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DEVICE FOR CALIBRATION OF LOW PRESSURE GAUGES DEVELOPMENT

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Abstract. *Vacuum system set-up is presented and used for calibration of pressure gauges in the region of rough vacuum, from 10^3 mbar to 10^{-1} mbar, with dry air. The capacitance manometer is used for the calibration of piezoresistant manometer, oil, mercury and mercury micrometers U manometers. The applicability of the experimental set-up and obtained results for the low pressure gauges calibration in the medium and high vacuum region is approved. It was shown how calibration of some cheaper pressure gauges might be performed and reliable measurements of the pressure may be made in the region that is of interest for atomic and molecular collision physics and low-pressure gas discharges. It was also shown that mentioned calibration procedure could be used for calibration of different U manometer types in order to renormalize older atomic and molecular collision data.*

Key words: *rough vacuum, calibration, pressure gauges*

1. INTRODUCTION

The main goal of this work is to show the possibility of using the U manometers in the rough vacuum region and as compared to the capacitance manometer in the range of lower pressures. In the recent years application of capacitance gauge has become standard and usually the data obtained by using different U manometers are regarded as unreliable unfairly. We have attempted to test the applicability and reliability of using U manometers primarily in order to check the older atomic collision data [1]. The U manometers used in this investigation are filled with one-fold vacuum distilled mercury, giving an uncertainty of up to 10^{-3} mbar, which is enough for the measurements performed in the rough vacuum region (10^3-10^{-1} mbar).

It is well known that term "low pressure gases or vapor" was used generally for the gases (or species in the gas state), having the pressure lower than the atmospheric (~10^3 mbar). Various basic experiments and industrial processes of production have been done under different conditions, therefore the term "low pressure" in physics and vacuum technique has a broad range of meaning.

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There are different pressure subfields: rough (10^3-10^{-1} mbar), medium (10^{-1}-10^{-3} mbar), high (10^{-3}-10^{-6} mbar), ultrahigh (10^{-6}-10^{-9} mbar) and extremely high ($p<10^{-9}$ mbar) vacuum. For every subfield one have to use characteristic way to obtain needed pressure range, and even more so, have to use specific measurement techniques (static gas pressure, method of gas expansion, method of increase or decrease gas pressure, method of slow gas and method of saturated vapor) and instrumentation to measure obtained pressures [2,3].

In the region of rough vacuum, from 10^3 mbar to 10^{-1} mbar, as primary standards U manometers filled with mercury or some other working fluid, are used. This kind of manometers can make the measurement of the gas pressure possible with an acceptable relative error (makes it possible to measure pressure in this range with acceptably small uncertaintly). In the recent years capacitive manometers were used as a standard in this range of pressures. The relative error with which we can measure gas pressures is the smallest in the region of rough vacuum.

2. Experimental set-up and procedure

Figure 1 shows the sample schematic diagram of experimental set-up used in this investigation. The operating principle of this experimental set-up is described in earlier publications [4,5]. The schematic diagram of the apparatus is given in Fig.1. Device consists of vacuum chamber made of stainless steel (Prva Iskra-Barič, YU) filled with gas in order to establish the required gas pressure for calibration. The vacuum chamber is evacuated using a mechanical prevacuum pump (EDWARDS, UK). The low limit value of the pressure achieved by the pump is $1{,}9\times10^{-2}$ mbar. Vacuum chamber and the pump are connected by a set of pipes, taps and valves. The following low pressure gauges are used for pressure measurements:

1. Primary gauges
   - 1.1. Oil U manometer, range (0,1-70 mbar), production Institute of Physics (IF), YU
   - 1.2. Mercury U manometer, range (0,1-800 mbar), production IF, YU
   - 1.3. Mercury micrometers U manometer, range (0,1-120 mbar), production IF, YU
2. Secondary gauges
   - 2.1. Capacitance manometer, range (0,02-1000 mbar), production MKS, USA
   - 2.2. Piezoresistant manometer, range (0-250 mbar), production Institute of Chemistry, Technology and Metallurgy (IHTM), YU
   - 2.3. Pirani gauge, range (0,01-1000 mbar), production EDWARDS, UK.

The following procedure was used.

During the measurement procedure it is important to check, always, the mechanical pump-needle valves system. If that system works properly, one can be shure that obtained results are real, specially working in the regime of increasing and decreasing dry air pressure.

First, the vacuum chamber must be evacuated from air. The quality and degree of reached vacuum depends on mechanical pump characteristics and quality of vacuum chamber. After that dry air flowed in the chamber. The manometers (capacitance, piezoresistant, oil, mercury and mercury micrometers U manometers) show pressure increase in the vacuum chamber. During that pressure increase the calibration procedure for all types of pressure gauges was applied measuring the pressure and comparing these results with the results obtained with capacitance manometer. The same procedure, but in reverse order, was applied when dry air was evacuated from the chamber.

The comparison between the above gauges and the capacitance manometer always give the linear functional dependence, as it was expected. These results are presented, in details, in the next chapter.

Pirani gauge was used for measuring the referent pressure in the vacuum chamber. In this paper we have used a newly purchased MKS capacitance manometer for calibration of other low pressure gauges.

For the filling of the mercury U manometer and mercury micrometers U manometer one-fold vacuum distilled mercury is used, while oil U manometer is filled with the silicon oil.

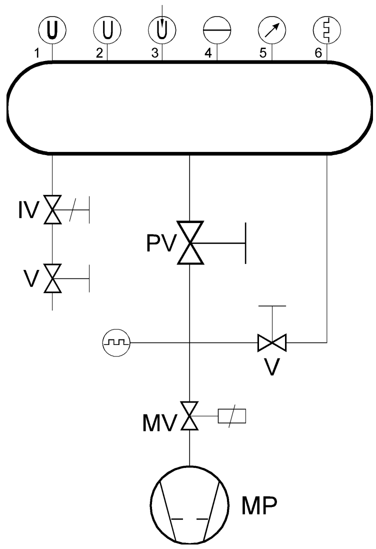

Fig. 1. Scheme of vacuum system set-up for calibration of low pressure gauges Pump system: MP-mechanical pump, IV-needle valve, V-valve, PV-partition valve, MV-magnetic valve and vacuum chamber Gauges of pressure: 1. Oil U manometer, 2. Mercury U manometer, 3. Mercury micrometers U manometer 4. Capacitance manometer, 5. Piezoresistant manometer and 6. Pirani manometer.

3. Results and discussion

In this chapter the calibration results obtained for a range of custom-built manometers are presented. These manometers were produced in IF and IHTM by using the capacitance gauge (MKS) as a secondary standard [6].

In Fig. 2. The results obtained for pressure measurement of dry air with capacitance (MKS, USA) and piezoresistant manometers (IHTM, YU) are compared. Capacitance manometer covers the range of 1000 mbar. But, piezoresistant manometer covers the range of pressure up to 250 mbar. This is the reason why the calibration was done up to that pressure. The experimental data, presented in that figure, shows the linear ratio between the results obtained by two devices, which allows us to do the calibration of the piezoresistant manometer. Measurements are performed in two working regimes: increasing (o) and decreasing (•) pressure of the dry air. These results give one the possibility to calibration the piezoresistant (MT) manometer with capacitance (BT) manometer. It must be pointed out here that experimental data have withdrawals from the functional dependence obtained with least squares method. The reason for that is only the procedure during the reading of the values on the needle scales, a great error is made. For each twenty-two values of the pressure is calculated the mean value of the pressure which presents piezoresistant and capacitance manometers p (MT)/p (BT) is 0.8585. The standard deviation is 0.0258. Comparing the results obtained by the capacitance and piezoresistant manometer it was found that the difference in the values given by these two devices is in the range of 3%.

In Fig. 3. The comparison of the capacitance (MKS, USA) and oil U manometers (IF, YU) pressure measurements results is presented. Oil U manometer covers the difference between the fluid heights in two shanks of the U manometer up to 80 mbar, so the calibration was done up to that pressure. Measurements are performed in two working regimes: increasing (o) and decreasing (•) pressure of the dry air. These results give one the possibility to calibration the oil U manometer with capacitance (BT) manometer. It is obvious that functional dependence of these measurements, for both working regimes, is linear. But this linearity in not as it is expected, i.e. it is not simple y = x dependence. The reason for this

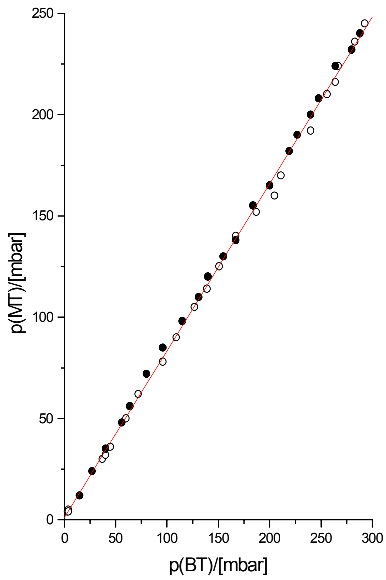

Fig. 2. Comparison between readings of the capacitance and piezoresistant manometers with dry air, solid line with points (in case of a pressure increase (o) and decrease (•))

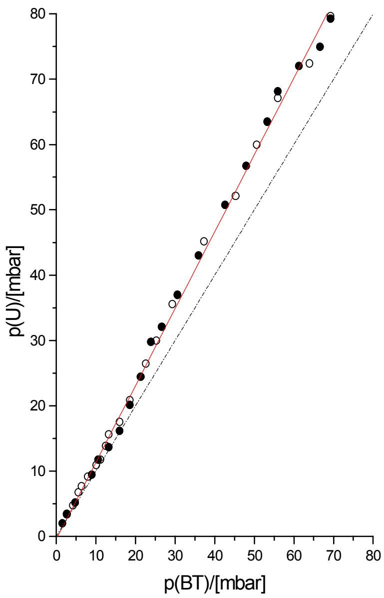

Fig. 3. Comparison between readings of the capacitance and oil U manometers with dry air, solid line with points (in case of a pressure increase (o) and decrease (•)). Linear relation y=x is shown as a dashed line

laying in the fact that working with oil brings some difficulties concerning the oil physical characteristics. For each twenty values of the pressure is calculated the mean value of the pressure which presents oil U and capacitance manometers p (U)/p (BT) is 1.1530. The standard deviation is 0.0461. The difference in the results of these two devices is up to 4%.

In Fig. 4. The pressure measurements comparison of the capacitance (MKS, USA) and mercury U manometers (IF, YU) is presented. Mercury U manometer covers the difference in the fluid heights in two shanks of the U manometer up to 800 mbar, so the calibration was done up to that pressure. Measurements are performed in two working regimes: increasing (o) and decreasing (•) pressure of the dry air. These results give one the possibility to calibration the mercury U (UHg) manometer with capacitance (BT) manometer. The experimental data are showing linear ratio between the results obtained by the two devices and make the calibration of mercury U manometer, possible. For each seventeen values of the pressure is calculated the mean value of the pressure which presents mercury U and capacitance manometers p (UHg)/p (BT) is 1.0595. The standard deviation is 00212. The results given by the two devices are different by up to 2%.

In Fig. 5. The comparison of the capacitance (MKS, USA) and mercury micrometers U manometers (IF, YU) is presented. Mercury micrometers U manometer covers the difference between the fluid heights in two shanks of the U manometer up to 120 mbar, so the calibration was done up to that pressure. Measurements are performed in two working

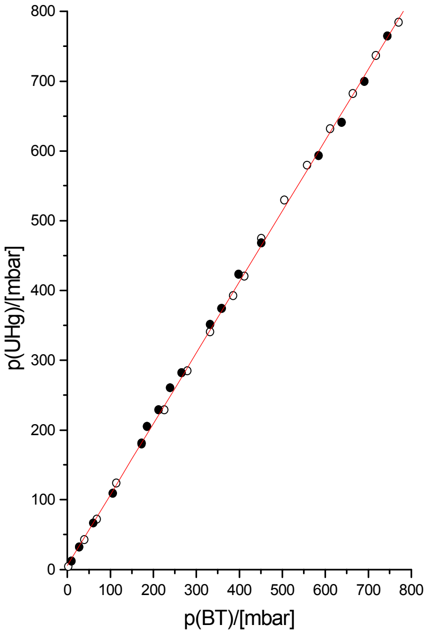

Fig. 4. Comparison between readings of the capacitance and mercury U manometers with dry air, solid line with points (in case of a pressure increase (o) and decrease (•))

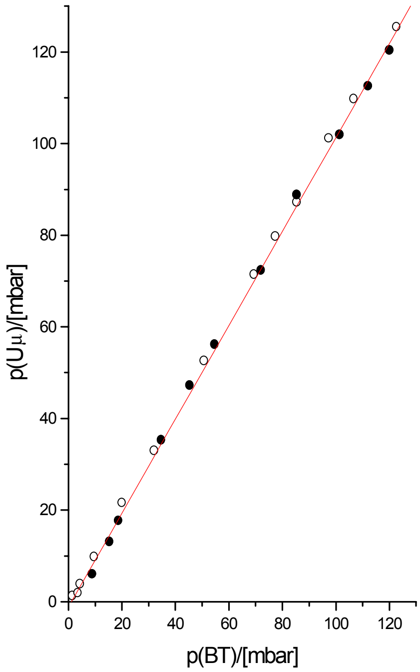

Fig. 5. Comparison between readings of the capacitance and mercury micrometers U manometers with dry air, solid line with points (in case of a pressure increase (o) and decrease (•))

regimes: increasing (o) and decreasing (•) pressure of the dry air. These results give one the possibility to calibration the mercury micrometers U (Uμ) manometer with capacitance (BT) manometer. Reading of the level position is gained by micrometers turn with gait 0,1 m. For each twelve values of the pressure is calculated the mean value of the pressure which presents mercury micrometers U and capacitance manometers p (Uμ)/p (BT) is 0.9735. The standard deviation is 0.0098. The resulting difference given by the two devices is 1% only.

4. CONCLUSION

In this work vacuum system set-up is presented together with the obtained results for pressure measurements with different vacuum gauges. The proposed calibration procedure of pressure gauges is used and described in the region of rough vacuum, from 10^3 mbar to 10^{-1} mbar. As it can be seen from the results presented in Fig. 2-5, the applicability of the experimental set-up has been confirmed and the results for the low pressure gauges calibration in the medium and high vacuum region have been obtained.

Using the capacitance gauge approves the calibration method of the absolute and relative low pressure gauges by using the capacitance gauge. It was obvious that mercury micrometers U manometer is often used in national bureaus for the calibration of low pressure gauges. It was shown that it is possible to calibrate not only these gauges, but also other devices for calibration of low pressure gauges.

The results of the present measurements may be used for the low pressure gauges calibration in the medium and high vacuum. Our conclusion and the main contribution of this paper is to show how calibration of some cheaper pressure gauges may be performed and reliable measurements of the pressure may be made in the region that is of interest for atomic and molecular collision physics and low-pressure gas discharges. In particular the results may prove as the basis for recalibration of some older measurements which are usually not taken into account due to assumed problems in pressure determination. It was shown that we might perform recalibration of the pressure scales in older measurements [1] obtained by U manometers.

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RAZVOJ I UHODAVANJE UREĐAJA ZA KALIBRACIJU MERILA NISKIH PRITISAKA

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Opisan je vakuumski sistem koji je korišćen za kalibraciju merila niskih pritisaka u domenu grubog vakuuma, od 10^3 do 10^{-1} mbar, sa suvim vazduhom kao radnim gasom. Iskorišćen je kapacitivni manometar za kalibraciju piezootpornog, uljnog, živinog i živinog mikrometarskog U manometra. Pokazano je da se ovaj eksperimentalni uređaj i dobijeni rezultati mogu primeniti i za kalibracuju merila niskih pritisaka u domenu srednjeg i visokog vakuuma. Takođe je pokazano kako kalibracija nekih jednostavnih merila niskih pritisaka može biti izvedena kao i korišćena za pouzdana merenja pritisaka koja su od interesa za atomsku i molekulsku fiziku sudara i gasna pražnjenja na niskim pritiscima. Ukazano je na mogućnost primene opisane kalibracione procedure za kalibraciju različitih tipova U manometara u svrhu renormalizacije vrednosti starijih atomskih i molekulskih podataka za sudare.

Ključne reči: *grubi vakuum, kalibracija, merila pritiska*