STUDY OF IODINE ADSORPTION IN THE DYNAMIC MODE FOR SEVERAL CARBON ADSORBENTS

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The absorption efficiency of iodine vapor in the dynamic mode for number carbon adsorbents from different manufacturers was studied. In the experiments we have used a stand which was created in NSC simulating the adsorber of NPP ventilation system. The amount of adsorbed iodine was determined by X-ray radiometric and nuclear physics (ANPC "SOKOL") methods. The offered technique will be used for the optimal choice of new adsorbents for carbon filters of NPP ventilation systems.

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1. INTRODUCTION

At operation of nuclear power plant (NPP) there is nuclear release from fuel elements into the first reactor contour and then into the working area. Main gas radioactive components in the ventilated air are xenon, krypton, iodine and its compound vapor. The isotope J^{131} and methyl iodide – the compound based on it – are particular dangerous because of the ability to accumulate in the human body. At present carbon absorbers type of $AU-1500$ are used on NPP of Ukraine for filtration of the ventilated air. Reliability of absorbers work ensures radiation safety on NPP and environmental protection. Many adsorptive filters on NPP exhausted their resource because of a long operation time. Renewal of $AU-1500$ adsorbers requires either the regeneration of applied presently in iodine filters active carbon SKT-3 or its replacement. Restoring adsorbers $AU-1500$ requires either regeneration of activated carbon SKT-3, currently applied in iodine filter, or replace it. As a production of SKT-3 coal was halted, there is a necessity of its replacement other adsorbent not worse than SKT-3 on working characteristics. At present on the market there are the active carbons of different manufacturers, which can be used for filling the adsorption filter. For the choice of active coals it is necessary to carry out the comparative analysis of their properties. In NSC KIPT a laboratory complex for determination of a number of carbon adsorbents technological characteristics: mechanical strength properties while abrasion, aerodynamic resistance of adsorbent layer in conditions of replicating adsorbers $AU-1500$ operations, iodine and iodine methyl adoption capacity at room temperature in static mode was created [1]. Active coals important characteristic is a degree of iodine and his connections absorption in the dynamic mode. In this connection research of iodine absorption from the ventilated air stream in conditions of replicating adsorbers $AU-1500$ operations is reasonable. This will make it possible to estimate adsorptive ability of adsorbents and to carry out proximate comparative analysis their iodine absorption effectiveness.

2. MATERIALS AND METHODS

Study of iodine admixture absorption from the ventilated air stream in conditions of replicating adsorbers $AU-1500$ operations was carried out on the special stand, including the layout of adsorber [2]. To obtain information on the dynamics of iodine adsorption along the height of adsorbent layer in adsorber we used layout, consisting of 6 tight connecting sections $48\,mm$ in diameter and $50\,mm$ long, filled with activated coal. The total adsorbent layer height and air flow intensity through the adsorber layout were $300\,mm$ and $0.48\,m^3/s\Delta m^2$ that correspond to the real layer height and to the mode of $AU-1500$ adsorber operations. Detection of iodine content in coal adsorbent test specimens after blowing through them air with iodine vapor was carried out by X-ray radiometric and nuclear physics methods on the basis of analytical nuclear physical complex "SOKOL" developed in NSC KIPT [3]. The coal adsorbents of different manufacturers were studied: DGF2 (Germany), Norit RKJ (Belgium), Electrod-D (Ukraine) and SKT-3I (Russia) in-use presently in adsorbers $AU-1500I$.

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Table 1. *Values of adsorbed iodine mass per adsorbent gram $\Delta m_J/m_0$ for different active coals at static adsorption*

Type of adsorbent	$\Delta m_J/m_0$
DGF2	$63.2 \cdot 10^{-3}$
Norit RKJ	$50 \cdot 10^{-3}$
SKT-3	$56.4 \cdot 10^{-3}$
SKT-3I	$67.3 \cdot 10^{-3}$
Electrod-D	$84.6 \cdot 10^{-3}$

These adsorbents were chosen because they have the complex of necessary technological characteristics. Static iodine adsorption during $75\,h$ at the temperature of $20°C$, atmospheric pressure and iodine vapor partial pressure $0.17\,Torr$ are given in Table 1. Evidently, coals of DGF2, Electrod-D and SKT-3I have higher adsorption capacity, than coal of SKT-3. Determination of iodine absorption in the dynamic mode was carried out at iodine vapor density in an air stream $0.077\,g/m^3$. Iodine vapor density was set by an air stream through the iodine vapor generator and temperature of water in the generator [4]. Iodine absorption in the first and second sections of model at duration of air stream blowing $\tau = 2$, 4 and $6\,h$ was studied. Measurements of Δm_J were carried out on three samples mass of $\sim 3\,g$, chosen from different areas of the test sections of adsorber layout.

3. RESULTS OF AN INVESTIGATION

Table 2 represents iodine absorption coals of DGF2 in the first section of adsorber layout. Resulted values are given with relative accuracy $\sim$ 10%. Variation $\Delta m_J/m_0$ for different specimen tests at the fixed experiment duration is connected with an allocation nonuniformity of the adsorbed iodine in an adsorbent volume in a section. Importantly, the presence of iodine in the second section was below than limit of the in-use method detection ($\sim 0.0017\,mass\%$).

The values of iodine absorption of Electrod-D in the first and second sections of layout are presented in Table 3. Relative accuracy of $\Delta m_J/m_0$ determination for the first section was $\sim$ 8%, for the second $\sim$ 15%, that is related to substantially lower iodine concentration in the second section. Table 3 shows that "breakthrough" of iodine molecules into the second section was observed for $\tau = 4\,h$ and $6\,h$. The considerable difference of $\Delta m_J/m_0$ values for two specimen tests at $\tau = 6\,h$ related to that the second section only began to fill up and filling character was nonuniform.

Table 2. *Values of adsorbed iodine mass per gram $\Delta m_J/m_0$ for adsorbent DGF2 and averaged values $(\Delta m_J/m_0)_{av}$ for different time τ of air stream blowing through the adsorber layout*

τ, h	$\Delta m_J/m_0$, $wt.\%$	$(\Delta m_J/m_0)_{av}$, $wt.\%$
2	0.0098 0.0061 0.0090	0.0083
4	0.0145 0.0162 0.0095	0.0134
6	0.0239 0.0271 0.0288	0.0266

Considering present dynamic adsorption data, it is necessary to take into account difference of investigational coals granules configuration which determines adsorber aerodynamics. Granules of DGF2 coal characterised of diameter $2\,mm$ and long $\sim 5\,mm$. Its packed density is higher unlike coal of Electrod-D with granules diameter $3\,mm$ and long to $20\,mm$. The consequence of this is the "breakthrough" molecular iodine into the second section for coal "Electrode D" and eventually in the subsequent sections, in spite of its high adsorption capacity.

Norit RKJ and SKT-3I are potassium iodide KJ^{127} impregnated coals. There is an isotopic exchange of J^{131} on J^{127} in the molecule of CH_3J in the process of absorption of radioactive methyl iodide vapor that considerably raises the cleaning efficiency of ventilation air from J^{131} when using these coals. At determination of absorption iodine amount by used in the present work method, it is necessary to take into account the presence of iodine in an initial matrix. Iodine content in an initial matrix for Norit RKJ was estimated as $1.4702 \pm 0.0882\,wt.\%$. That corresponds to certificate data of the coal. For coal SKT-3I this value was estimated as $1.27 \pm 0.08\,wt.\%$, that also corresponds to certificate data. As an accuracy of determining the adsorbed iodine amount at presence of iodine in an initial matrix goes down substantially, then more long duration of air stream blowing and higher iodine concentration in ventilated air are required for a reliable data obtainment.

Thus, the method used in the present work can be applied for the express analysis of adsorptive capacity of adsorbents in the dynamic mode. However additional experiments are necessary for determination of the optimal regimes of ventilated air blowing and iodine density in a stream.

Table 3. *Values of adsorbed iodine mass per adsorbent gram* $\Delta m_J/m_0$ *and averaged values* $(\Delta m_J/m_0)_{av}$ *for different time* τ *of air stream blowing through the absorber model filled of Electrod-D coal*

τ, h	$\Delta m_J/m_0$, wt.%	1-th section, $(\Delta m_J/m_0)_{av}$, wt.%	2-th section, $(\Delta m_J/m_0)_{av}$, wt.%
2	0.0240 0.0220 0.0240	0.0230	not revealed
4	0.0546 0.0549 0.0648	0.0581	0.00240
6	0.1362 0.1457 0.1382	0.1400	0.00445 0.00187 0.00187

4. CONCLUSIONS

Absorption efficiency of iodine vapor in the dynamic mode for a number of different manufacturers of carbon adsorbents (DGF2 - Germany, Norit RKJ – Belgium, Electrode-D - Ukraine and SKT-3I - Russia) was studied. Developed and created in NSC KIPT special stand simulating an operation of ventilation systems of NNP $AU-1500$ and X-ray radiometric method for determination of the adsorbed iodine amount were used. It is shown that an efficiency of iodine vapor absorption from the ventilated air by Electrod-D coal is higher than by coal of DGF2. "Breakthrough" of iodine molecules in adsorber layout was found for Electrod-D coal. It is conditioned Elektrod D has got lower packed density than DGF2, what is connected with granule configuration.

Achievement of necessary accuracy of determination of adsorbed iodine amount for impregnated adsorbents of Norit RKJ and SKT-3I, having in the initial matrix $\sim$ (1.3...1.5) *wt.*% "technological" iodine, requires the increase of duration of air blowing. The offered methodology can be used for determination of the efficiency of iodine vapor absorption from the ventilated air stream in conditions of replicating operations of adsorbers at NPP ventilation system. This will make it possible to decide the problem of new adsorbent choice for the use at NPP ventilation systems in Ukraine.

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References

1. V. I. Sokolenko, M. A. Khazhmuradov, O. I. Volchok, E. I. Vinokurov, T. K. Grigorova, R. M. Sibileva. Optimization of adsorbents choice for renewal of filters at NPP ventilation systems // *Sbornik naukovych statey za programoyu "Problemy resursu I bezpeky expluatazii konstrukziy, sporud ta mashin"*. 2012, Kyiv Instytut electrozvariuvannia im. Patona NAN Ukrainy, p.172-175 (in Russian).

2. V. G. Kolobrodov, M. A. Khazhmuradov. Creation of stand and method of measuring iodine and iodine methyl absorption by adsorption filters in conditions of replicating the systems of ventilation and special gas cleaning operations at NPP // *Sbornik naukovych statey za programoyu "Problemy resursu I bezpeky expluatazii konstrukziy, sporud ta mashin"*. 2009, Kyiv, Instytut electrozvariuvannia im. Patona NAN Ukrainy, p.208-215 (in Russian).

3. V. N. Bondarenko, et al. Analytical nuclear physics complex NSC KIPT "Sokol" // *Int. Conf. Current Problems in Nuclear Physics and Atomic Energy. Book of Abstracts.* 2006, p.163.

4. V. G. Kolobrodov, V. I. Sokolenko, M. A. Khazhmuradov, R. M. Sibileva, E. V. Demura. Introduction of water, iodine and iodine methyl vapor admixtures in the stream of the ventilated air in conditions of replicating adsorbers AU-1500 of ventilation system at NPP operations // *IV Mizhnarodna naukova konferenziya "Ekologichna bezpeka: Problemy i shlyachy vyrishennia". Zbirnyk naukovych statey.* 8-12 veresnia 2008 r., Alushta, AR Crimea, Ukraine, v.1, p.220-224 (in Russian).

ИССЛЕДОВАНИЕ ПРОЦЕССА ПОГЛОЩЕНИЯ ЙОДА В ДИНАМИЧЕСКОМ РЕЖИМЕ РАЗЛИЧНЫМИ УГЛЕРОДНЫМИ АДСОРБЕНТАМИ

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Проведено исследование эффективности поглощения паров йода в динамическом режиме для ряда углеродных адсорбентов различных производителей. В экспериментах использовался созданный в ННЦ ХФТИ стенд, моделирующий работу адсорбера АУ-1500 системы вентиляции АЭС. Количество адсорбированного йода определялось рентгенорадиометрическим и ядерно-физическим (АЯФК "СОКОЛ") методами. Предложенная методика будет использована для оптимального выбора новых адсорбентов для угольных фильтров систем вентиляции АЭС.

ДОСЛІДЖЕННЯ ПРОЦЕСУ ПОГЛИНАННЯ ЙОДУ В ДИНАМІЧНОМУ РЕЖИМІ ДЕЯКИМИ ВУГЛЕЦЕВИМИ АДСОРБЕНТАМИ

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Проведено дослідження ефективності поглинання пари йоду в динамічному режимі для деяких вуглецевих адсорбентів різних виробників. У експериментах використовувався створений в ННЦ ХФТІ стенд, що моделює роботу адсорбера АУ-1500 системи вентиляції АЕС. Кількість адсорбованого йоду визначалася рентгенорадіометричним і ядерно-фізичним (АЯФК "СОКІЛ") методами. Запропонована методика буде використана для оптимального вибору нових адсорбентів для вугільних фільтрів систем вентиляції АЕС.