EFFECT OF SHRINKAGE AND MECHANICAL WEAR OF THE ADSORBENT ON THE AERODYNAMIC PARAMETERS OF AU-1500 CARBON ADSORBERS FOR VENTILATION SYSTEMS OF NUCLEAR POWER PLANTS

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A possible mechanism leading to a substantial increase in the aerodynamic resistance of AU-1500 iodine carbon adsorbers used in the ventilation systems of nuclear power plants is examined. It is shown that the relatively small wear (several percent) of SKT-3 adsorbent granules with formation of a dust fraction can result in a substantial (ten-fold) increase of the aerodynamic resistance of adsorbers. Possible reasons for the wear of an absorbent and dust getting into an adsorber are given. 4 figures. 6 references.

The rooms in the monitored zone of a nuclear power plant with a VVER-1000 reactor, which are designed for pressure (pressurized reactor shell) and not designed for pressure (the building and the main part of the reactor compartment, special housing), are characterized by the fact that in all operating regimes the air contains radioactive inert gases, iodine, and aerosols. To guarantee the design parameters of the air in the enclosures in the controlled zone of a nuclear power plant, admissible emissions of iodine into the atmosphere, and purification of the outside air introduced into the room with the control panels during a general radiation accident, AU-1500 type carbon adsorbers are installed and operate in a part of the ventilation systems.

Experience in operating the exhaust ventilation systems of the monitored zone and the emergency inflow systems shows that a nonstandard increase in the resistance of carbon adsorbers compared with the ratings data is observed (by a factor of 10 or more in 8–20 months for the design flow rate). In addition, the ventilation system becomes less capable of performing its functions with respect to the design flow rate of air, rarefaction, and radiation safety (directed motion of air from less to more contaminated enclosures, safe velocity of air in openings) in enclosures in the monitored zone. Adsorbers have been examined and carbon has been analyzed with respect to the bulk density and fraction composition for several years, but no single reason has been found for the indicated phenomenon.

Analysis of the state of carbon absorbers shows that nonstandard growth of their aerodynamic resistance is observed in all ventilation systems, irrespective of the operating intensity. At the Zaporozh’e nuclear power plant, 663 of the 854 installed carbon absorbers must now be replaced.

Calculation of the Aerodynamic Resistance of an Adsorber on the Basis of a Capillary Model. According to plant data, for the initial adsorbent load the aerodynamic resistance of the adsorber, i.e., \( \Delta P \), with a constant volume flow of air \( J \) equal to 500, 1000, 1500, and 2000 m\(^3\)/h is 340, 880, 1570, and 2450 Pa, respectively.

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On the basis of experience in the development and operation of the dynamic adsorption systems at the National Science Center at the Khar'kov Physicotechnical Institute [2, 3] and analysis of the data (see, for example, [4, 5]), it can be asserted that for prolonged operation of adsorbers their aerodynamic resistance increases as a result of compaction of the layer with shrinkage and appearance of fine dust-like fractions, associated with the wear of the adsorbent material, in them. With time the resistance increases severalfold and depends on the construction of the adsorber, the operating conditions, and the mechanical properties of the adsorbents. The effect of these factors on the aerodynamic resistance of an adsorber has been analyzed using a capillary model of the adsorption layers [6]. In this model, the entire free space through which the gas flows is represented in the form of a system of identical cylindrical channels. For each specific medium, the problem reduces to a correct choice of the effective length and diameter of the channel. In our case, all granules of the adsorbent were treated as beads with the same diameter \(d\). Let \(\Omega\) be the porosity of the transverse cross section of the adsorber (i.e., the ratio of its free area to the total area), and let \(D\) be the diameter of the adsorber. As follows from geometric considerations, for example, for the case of close packing of spheres, the number \(N_c\) of channels is two times greater than the number of adsorbent granules. Then the number of channels can be expressed by the formula

\[
N_c = 2(D/d)^2(1 - \Omega),
\]

and the effective diameter of the channel can be expressed as

\[
d_0 = \left[ \frac{\Omega d^2}{2(1 - \Omega)} \right]^{1/2}.
\]

The length of each channel was taken to be the height of the adsorbent (300 mm).

The degree of turbulence of the air flow passing through the channel was estimated using the Reynolds criterion

\[
\text{Re} = \frac{4Jm}{\pi d_0 \eta V} = \frac{4Jmd}{\sqrt{\eta D^2(2\Omega(1 - \Omega))^3}},
\]

where \(m\) is the molecular mass of the air, \(V\) is the molar volume of the air, and \(\eta\) is the dynamic viscosity of air under normal conditions. The value 1.55 mm was chosen for \(d\). This corresponds to an average granule size taking into account the fact that in practice many granules are broken up into parts. The adsorber diameter is 1000 mm, and the porosity of the transverse cross section is 23% in accordance with the well-known bulk density of the absorbent. For calculations, the typical values of the air flow through the adsorber were used. It was found that in all cases \(\text{Re} < 2300\), which corresponds to laminar flow.

The pressure drop on the adsorber for laminar flow can be determined using the Poiseuille law (see, for example, [6]):

\[
\Delta P = \frac{128\eta h(1 - \Omega)Jm}{\pi \rho (dD^2)^2 V},
\]

where \(\rho\) is the air density under normal conditions.

For air flow rates of 500, 1000, 1500, and 2000 m\(^3\)/h, the computed pressure differential \(\Delta P\) is 380, 760, 1150, and 1500 Pa. This agrees with the initial plant data. This result shows that the model chosen is adequate for describing the aerodynamics of a carbon adsorber.

**Shrinkage of the Adsorber.** During operation of any adsorber in which a bulk adsorbent is used, shrinkage (compaction) of the adsorber occurs. Therefore, the height and porosity of the adsorbent layer decrease. If the change in height of the adsorbent layer is denoted as \(\Delta h\) and the relative change in height of the layer is denoted as \(y = \Delta h/h\), then we obtain

\[
d_{0y} = \left( \frac{\Omega - y}{2(1 - \Omega)} \right)^{1/2} d
\]

for the effective diameter of the channel,