

Experimental detection of rated peculiarities of IR spectra at (111) channeling in a thin crystal Si is possible at initial angular divergence of positron beam $\Delta\theta_0 < \theta_{sc}$. Angular distribution and polarization as well as

account of dechanneling and electron comparison with IR are examined in a separate work.

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REFERENCES

1. Baier V.N., Katkov V.M., Strakhovenko V.M. Electromagnetic processes at high energy in directed monocrystals. – Novosibirsk: Nauka, 1989. – 400 p.
2. Akhiezer A.I., Shulga N.F. Electrodynamics of high energies in a substance. – Moscow: Nauka, 1993. – 344 p.
3. Kumakhov M.A. Radiation of channeled electrons. – Moscow: Energoatomizdat, 1986.
4. Theory of relativistic particle radiation / Ed. by V.A. Bordovitsina. – Moscow: Fismatlit, 2002. – 576 p.

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GAMMA SPECTROMETRIC METHOD TO CONTROL ACTIVITY AND NUCLIDE COMPOSITION OF GASEOUS RADIOACTIVE WASTE FORMED AT OPERATION OF NUCLEAR POWER PLANTS

P.M. Gavrilov, A.G. Kokhomsky, K.M. Izmestiev, I.N. Seelev, M.E. Silaev*

FSUE «Siberian chemical enterprise», CTAF Seversk of Tomsk region

*Tomsk Polytechnic University

E-mail: silaev@k21.phtd.tpu.ru

Gamma spectrometric method was developed to monitor continuously and on line radioactivity and nuclide composition of inert radioactive gases, radioactive aerosols and iodine in gas aerosol emissions from power reactor facilities. This method is based on continuous representative sampling of gas aerosol samples and quasi-continuous automated recording of nuclide composition and radioactive material emission rate. Low detectable level of the method is about 0,1 Bq/m³, highest detectable level for noble gases (Ar-41, isotopes Xe and Kr) is about 10⁶ Bq/m³.

Introduction

Increase of quality of controlling radioactive gas aerosol emissions is one of the key directions of radiation safety at operation of power reactor facilities (PRF) [1].

At PRF operation the main components of gaseous radioactive wastes (RAW) are: inert radioactive gases (Ar-41, isotopes Xe and Kr), radioactive aerosols and gaseous iodine [2].

Application of radiometric methods for continuous control of gas aerosol emissions of PRF allows determining just integral activity of gas released in atmosphere. In conditions of variable nuclide composition of gas aerosol emissions the radiometric method does not allow estimating contribution of individual radionuclides into total activity [3]. It is necessary to determine a contribution of individual radionuclides for estimating the consequences of emission and reporting towards control organizations. Radioisotope composition of emission may be analyzed by semiconductor gamma spectrometers [4].

The feature of using laboratory spectrometers for controlling emissions is the fact that measurements are not carried out directly at gas main lines but by sampling. Gas aerosol sampling is carried out during a long period of time (a day, as a rule). After that a sample (aerosol filter, gas capacity, coal column etc.) is taken by operator from a sampling line and put to a semiconductor detector of gamma spectrometer for measuring.

Gamma spectrometric analysis allows determining activity and nuclide composition of a sample as well as integral quantitative characteristics of gas aerosol emission in general. However, application of laboratory gamma spectrometers for controlling activity and nuclide composition of radioactive emissions of PRF taking controlled samples from sampling lines does not allow fulfilling continuous on-line control of current values of activity and radionuclide composition of gas aerosol emissions. The method is not rather operative.

In accordance with new standards [1] there is a necessity to develop operative automated control system of emissions allowing as soon as possible recording, computing and analyzing increase of activity of gaseous RAW. Practical value of the results of operative gamma spectrometric analysis is conditioned by a possibility of determining the connection of the results of detecting radionuclide composition and activity of radionuclides with technological processes occurring at nuclear power plant (NPP). Awareness of these connections allows determining the source of emission and taking measures on optimization of technological processes (for example, preventing development of emergencies connected with integrity of pipe lines of reactor primary coolant circuits and controlling hermiticity of PRF fuel element blanket).

The aim of the work was to develop the automated information-measuring complex for on-line continuous control of activity and nuclide composition of emissions

of inert radioactive gases (IRG), radioactive aerosols and iodine by gamma spectrometric method including proper methodological and metrological assurance.

Gamma spectrometric method of on-line continuous control of activity and nuclide composition of gaseous RAW

The proposed gamma spectrometric method consists in continuous representative selection of gas aerosol samples from ventilation pipe of PRF and quasi-continuous recording of nuclide composition and amount of IRG emissions, radioactive aerosols and iodine by automated gamma spectrometric complex.

Automated gamma spectrometric complex consists of two gamma spectrometers made by a group of enterprises «Green Star» [5] one of which controls emissions of inert radioactive gases (IRG) and another one of radioactive aerosols and iodine. The complex allows recording, computing and analyzing continuously and with high resolution the activity level of all gamma radiated radionuclides of IRG composition, radioactive aerosols and iodine released by PRF.

The diagram of the device for measuring activity and nuclide composition of radioactive aerosols and iodine in gas aerosol emissions of PRF is given in Fig. 1.

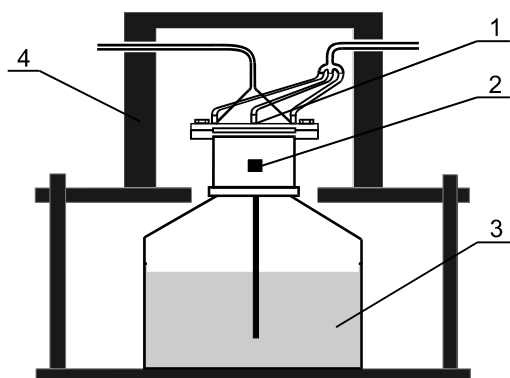


Fig. 1. The diagram of the device for measuring aerosols and iodine: 1) sampling device; 2) Ge(Li) detector; 3) Dewar vessel; 4) protection

Air containing radionuclides is pumped through a special sampling device with constant consumption. In this case radioactive aerosols and iodine are concentrated at a total filter fixed inside the sampling device (Fig. 2). The total filter consists of one aerosol filter of the AAF type (aerosol analytic filter) intended for precipitation of radioactive aerosols and one iodine filter of the SFT type (sorption-filter iodine tape) intended for precipitation of radioactive iodine.

The feature of this sampling device is the fact that it is set directly at a detector of gamma radiation. In this case a sample is maximum approximated to detector active region.

Count rate for discrete energies of gamma radiation of gas aerosol sample selected continuously in a specified energy range is measured using gamma spectrometer. Volumetric activity of radionuclides being on a total fil-

ter is identified and calculated by special software. The measured count velocities in complete absorption peaks and spectrometer calibration characteristic are used for this purpose.

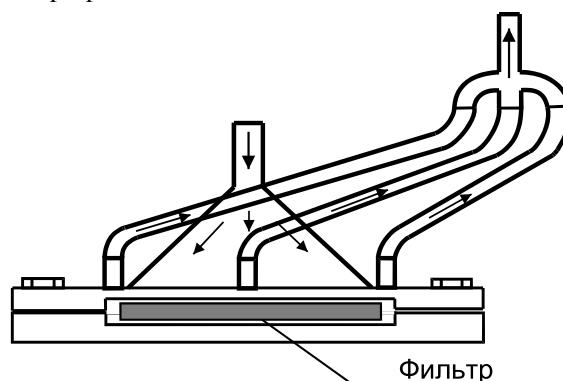


Fig. 2. Sampling device for on-line control of aerosol and iodine

Lower limit of measuring nuclide volumetric activity at random uncertainty 25 % amounts to 0,1 Bq/m³. Upper limit of volumetric activities of gamma radiative nuclides of radioactive aerosols and I-131 measured by this technique amounts to 10⁴ Bq/m³. Energy range of recording gamma radiation of radionuclides (I-131, Co-60, Cs-134, Cs-137, Fe-59, Cr-51 etc.) amounts from 50 to 3000 keV. Extended uncertainty ($P=0,95$) of calculating nuclide volumetric activity does not exceed 60 %.

To calibrate spectrometer of controlling radioactive aerosols and iodine a reference source of special purpose should be used in total filter geometry. Radionuclides Ba-133, Cs-137, Co-60, Eu-152 with activity 1000 Bq each should be included into a set of reference source of special purpose.

Activity and nuclide composition of inert radioactive gases are measured in geometry of Marinelly vessel (cover geometry). Marinelly geometry is implemented by a special vessel with volume of 3 l. The diagram of sample drawer is given in Fig. 3. The vessel is set directly on gamma radiation detector surrounding it almost from all sides. The efficiency of measuring process increases in this case in comparison with the measuring process at which the sample is placed from one of sides of coaxial detector.

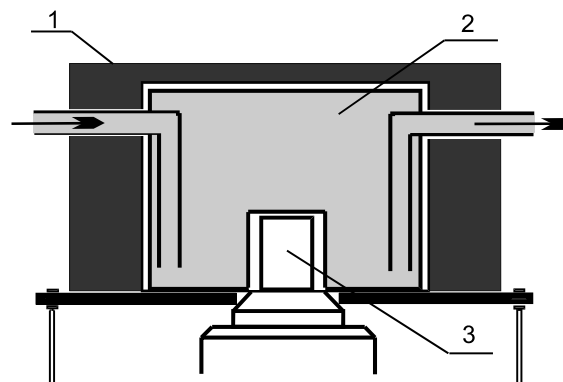


Fig. 3. Sample drawer for controlling IRG emissions: 1) lead protection; 2) Marinelly vessel; 3) Ge(Li) detector

Air containing radionuclides of IRG and air purified of radioactive aerosols and iodine with constant consumption is pumped through Marinelly vessel. In Marinelly vessel the sample is not concentrated and each point of time the value of current volumetric activity and IRG nuclide composition in PRF emission are measured at gamma spectrometer. Volumetric activity of radionuclides being in measuring capacity is identified and calculated by special software. The measured count velocities in complete absorption peaks and spectrometer calibration characteristic are used for this purpose.

Lower limit of measuring nuclide volumetric activity amounts to 0,1 Bq/m³. Upper limit of volumetric activities of gamma radiative nuclides from IRG composition (Ar-41, isotopes Xe and Kr) measured by this technique amounts to 10⁵ Bq/m³. Energy range of recording gamma radiation of radionuclides amounts from 80 to 1300 keV. The extended uncertainty (at confidence coefficient $P=0,95$) of calculating nuclide volumetric activity does not exceed 60 %.

To calibrate spectrometer of controlling IRG it is necessary to use the reference poured standard of specific activity in the form of grains (gas simulator) on the basis of radionuclides Am-241, Co-60, Cs-137, Eu-152 and Ba-133 with saturated density 0,01...0,04 g/cm³ and specific activity 40 Bq/kg for each radionuclide. Marinelly vessel is filled up with poured source. Thus, calibration geometry coincides completely with measuring geometry.

One of the main conditions of the proposed on-line continuous control of IRG emission, radioactive aerosols and iodine is to support cyclicity of gamma spectrometric measuring. To provide cyclicity of operation of spectrometric complex without operator participation in the program of processing gamma spectra the operation mode «diurnal period» is implemented. In this mode before operation the operator introduces the required parameters (values of air consumption in ventilating system, air consumption in sampling line, value of Marinelly vessel volume etc.) and then spectrometer opevelocites automatically.

The function of estimating current activity of controlled nuclides is additionally implemented in the program of spectra processing. The operator may estimate activity of any controlled nuclide without breaking measuring period.

The important parameter when measuring IRG emission, radioactive aerosols and iodine by the developed gamma spectrometric technique is optimal duration of one measuring period at which the balance between control responsiveness and measuring result presence is observed.

Exposure time is 2 h. At such period duration the required statistics is supported even at low activity of emission. At less exposure time the threshold of mini-

mal detected activity increases. Increase of duration of one step is unjustified as control responsiveness decreases and emission dynamics is seen worse.

The specified exposure time is not final one and may be reconsidered improving path characteristics such as efficiency, energy resolution.

At the end of each period the composed spectrum is treated and period report is formed. At the end of a day period the diurnal report is formed.

The proposed gamma spectrometric technique of measuring activity and nuclide composition of inert radioactive gases, radioactive aerosols and iodine was introduced at Reactor plant «Siberian chemical enterprise» and executed in the form of analytic techniques of measuring: «Control of activity of gamma radiative radioactive inert gases in gas aerosol emissions of SCE RP» and «Control of activity of aerosols and iodine in emissions of SCE RP». The measuring techniques are metrologically certified and coordinated with Russian State standard of ЦММИ ФГУП «ВНИИФТРИ».

Conclusion

The automated complex of on-line control of activity of PRF air-gas emission was created by gamma spectrometric technique on the basis of semiconductor detector provided with proper methodical and metrological supply and being operationally tested at SCE Reactor plant.

Complex allows recording, calculating and analyzing quazi-continuously with high resolution the level of activity of all radionuclides from composition of gas aerosol emissions of PRF. Lower limit of measuring radionuclide activity amounts to 0,1 Bq/m³, the upper limit of measured volumetric activities of radionuclides from IRG composition (Ar-41, isotopes Xe and Kr) – 10⁵ Bq/m³.

Registrations of gamma spectrometric complex reflect changes of activity and nuclide composition of emission due to various technological operations at PRF that allows controlling efficiently the state of reactor equipment including integrity of primary system pipe and hermeticity of fuel cladding as well as giving references on technological process optimization.

The carried out instrumental-methodical developments give a possibility to organize the order of handling with gaseous RAW according to the requirements of effective federal standards and rules in the field of using atomic energy.

The developed complex may be used for controlling radioactive gas aerosol air emissions of any radiationally-dangerous enterprise.

REFERENCES

1. NP-021-2000 Federal standards and rules in the field of using atomic energy «Treatment of gaseous radioactive wastes. Safety requirements». – Moscow: Gosatomnadsor Rossii, 2000. – 10 p.
2. Panov E.A. Practical gamma spectrometry at atomic stations. – Moscow: Energoatomizdat, 1990. – 75 p.
3. Fertman D.E., Risin A.I., Stas K.N. Increase of measurement reliability in aerosol radiometry // Izmeritel'naya Tekhnika. – 1996. – № 12. – P. 23-30.
4. Gilyarovich E.L., Gryaznov A.N., Inikhov A.G., Kostyleva Yu.G., Mysev I.P., Nikolaev A.M. Modern practice of supporting quality of measuring ionizing radiation. Nuclear measuring-information technologies. – Moscow: SRC «SNIIP», 1997. – 35 p.
5. Single-board spectrometer SBS. User's guide. – Moscow: Group of enterprises «Green Star», 2005. – 27 p.

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