New state primary standard GET 49-2016 of reproduction pressure unit in range $10^{-6}$–$10^3$ Pa

V N Gorobei, E K Izrailov, R E Kuvandykov, D M Fomin and A A Chernyshenko
D. I. Mendeleev Institute for Metrology (VNIIM), 190005, St. Petersburg, Russia

E-mail: V.N.Gorobey@vniim.ru, ruskuw@mail.ru, fomindm@yandex.ru, vacuum@vniim.ru

Abstract. The article contains data on composition, principle of operation, measuring and functional capabilities of the state special primary standard of pressure unit for absolute pressures in the range $10^{-6}$–$10^3$ Pa.

1. Introduction
The state special standard of pressure unit for absolute pressures in the range $10^{-6}$–$10^3$ Pa (GET 49-2016) was approved in D. I. Mendeleev Institute of Metrology in 2016. It was developed in the course of work to improve the Russian reference base. As a result of work for improving the state standard for absolute pressure the system and some of functional characteristics of the previous standard were changed.

2. Principle of operation and composition of GET 49-2016
The state primary standard GET 49-2016 is a measuring complex designed for reproducing, storing and transferring the pressure unit to the reference and working measurement instruments (MI) in the range of $10^{-6}$ ... $10^3$ Pa. There are several principles of measurements in the standard:

1. Compensation principle, based on balancing between the pressure force and electrostatic force acting on the plates of flat capacitor. This principle is realised in the membrane-capacitive converter of the compensating type. The equation for measurements has the following form:

$$ p = kU^2 $$

2. The principle of static expansion, based on isothermal expansion of gas and the Boyle-Mariott Act. The equation of measurement has the following form:

$$ p = p_1 \left( \frac{V_1}{V} \right) = k p_1 $$

where $p$ is the reproducible pressure; $U$ - compensating voltage; $k$ is the constant. The constant of the membrane-capacitance manometer is calculated on the base of measurement and capacitance of the flat capacitor.

2. The principle of dynamic expansion (reduction), based on the equations of continuum. The equation of measurement has the following form:
\[ p_x = p_0 + k \Delta p + 0.5q Q_l \]  
(3)

where \( p_x \) is the reproducible pressure; \( p_0 \) - residual pressure in ultrahigh vacuum chamber of the standard; \( \Delta p \) is the pressure difference between the initial pressure in reference chambers and the measuring chamber. \( k \) is the reduction coefficient determined by the ratio of the conductivities of the elements in vacuum system of the standard; \( 0.5q Q_l \) - gas evolution from the surface of the vacuum system of the standard.

These measurement principles are implemented in the standard GET 49-2016 in the form of several reference complexes and installations: figures 1 and 2 shows its structural scheme and the general view of the primary standard.

3. Results of testing the state primary standard and metrological characteristics of the standard GET 49-2016

During the development of the GET 49-2016 the practical and theoretical testing was carried out which included the following stages:

1. Theoretical and practical researching of metrological characteristics of reduction installation.
2. Interlaboratory comparisons of the developed standard with the state special standard for pressures difference GET 95-75.
3. The first stage of bilateral comparisons of national standards of Russia and Turkey in the range of low absolute pressures and vacuum according to the instructions COOMET 711/TR/16 and 712/TR/16.

The researches have confirmed theoretical calculations and assumed metrological characteristics of the standard GET 49-2016. The standard has the following metrological characteristics:

- Measurement range of absolute pressure, Pa: \( 1\cdot10^{-6} \ldots 1\cdot10^{3} \).
- Number of independent measurements: 10.
- The mean square deviation of the measurement result, \( S_{m} \), not more than:
  - \( 0.15\cdot10^{-2} \) in the range of \( 1\cdot10^{-3} \ldots 40 \) Pa;
  - \( 0.30\cdot10^{-2} \) in the range \( 1 \ldots 1\cdot10^{3} \) Pa;
  - \( 2.0\cdot10^{-2} \) in the range of \( 1\cdot10^{-6} \ldots 1\cdot10^{-2} \) Pa.
- Unexpected systematic error, \( \theta_{o} \), not more than:
  - \( 0.17\cdot10^{-2} \) in the range of \( 1\cdot10^{3} \ldots 40 \) Pa;
  - \( 0.30\cdot10^{-2} \) in the range \( 1 \ldots 1\cdot10^{3} \) Pa;
  - \( 2.5\cdot10^{-2} \) in the range of \( 1\cdot10^{6} \ldots 1\cdot10^{-2} \) Pa.
4. The results
The obtained results confirmed the correctness of the technical solutions adopted by the improvement of the reference base in the field of absolute pressures. The development of the reference system was based on the use of modern digital, precision electronics. The standard is built with using the latest vacuum technologies, components and instruments: oil-free pumps for creating and maintaining pressure, electrolytic polishing of internal vacuum surfaces, modern vacuum gauges, fittings and valves.

During the work the measurement range was extended by three orders. The accuracy at the range of high vacuum is increased, and also the functionality of the GET 49-2016 has been improved.

The state primary standard GET 49-2016 satisfies requirements of industry and allows to solve the problems.

5. Prospects and ways of further improvement
Research work carried out for improving the standard for the range of absolute pressures allowed to formulate and plan further work to improve the Russian reference base for measurement of low absolute pressure and vacuum. In the future the following researching works should be carried out:
- Development and creation of a new membrane-capacitive converter of compensation type with adaptive membrane;
- Development and creation of the standard and reference measurement instruments based on MEMS technologies;
- Development and creation of a natural standard of absolute pressure (the realization of a triple points);
- Development of the system for standard complex in the range of ultrahigh vacuum up to $10^{-10}$-$10^{-12}$ Pa;
- Unification of existing pressure standards into one complex of one state standard.

References
[1] Rozanov L N 1990 Vacuum Technique (M.: Higher School) 320
[2] Gorobey V N and Izrailov E K 2015 Vacuum technique and technology 2 49–53
[3] Kuzmin V V 1992 Vacuum measurements (Moscow: Standards) 228
[4] Gorobey V N and Izrailov E K 2011 Measuring technique 4 70–3
[5] Katys G P and Katys P G 2001 Nano-and microsystem technology 11 3–7