Test results for approval of the type of installation for reproduction of micro-flows of gases in vacuum

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Abstract. The article presents data on the composition and principle of operation of the unit of reproduction of micro-flows of gases in vacuum, as well as the results of its tests for the purpose of type approval on the state secondary (working) standard unit of gas flow in vacuum.

1. Introduction
In recent years, the requirements have raised for quality control of products of the aerospace industry of the Russian Federation, as well as to the input quality control of imported units and products for the aerospace industry.

In this regard, special attention is paid to vacuum measurements and tightness control. The task of tightness control until recently was the search and localization of defects in the design of products. Currently, the requirements for the tightness of various objects of the aerospace industry are such that it is not enough to find and localize the leak, but it is necessary to accurately measure and estimate the amount of leakage, i.e. the amount of gas flow entering the product or flowing out of it [1]. The most common devices for this purpose are helium leak detectors. However, these devices do not solve all the problems associated with the control of tightness and quality of products in the aerospace industry.

2. Brief description of the test equipment for measuring gas flow in vacuum and their metrological assurance
With the aim of improving the quality control in the aerospace industry, ensuring the uniformity of measurements of the gas flow in vacuum and increase the competitiveness of the aerospace industry in the domestic and global markets, in NPO "Technomash" was designed and manufactured a range of units designed to control the tightness and measurement of gas flow in vacuum. The most interesting developments among them are the installation to control the total leakage and localization of places of leaks of parts, assembly units and units of rocket and space technology of the new generation and the installation of reproduction of micro-flows of gases in a vacuum. First of all, it should be noted that these devices implemented a method of comparison with the reference flow using mass spectrometers. However, unlike most analogues available on the market, these devices use quadrupole-type mass spectrometers, which allows to measure the flow of almost any gas, while the bulk of the measuring instruments (MI) for gas flow is focused on measuring the flow of any one gas (helium, hydrogen, various refrigerants). In addition to this advantage, in a constructive and functional sense, the installation for the control of total leakage and localization of places of leaks of parts, assembly units and units of rocket and space technology of the new generation is not much different from the existing
leak detectors on the market. However, it should be noted that the installation of reproduction of micro-flows of gases in vacuum is a new step in the development of product quality control in the aerospace industry. Since this MI allows not only to measure the gas flow and leakage of the tested products, but also reproduces the gas flow in a wide range. This advantage allows verification and calibration of such MI of gas flow in vacuum as gas flow measures and leak detectors.

A general view of the installation of reproduction of micro-flows of gases in vacuum is shown in figure 1.

![Figure 1. General view of the installation of reproduction of micro-flows of gases in vacuum.](image)

Structurally, the installation of reproduction of micro-flows of gases in vacuum consists of:
1. System of creating and maintaining pressure and vacuum;
2. Original design flow sensor designed for playback and smooth flow control in a wide range;
3. A quadrupole mass-spectrometer designed to measure and compare flow;
4. Control and registration device;
5. Reference measures of gas flow.

In D. I. Mendeleev Institute for Metrology (VNIIM) tests were carried out in order to approve the type of a new measuring device – the installation of reproduction of micro-flows of gases in vacuum.

The principle of operation of the installation is based on the diffusion of helium through a selectively permeable polymer membrane, which is located inside the body of the control leak (flow detector), which is part of the installation. Pre-calibrated external control leaks allow the necessary calibrated helium flows to be installed in the vacuum volume of the plant, depending on the pressure generated by the pneumatic part of the pressure generation and maintenance system. The flow value is controlled by the partial pressure of the sample gas in the residual gas. The resulting calibration curve is used in further tests, settings and calibration of MI for gas flow in vacuum.

The definition of the metrological characteristics of the new measuring device were carried out at the state secondary (working) standard unit of gas flow in vacuum in the range of $1 \cdot 10^{-12}$ to 1 Pa·m$^3$/s (GVET 49-2-2006) [2, 3]. The general view of the standard and the vacuum circuit diagram are shown in figures 2, 3.
Figure 2. The basic vacuum scheme of the state secondary (working) standard unit of gas flow in a vacuum in the range $1 \cdot 10^{-12} ... 1$ Pa⋅m$^3$/s (GVET 49-2-2006).

Figure 3. General view of the state secondary (working) standard unit of gas flow in vacuum in the range $1 \cdot 10^{-12} ... 1$ Pa⋅m$^3$/s (GVET 49-2-2006).

The standard has the following metrological characteristics:
- measuring range: $10^{-12} - 1$ Pa⋅m$^3$/s;
- the mean square deviation $S_{x_0}$ of the error of storage and transmission of the unit size of the gas flow in vacuum, determined as a result of indirect measurements of the gas flow on the basis of direct measurements of pressure, volume and time interval (taking into account the instability of the standard):
  - in the range from $10^{-12}$ to $10^{-9}$ Pa⋅m$^3$/s no more than 0.1–0.015;
  - in the range above $10^{-9}$ to 1 Pa⋅m$^3$/s no more than 0.015.

The unit size of the gas flow in the vacuum unit is transmitted from the national pressure unit standard for the low absolute pressure area GET 49-2016.

The working standard implements two complex methods of gas flow measurements in vacuum:
1) static method based on the ideal gas equation of state;  
2) dynamic method based on the continuity equation.

3. Results and discussion

Tests of the installation of reproduction of micro-flows of gases in vacuum were carried out by comparisons with the working standard using comparison standards. As a result of the tests, the metrological characteristics of the device were determined and a verification technique was developed. The main metrological and technical characteristics obtained from the results of tests of the installation of reproduction of micro-flows of gases in vacuum are given in Table 1.

| Technical specifications                          | Value                                      |
|--------------------------------------------------|--------------------------------------------|
| Reading range, Pa·m\(^3\)/s                      | \(5 \times 10^{-13} \ldots 1 \times 10^{-3}\) |
| Measuring range, Pa·m\(^3\)/s                    | \(9 \times 10^{-11} \ldots 9 \times 10^{-5}\) |
| Limits of permissible relative error, % of the measured value: |                                          |
| in the range from \(9 \times 10^{-11}\) to \(9 \times 10^{-9}\) Pa·m\(^3\)/s | \(\pm 50\)                                |
| in the range above \(9 \times 10^{-9}\) to \(9 \times 10^{-5}\) Pa·m\(^3\)/s | \(\pm 20\)                                |
| Time to enter standby mode, no more than, min    | 5                                         |
| Setting time of the output signal, no more than, min | 15                                        |
| Power supply parameters                          | AC 220 V, 50 Hz                           |
| Power consumption, V·A                           | 1300                                      |
| Overall dimensions (length×width×height), not more than, mm | 900×700×1800                            |
| Weight, not more than, kg                        | 180                                       |
| Mean time to failure, h                          | 1000                                      |
| Average service life, years                      | 5                                         |

The unit size of the gas flow in vacuum is transmitted from the standard GVET 49-2-2006 of the micro-gas flow reproduction unit in vacuum in accordance with the approved local calibration scheme. The installation of reproduction of micro-flows of gases in vacuum has been tested in order to approve the type of measuring instrument with a positive result.

4. Conclusions

In conclusion, it should be noted that at the moment D. I. Mendeleyev Institute for Metrology (VNIIM) together with NPO "Technomash" carry out works aimed at creating a unified system of metrological measurement of gas flow in vacuum in the aerospace industry and in the Russian Federation as a whole, the primary state standard of gas flow in vacuum, as well as ensuring the unity of measurements in this field.

References

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