also given for the actual construction of such instruments, and for the possibilities to extend the lower limit of measurement.

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