Vacuum 127 (2016) 30–37

Contents lists available at ScienceDirect

Vacuum

journal homepage: www.elsevier.com/locate/vacuum

Development of a transportable apparatus for vacuum gauge calibration

Zhenhua Xi*, Detian Li, Yongjun Cheng, Yongjun Wang, Huzhong Zhang, Jiatong Liu, Baoguo Guan, Kang Ji

Lanzhou Institute of Physics, Lanzhou 730000, China

ARTICLE INFO

Article history:
Received 11 October 2015
Received in revised form
29 January 2016
Accepted 30 January 2016
Available online 15 February 2016

Keywords:
Transportable apparatus
Pressure attenuation method
Direct comparison
Metrological characteristic

ABSTRACT

A new ultrahigh vacuum transportable apparatus for vacuum gauge calibration in the pressure range from 10^{-5} Pa–10^{5} Pa is developed. On the basis of modularization design, it can be easily extended and assembled. A standard pressure p_{std} with various gas species can be generated by means of pressure attenuation module which is easy to introduce the corresponding calibration gas through an orifice. The standard pressure p_{std} in the range from 10^{-5} Pa to 10^{-2} Pa could be obtained by changing the upstream pressure from 1 Pa to 10^{3} Pa with an uncertainty of approximately 2.4%. At the same time, calibration can also be performed by direct comparison with a reference gauge either in static or stationary equilibrium. The ultimate pressure could be in the level of 10^{-6} Pa typically. The pumpdown characteristic and outgassing rate of the apparatus after exposing to atmospheric pressure are presented. The main metrological characteristics of the apparatus are given. The size and weight of this apparatus are 475 mm × 420 mm × 800 mm and 37.8 kg, respectively. Its calibration range is from 1.96×10^{-5} Pa to 1.03×10^{5} Pa with the relative combined standard uncertainty from 2.8% to 0.40%.

1. Introduction

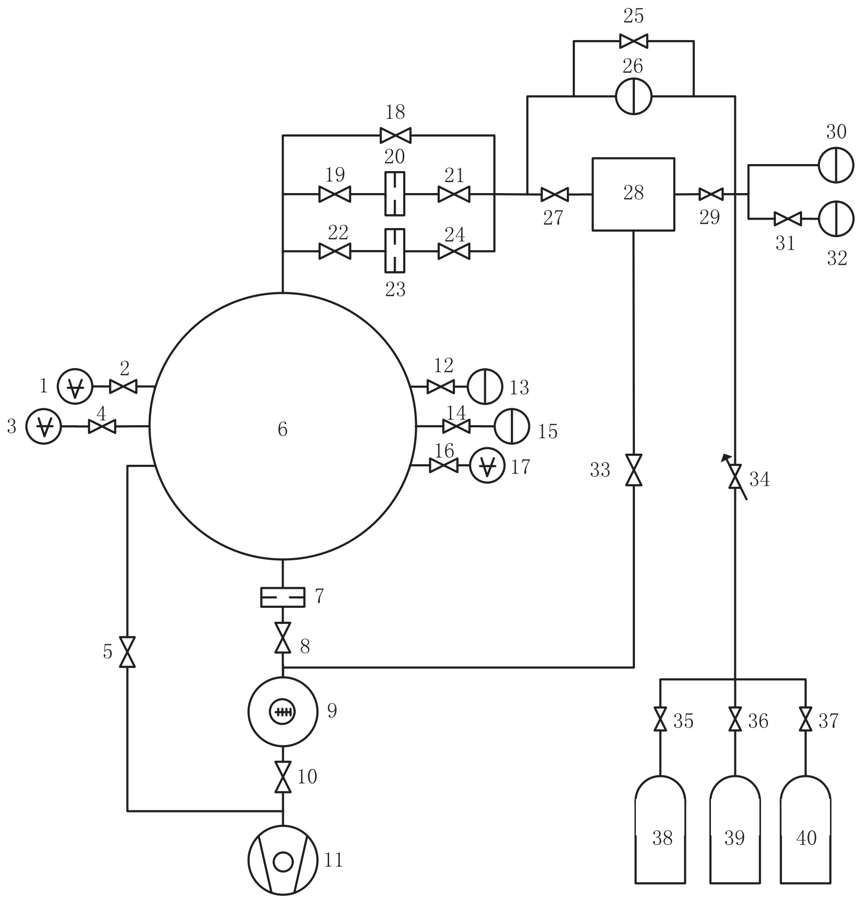
Many important industrial processes (e.g. semiconductor industry, photovoltaic, etc) as well as scientific experiments (e.g. particle accelerator for Nuclear Physics, surface science, storage rings, etc) are carried out in high vacuum or ultra-high vacuum (UHV) condition [1,2]. In order to obtain reliable measurement of UHV, there is a strong demand for periodic calibration of vacuum gauge. So a great deal of vacuum calibration systems, such as static-expansion systems, orifice-flow systems (also called continuous-expansion systems) are widely used for high and ultrahigh vacuum standards [3–7]. It is well known that the users have to stop their process for at least several weeks during the period of calibration [8]. Moreover, some users are worried about to damage their vacuum gauge during transportation, and the others seemed to be at their wits end as the controller and cables of vacuum gauge are installed in a fixed way sometimes. So efficient calibration of vacuum gauge on user's site is also required urgently. Some kinds of transfer standard package (TSP) for the range 100 Pa–130 kPa have been developed for new calibration services or Key Comparisons which require transporting the standard between national metrology institutes (NMIs) [9,10]. Other state-of-the-art portable vacuum calibration systems for the range 10^{-3} Pa to 10^{5} Pa have also been designed [11,12]. As the comparison method are adopted by all the above systems, and hence the calibration ranges have to be depended on the used reference gauges, namely the secondary standard. Thus the hot or cold cathode ionization gauges could just be calibrated over the upper end of their measurement range or not be calibrated at all. So it is difficult to satisfy the users' requirement for extending the calibration capability down to 10^{-5} Pa or even lower. To address these issues, a new transportable vacuum calibration apparatus, with the technical advantages including simple structure, light weight, small size, high efficiency and low cost, was developed on the basis of modularization design in Lanzhou Institute of Physics (LIP). The wide calibration range could be achieved by three methods in combination. Its major metrological characteristics and estimation of uncertainties of the generated pressure are presented.

2. Calibration apparatus description

Fig. 1 shows the schematic illustration of the apparatus. It

* Corresponding author.
E-mail address: comanche_xzh@126.com (Z. Xi).

http://dx.doi.org/10.1016/j.vacuum.2016.01.025
0042-207X/© 2016 Elsevier Ltd. All rights reserved.



1: Bayard-Alpert & Pirani Gauge; 2, 4, 5, 8, 10, 12, 14, 16, 18, 19, 21, 22, 24, 25, 27, 29, 31, 33, 35, 36, 37: isolation valve; 3: vacuum gauge under calibration; 6: calibration chamber; 7: orifice; 9: turbo-molecular pump; 11: rotary pump; 13, 32: FS133 Pa absolute capacitance diaphragm gauge; 15, 30: FS133 kPa absolute capacitance diaphragm gauge; 17: spinning rotor gauge(or secondary standard ionization gauge); 20, 23: laser drilled orifice; 26: FS133 Pa differential type capacitance diaphragm gauge; 28: upstream chamber(1L standard vessel); 34: metering valve; 38, 39, 40: gas cylinder.

Fig. 1. Schematic diagram of the transportable apparatus for vacuum gauge calibration.

consists of pressure measurement module, gas supply module, pump module, pressure attenuation module and bake module. Fig. 2 is a photograph of the apparatus. A standard pressure p_{std} with various gas species (e.g. N_2, Ar, He, etc) can be generated by means of pressure attenuation module which is easy to introduce the calibration gas through an orifice. Additionally, it also takes the temperature differences between upstream chamber and calibration chamber into account. The standard pressure p_{std} is given by

$$p_{std} = \frac{p_0 \cdot R_c}{(1-\alpha)}\sqrt{\frac{T_1}{T_0}} \tag{1}$$

where R_c is the conductance ratio of orifice (20) to orifice (7) or the conductance ratio of orifice (23) to orifice (7), α is the back-streaming ratio, p_0 is the pressure in the upstream chamber (Pa), p_{std} is the generated pressure in the calibration chamber (Pa), T_0 is the temperature in the upstream chamber (K), and T_1 is the temperature in the calibration chamber (K). According to the conductance ratio, the initial pressure p_0 is reduced to p_{std}, representing just the desired calibration pressure. As the conductances of two orifices C_{20} and C_{23} are very small (typically 10^{-8} m^3/s and 10^{-6} m^3/s) compared to C_7 (typically 10^{-2} m^3/s), the standard pressure p_{std} in the range from 10^{-5} Pa to 10^{-2} Pa could be obtained by changing the upstream pressure from 1 Pa to 10^3 Pa. So the apparatus can realize the pressure quantity value covering the range of 10^{-5} Pa to 10^{-2} Pa with pressure attenuation method. In addition, calibration can also be performed by direct comparison with a reference gauge under static or stationary equilibrium conditions [12,13]. The calibration range is between 10^{-5} Pa to 10^{-2} Pa with stationary equilibrium method. Due to outgassing and desorption in the calibration chamber, the calibration range is from 10^{-1} Pa–10^5 Pa with static method. According to the calibration range, the reference gauge is either a calibrated gauge, traceable to a vacuum