METHOD FOR DETERMINATION OF CONTENT OF GAMMA-EMITTING NUCLIDES IN AEROSOL DISCHARGES

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The timely detection and elimination of ecologically harmful sources of discharges is one of the most effective methods for reduction of the entry of radioactive materials into the atmosphere from installations with a nuclear-fuel cycle, which requires the use of real-time methods to monitor the content of radionuclides in aerosol discharges [1].

One of the main sources of radioactive discharges that contaminate the environment is the exhaust ventilation systems of the rooms in which the technological equipment is located. Removal of the disperse phase of the aerosol by means of filters of FPP and FPA materials does not completely prevent the increased discharge of radionuclides when the radionuclides come from the technological-equipment rooms due to loss of their integrity.

The existing methods for monitoring the radionuclide content of discharges are based on sampling of the disperse phase of the aerosol by means of technically complex instruments. Their installation and operation at sites where the number of potential sources of increased discharges reaches several hundred require large expenditures of material and labor. In addition, it is possible to ensure that a sample is representative, which is important to increase monitoring accuracy, only as a result of study of the characteristics of the discharges (disperse and chemical compositions and velocity curves) and complication of the construction of the sampling apparatus (the use of a multipoint intake probe and nozzles of various sizes).

We shall examine a nonsampling monitoring method, which is based on measurement of the exposure dose rate on the outside surface of the housing of the air filter of the exhaust ventilation system.

The relationship between the increment in the exposure dose rate $\Delta P_{A}$ at a selected point $A$ on the surface of the filter housing after a certain time interval and the average concentration of radionuclides from the disperse phase of the aerosol that arrive for removal can be obtained by experiment or calculation. In the experimental determination of this relationship, the measured dose-rate increment is related to the radionuclide concentration found by a laboratory method with sampling by analytic filters. Calculation of the relationship is based on a mathematical model that takes into account the accumulation of radionuclides on technological filters of a specific type and the variation of their activity using one detector located near its outside surface.

The processes of activity accumulation and measurement of exposure dose rate can be described by the following system of equations

\[
\begin{align*}
A_f &= C_{\eta} \omega t; \\
A_f &= \sum_{j=1}^{m} q_j \delta t; \\
q_j &= \Delta P_{A} / [4P_{UJ}];
\end{align*}
\]

(1)
Fig. 1. Measurement geometry for D-9U filters.

\[ \bar{C} = \sum_{j=1}^{m} C_j; \]

\[ \Delta P_A = \sum_{j=1}^{m} \Delta P_{A_j}; \]

\[ \bar{C} = \bar{C}_{B_j}, \]

where \( \delta \) is the activity of the filter cloth; \( \eta \) is the cleaning factor; \( \omega \) is the volume through-rate; \( \sigma \) is the surface activity density of the filter cloth for the \( j \)-th radionuclide; \( S \) is the area of the filter cloth; \( \Delta P_{A_j} \) is the dose-rate increment at point \( A \) due to the gamma radiation of the \( j \)-th radionuclide; \( P_{\gamma j} \) is the gamma constant of the \( j \)-th radionuclide; \( I_j \) is a factor that takes into account the measurement geometry and absorption by the structural materials of the gamma radiation of the \( j \)-th radionuclide; \( C_j \) is the volume concentration of the \( j \)-th radionuclide averaged over time interval \( t \); and \( q_j \) is the contribution of the activity of the \( j \)-th radionuclide. By solution of system (1), we obtain

\[ \bar{C} = \Delta P_A / 4 \eta \omega t \sum_{j=1}^{m} P_{\gamma j} I_j q_j. \]

In formula (2), the \( q_j \) values are set by the known isotopic composition of the discharges, which, as a rule, coincides with the isotopic composition of the radioactive product [3]; and \( I_j \) is to be calculated.

The measurement geometry for D-9U filters is shown in Fig. 1. Each of the filter layers can be considered a plane rectangular source of thickness \( \mu_j d(i - 1) \sec \theta \). Then the formula for the geometrical factor will have the form

\[ I_j = \sum_{i=1}^{n} \left\{ \begin{array}{c} \arctg \frac{H}{\alpha} + \int_{0}^{\frac{\pi}{2}} \frac{d\psi}{\sec \theta} \left[ \tan \theta \exp \left\{ -\mu_j d(i - 1) \sec \theta \right\} d\theta \right] \right\}, \]

where \( \mu_j \) is the linear gamma-attenuation factor of the perforator material at the energy of the \( j \)-th radionuclide; and \( l \) is the total thickness of the filter.

In the derivation of formula (3), it was assumed that \( \eta \) was independent of \( \bar{C} \) and \( t \), the activity was uniformly distributed over the area of the filter cloth, the material of the filter cloth had practically no effect on the gamma radiation, and the delay of short-lived radionuclides was negligible for a short measurement time.