Quantitative assessment of leakage flows (inleakage) while mass spectrometric monitoring of leak tightness is still a topical challenge in spite of available computerized leak detectors with the implemented initial data processing algorithms. In most cases the assessment is made through comparing the unknown values of flows with the known ones for the standards. At the same time the calibrated leaks used as the gas flow measures (such as of GELIT type) correspond with higher degree of confidence to real gas exchange conditions through leaks in case of molecular flow mode, and with less confidence in case of viscosity mode.

As a rule, obtaining of reliable results of flow rates through open-end channels is problematic because of the lack of data on dimensions and shapes of the controlled leaks, therefore it is quite a laborious task to get the result approximating to the actual value without using special methods and calculations.

The aim of this paper is to analyze and investigate the dynamics of working gas mass flow rate (leak) through the leakages in gas-filled micro dischargers depending on determined effect of different gas flow modes taking into account specified sequence of the process operations while high-sensitive monitoring of leak tightness [1]. In case of envelope leaks, the leak (inleakage) flow rates depend in a certain way on alternate transitional processes caused by the change of pressure inside the recipients due to variation of external conditions (keeping in an open air after production, evacuation, pressure testing (in case of large leaks), the following repeated evacuation, discharge of the working gas to vacuum (without evacuation)) that are a part of operations accompanying the control. Besides it was necessary to find certain interrelation between the volume of gaseous neon in the atmosphere and a possibility to extend essentially operating range of the detected comparatively large leaks by means of increasing the upper sensitivity threshold for rejecting the dischargers using mentioned gas as a working medium.

It is difficult to apply leak detection equations for calculation since it is impossible to examine small channels visually and measure them; and their geometric parameters cannot be used as initial data as it is made for vacuum calculations of gas flows $Q$ through pipelines. Therefore the most rational approach to the calculation-based leak detection is to use relative assessment. When the flow ratios for different substances going through the same leak at different pressure values but within the same flow mode are calculated, the parameters describing the leak geometry are excluded. An air flow
$B$ from atmosphere to vacuum at room temperature, i.e., gas flow in normalized conditions is taken as initial characteristic of leak value. However, confidence of calculation is limited by uncertainty of boundaries of purely viscous and molecular modes, when there is no data, as noted above, on leak channel dimensions [2].

Based on the differential form of the universal empirical equation proposed [3] for describing gaseous flows through leaks of arbitrary geometry, the results of theoretical investigations [4, 5] on assessment of neon leak flows from gas-filled micro dischargers ($V_p = 0.43 \text{ cm}^3$) through leakages were obtained for general case of viscous-molecular-diffusion flow mode. Calculations were made using relative parameter $\varphi (\varphi = B_d/B_n$, where $B_d$ is a diffusion leakage defined by a neon flow from the gas atmosphere to air (if there is no total pressure differential), $B_n$ is a neon leakage characterized by the neon flow from the gas atmosphere to vacuum). It should be noted that the nondimensional parameter introduced fully characterizes the flow mode from viscosity $\varphi = 0$ to molecular mode $\varphi = 1$ [6].

Theoretical calculation research for different working gas flow modes (molecular, diffusion and viscous) was based on calculation of controlled flow $Q_n$ as a function of the leak rate $B$ ($Q_n = f(B)$) with consideration of atmospheric neon component and without it. $Q_n$ was calculated using the systems of mathematical models that describe approximately specified combinations from the sequence of the standard operations executed as stated in the developed methodology for the finishing control of the leak tightness implemented on computerized mass-spectrometer setup UFKG [7]. However, it is impossible to show all the results obtained in this work, so it is suggested to consider that investigations were carried out in two stages in order to limit the discussion (figure 1).

![Figure 1](image.png)

**Figure 1.** Superposition of curves that show $Q_n = f(B)$ functions obtained at stages 1 and 2 (table 1). Curves a, b, f and c, d, e, g are plotted respectively with and without consideration of neon in atmosphere at $\varphi = 0.001$ (a, b); $\varphi = 0.1$ (c, d); $\varphi = 1$ (e, f, g).

The first stage included calculations with analytical consideration of storage of the discharger with hypothetic leak $B_i$ of the specified levels in the air; time was reckoned starting from the discharger manufacture (after it was filled with the neon working gas at pressure $p_n = P_n^0$ (101.3 kPa here) and when the exhaust tube was sealed) for time period $T_{vd}$ with the following evacuation lasted for $t_{ev}$. The
second stage of investigations consisted of all the operations from the first stage, but there were additionally introduced by mathematical simulation: neon pressure test at $P_{pr}$ for $T_{pr}$ and the following repeated evacuation for $t_{ev}$ (table 1).

Table 1. Parameters of the investigation stages.

| Stage | $T_{vd}$, h | $P_{pr}$, atm | $T_{pr}$, h | $t_{ev}$, h |
|-------|------------|--------------|------------|------------|
| 1     | 72         | 0            | 0          | 3          |
| 2     | 72         | 1            | 48         | 3          |

Figure 1 demonstrates graphical view of the obtained theoretical functions $Q_n = f(B)$ that show that the most pronounced effect of atmospheric neon penetrating through the leak(s) into the sealed envelope of the discharger chamber takes place in the molecular flow mode. And it is possible to explain a spike in the bottom of g-curve (3 d, 3 h, $\phi = 1$, Ne (see figure 1)) by means of analyzing the functions from figure 2.

Figure 2. Superposition of functions that show the change of neon pressure $p_n = f(B)$ and air pressure $p_v = f(B)$ in the discharger after the end of control operations for two research stages (table 1). Curves a, c, e, g, i, k correspond to the atmospheric neon gas taking into account its presence in the atmosphere; curves b, d, f, j, l, m are for air at $\phi = 0.001$; $\phi = 0.1$; $\phi = 1$ respectively.

The analysis of the results (figures 1, 2) obtained for viscosity mode ($\phi = 0.001$) show that while discharger storage in the air the partial pressure of the neon gas inside even at the leak values $B$ up to $\approx 10^{-6}$ Pa·m$^3$/s is kept at the level $p_n \approx P_a$. Pressure test in the neon medium has no significant effect on the neon partial pressure in the same way as for the discharger that was not subject to pressure testing. This, in its turn, consequently has no effect on the leak rates, though the values of the leakage are quite
high. The repeated evacuation of the working volume of the down-hole chamber with the discharger before monitoring also has practically no effect on leak rates, however there is a sharp fall within an open interval $B \geq 2 \cdot 10^{-4}$ Pa·m$^3$/s on the curves for the neon flow $Q_n = f(B)$ (figure 1, curves a, b). The dynamics of air pressure $p_a$ inside the instrument remains quite stable within the leak range from $2 \cdot 10^{-12}$ to $3 \cdot 10^{-7}$ Pa·m$^3$/s, and the repeated evacuation after the pressure test starts influencing significantly on the air pressure level for leak rates $B \geq 5 \cdot 10^{-6}$ Pa·m$^3$/s (figure 2, curve b), and the pressure is going down practically by six decades ($10^6$) unlike similar version of investigations 1 (figure 2, curve d) without pressure test and repeated evacuation, where $p_a$ is ranged between 150 to 500 Pa.

For the molecular flow mode ($\varphi = 1$) with leaks $B$ from $10^{-7}$ to $10^{-6}$ Pa·m$^3$/s in the dischargers the partial neon pressure after pressure test is approximately equal to the molding pressure. The neon flow $Q_n$ is slowly going up in the area of leaks $B = (5 \cdot 10^{-7} \ldots 5 \cdot 10^{-6})$ Pa·m$^3$/s due to the increase of conductivity of the leak channel $B$; and increase of its numeric value influences on $Q_n$ value here greater than little decrease of neon pressure $p_n$ in the discharger.

The neon pressure difference in case of $B < 10^{-7}$ Pa·m$^3$/s leaks is practically similar for viscosity and molecular flow modes, but more significant neon loss in molecular flow mode initiates fall of $Q_n$ on the curve $Q_n = f(B)$ at essentially less values of $Q_n$ than in case of $\varphi = 0$. Tending to slow fall of $Q_n$ at $B > 2 \cdot 10^{-6}$ Pa·m$^3$/s (figure 1, curve g and figure 2, curve k) relates to the area of neon pressure $p_n$ in the discharger due to its equalizing while keeping in the air to the level comparable with the partial pressure of the atmospheric neon (1.8 Pa). It is evident that the discussed area characterizes capabilities of rejecting gas-filled dischargers with the specified storage time based on the content of atmospheric neon inside them without additional pressure test. Hence for research stage 1 this effect can be used in practice for the extension of the upper check limit of dischargers rejection from $3 \cdot 10^{-6}$ to $3 \cdot 10^{-5}$ Pa·m$^3$/s.

Thus based on the analytical assessment of gas exchange through the open-end low-conductivity channels in the sealed envelopes of gas-filled micro dischargers it is determined that the values of relatively large leaks depend on the working gas flow through the leaks as well as on a sequence of the process operations performed during control considering a number of variable process parameters (time of storing, pressure test, evacuation, etc.). Besides, for the leaking dischargers exposed to atmosphere with the leak related to the molecular flow mode it is necessary to consider atmospheric neon inside the controlled sealed envelope since it affects essentially the calculation-based assessment of sensitivity of the leak tests performed using UFKG.

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