THE DETECTION OF THE LEAKS LOCATION IN THE VACUUM CHAMBER ACCORDING TO SPUTTER-ION PUMPS CURRENT MEASUREMENTS

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The present work is focused on developing methods to determine the locations of leaks in the extended vacuum chamber what is similar to chamber proton synchrotron U-70. This refers to small leaks that are difficult to detect by leak detector. Leak location is determined by measuring the air pressure in the chamber near the connectors of the diode-type sputter-ion pumps which pump out the chamber. The pumps discharge currents were used as the pressure gauges, as described in [1]. The main components of residual gas in the chamber are hydrogen and air, which come from gassing at the walls and above mentioned uncontrolled leakages, respectively. The flow and the pressure of hydrogen in the chamber were determined as described in [2], and the current of discharge corresponding to this pressure was determined as described in [1]. The discharge current corresponding to the air was determined by subtracting the current required for pumping out hydrogen from the total pump discharge current. Air pressure can be determined by the formula:

$$P = 1.67 \times 10^{-4} I^{0.92} \tag{1}$$

where the discharge current is expressed in amperes and the pressure in mm Hg. We assume that the sections of the ring between two adjacent pumps are the separate chambers. During a number of sessions of the accelerator we carried out measurements of currents in the process of alternate shutdown of neighboring pumps in six chambers. For some of these chambers the locations of leaks and air flows through them were known [3]. These observations allowed us to determine the empirical coefficients, showing what fractions of air pressure at pump connections to the chamber are the partial pressures of air components - nitrogen, oxygen and argon, as well as what are the fractions of flow of air components in the chamber and their fractions of total air discharge current. This allowed us to develop a methodology to detect a leak at its arbitrary location.

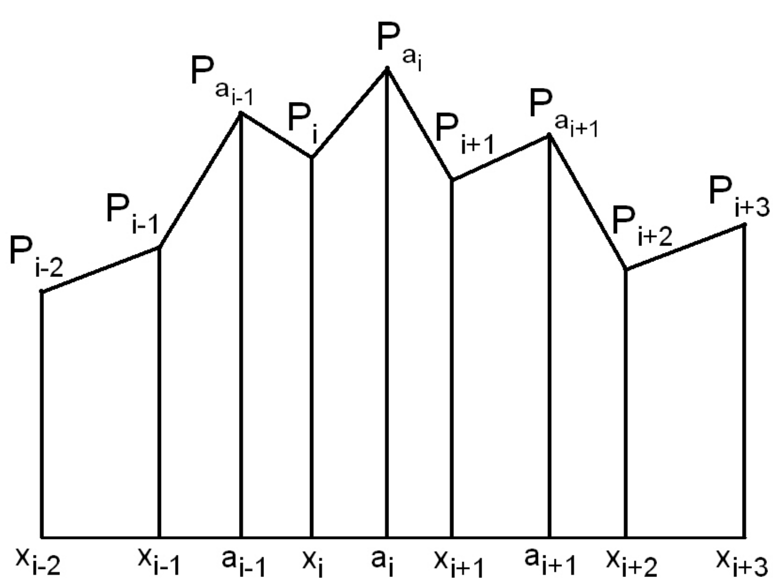

Figure.1. The diagram of pressure changes from the sites of leaks to the sites of pumps in the case of an area of three chambers having leaks, when the chambers at the beginning and the end of the area are without leaks.

Figure 1 schematically shows the change in pressure along the length of several neighboring chambers with leaks. Let us assume that the chamber *i* has a leak at the point a_i, the flow through which is Q_i. The geometric dimensions of vacuum leaks are very small, so the leak can be considered a point source of gas and can be characterized using the impulse δ - Dirac function [3]. Then in the interval from x_i to x_{i+1} air pressure change can be described by the following equation:

$$u_0 \frac{d^2 P}{dx^2} = -Q_i \delta(x - a_i) \qquad (2)$$

where u_0 - is the specific conductivity of the chamber for the gas of consideration. From the solution of equation (2) with boundary conditions $x = x_i$, $P = P_i$; $x = x_{i+1}$, $P = P_{i+1}$ follows:

$$P_{ai} - P_i = \frac{Q_i(a_i - x_i)}{2u_0} \qquad (3)$$

$$P_{ai} - P_{i+1} = \frac{Q_i(x_{i+1} - a_i)}{2u_0} \qquad (4)$$

where P_{ai} - is the pressure at the point of leak. By eliminating this pressure from (3) and (4), we obtain the following relation between a_i and Q_i:

$$Q_i(x_i + x_{i+1} - 2a_i) = 2u_0(P_i - P_{i+1}) \qquad (5)$$

Applying (3) and (4) for nitrogen and oxygen separately, we obtain a system of four linear algebraic equations with four unknown parameters: $a_i, Q_i, P_{aiN_2}, P_{aiO_2}$, because the source of leak is the same for nitrogen and oxygen and the fractions of air flow (Q_{iN_2}, Q_{iO2}) and the partial pressures (P_{iN_2}, P_{iO_2}) are known from the measurements of the coefficients at the above-mentioned six chambers. This system of equations was solved using mathematical software Mathcad. There is no need for obtaining a_i in analytical form. The parameters of argon were not used due to the worst accuracy of experimental data for argon pressure as compared to nitrogen and oxygen pressure. Perhaps this was due to release of argon from the sputter-ion pumps and because of lower speed of pumping of argon compared to nitrogen and oxygen. The obtained approximate value of the root a_i was checked by equation (5) for the air. Such calculations were carried out for all the chambers what gave an idea of the ring U-70 tightness. Estimation of maximum pressure in the leaks locations allowed to determine the average pressure of air and argon in each chamber and in the whole ring. This can be of significance for studying the scattering of protons by the residual gas. Determination of the value of leak flow is not of practical significance, except in the case of large leaks. The calculated values of a_i were compared with those obtained previously by other methods [3] and in other sessions of the accelerator. In most cases the obtained values were not significantly different (in the range of ± 15% of difference). One can estimate the accuracy of determination of the leak location, which is at least not better than the accuracy of measurement of pressure using the discharge current pump. Therefore, an optimistic estimation of the accuracy of calculation of leak location gives a value in the range of ± 30cm . This implies that the method described above so far cannot replace the search of leaks using a helium leak detector. However, compared to conventional techniques, the described method has the following important features:

1. It allows to determine the most feasible leak location, for example, the nearest welding seam or sealing, what significantly reduces the time of searching.
2. The leaks can be determined remotely and in advance, during a session of the accelerator by the special program without the participation of an operator.
3. The present technique permits the detection of such leaks that are difficult to find using the conventional leak detector, for example, due to the extended time of helium passage or due to adverse conditions of helium access through a long channel.
4. The upgrading of method of leakage determination in all chambers of the ring allows to define more accurately the value of an average pressure of air and argon during the session of the accelerator work.

In the case of improving the system of measurement of discharge currents of pumps and improving the accuracy of pressure measurements, the error of the leak determination can be reduced, which would make this method more promising.

In conclusion, the technique of determining the leak location in the vacuum chamber has been developed. This technique is of significant interest for an application to both separate and extended vacuum chambers with a large number of the same type of electro-physical pumps.

REFERENCES

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