Graphite Research Reactor (RFT) Spectrometric Investigation During Dismantling. – 17006

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ABSTRACT

Dismantling of research reactors are carried out at the National Research Centre "Kurchatov Institute". Technical start-up of the 20 MW capacity experimental graphite water cooling reactor (RFT) was started up in 1952. During experimental work, some accidents, followed by a pollution of a graphite blocks by fission products of nuclear fuel, took place. After 10 years working period the reactor was shut down. The fuel was removed and the reactor was partially dismantled. Reactor graphite stack (cylinder 380 cm high and 260 cm in diameter) was isolated.

RFT reactor dismantling was began in 2015. Video investigation of reactor channels in graphite stack was made before dismantling. Graphite in channels near active zone of reactor was destroyed. Measurements of exposure dose rate inside the channels near active zone showed value up to 2 Sv. The samples were taken from different layers of stack during graphite blocks removing from the reactor. Complex α-, β- , γ- spectrometric analysis of this samples was made. The graphite blocks were contaminated by fuel components and its fission products. It was found that ^{137}Cs and ^{90}Sr were the main contamination radionuclides in graphite.

After graphite block removing and reactor vessel bottom cleaning, exposure dose rate reached 5-7 mSv/h at upper level of the reactor vessel and at the bottom ~ 40 mSv/h at the bottom. Gamma-spectrometric analysis of reactor vessel was made. These measurements showed that activated in iron reactor vessel ^{60}Co made the main contribution to exposure dose rate. After reactor vessel dismantling exposure dose rate reached 2 mSv/h at upper level of the reactor vessel and~ 3 mSv/h at the bottom.

INTRODUCTION

Experimental water cooling graphite reactor (RFT) with a capacity of 20 MW was started up in 1952 [1]. After 10 years' period of intensive using, it was shut down and partially dismantled. The reactor vessel, graphite stack of the core and the reflector, cooling pipes, building constructions, equipment, covering of reactor pit were isolated. Graphite stack of core and reflector RFT was cylinder 380 cm height and 260 cm diameter (total weight of the graphite blocks ~ 34 t). Graphite stack was into the steel reactor vessel (diameter 269 cm, wall thickness 20 mm) [1]. Reactor was covered 10-cm layer of iron shot and 60 cm layer of concrete. In 2015 the reactor RFT dismantling was began.

PRELIMINARY INVESTIGATION

After RFT reactor vessel depreservation we received access to working channesl, and preliminary investigations were carried out. Its included video, dosimetric and spectrometric investigations. Some of the channels were not available because of difficulties removing covers. Video inspection showed that in active zone of reactor the graphite plugs of the working channels were destroyed in the most cases. (Fig. 1).

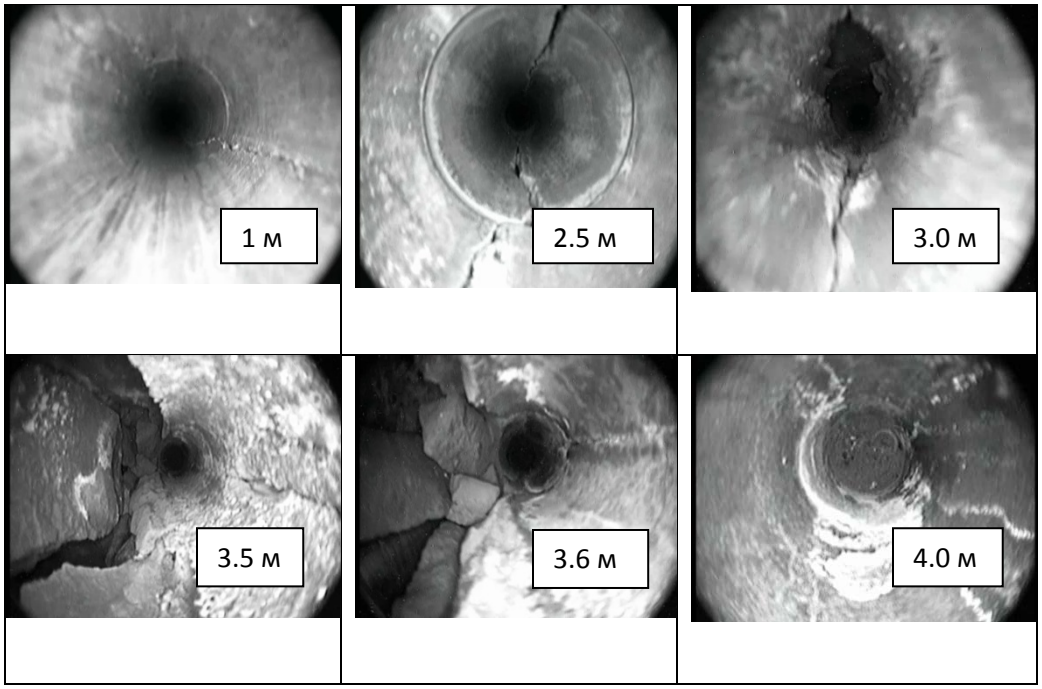

Fig.1 Photo of channel in graphite stack on different depth.

Typical distribution of the exposure dose rate (EDR) along the channel depth is presented in fig. 2.

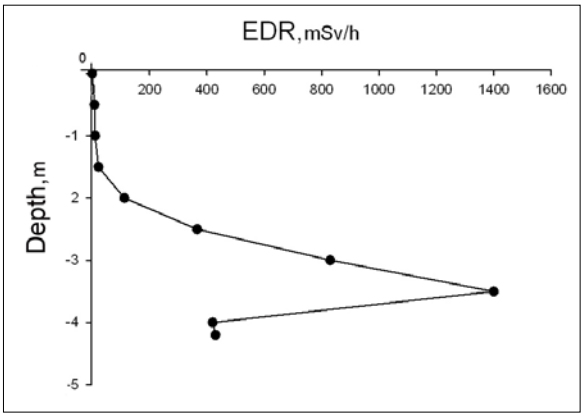

Fig.2 Distribution of the exposure dose rate (EDR) along the channel depth.

Represented data showed that exposure dose rate has the maximal value in active zone in some cases achieve 2 Sv/h. EDR values in various channels in active zone of the reactor RFT are presented in fig. 3.

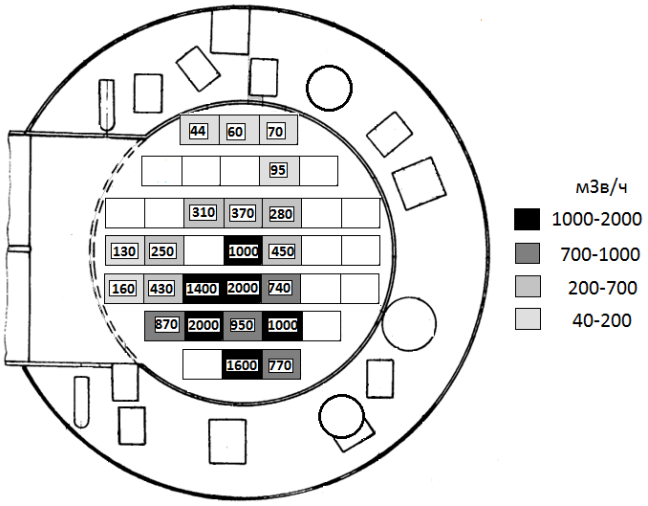

Fig.3 Distribution of EDR value at active zone of reactor.

The zone of the maximal contamination of a graphite stack by fission products and components of fuel was situated into the channels where emergency depressurization of fuel elements took place. Spectrometric investigation carried out by CdZnTe detector showed that the main dose forming radionuclide in the channels was ^{137}Cs.

GRAPHITE BLOCKS REMOVAL

To provide access to the graphite blocks the reactor upper cover was removed. The cover had a 2.6 m diameter with 60 cm thickness and 27t weight. Unloading of graphite stack was carried out by the remotely-controlled mechanisms Brokk Company equipped with the universal clamshell capture (fig.4).

Fig.4 Unloading of graphite blocks.

Before unloading the exposure dose rate on the surface of graphite blocks was in range of 30-50 μSv/h. After unloading of blocks EDR reached 20 mSv/h at the upper level of the reactor vessel and 70 mSv/h at the bottom. During unloading of graphite blocks the samples were taking from different layers for further definition of contamination of graphite blocks by components of nuclear fuel and fission products. Control of the graphite block contamination was an actual problem because accidents occurred during reactor RFT operation. The concentration of γ-ray radionuclides was estimated by the spectrometric complex InSpector-2000 of the Canberra Company that included a semi-conductor detector using HP Germanium GC-4018. The analysis of the gamma-spectrum was made by the GENIE-2000 software. The concentration of ^{90}Sr was detected by the scintillation β-ray spectrometer "Progress-beta", with the plastic scintillation detector BDEB-3-2U. Using the "Progress-5" software the spectra were analyzed in 0.9 MeV to 30 MeV range with the assumption that the sample contained ^{40}K and ^{90}Sr in equilibrium with ^{90}Y. Presence of ^{241}Pu was detected by the highly sensitive spectrometric complex SKS-07P-B11 with liquid scintillator ULTIMA GOLD AB. The concentration ^{241}Pu in samples was calculated by the "Liquid Master" software.
The concentrations of uranium and plutonium radionuclides in the samples were determined by alpha-spectra of the targets, prepared by the electrochemical method after separation by extraction 30% solution of TBP in toluene [2]. The results of spectrometric analysis represented in table I.

Table I. The specific activity of radionuclides in graphite blocks, Bq/kg.

Sample	Cs-137	Co-60	Am-241	Sr-90	Eu-152	Eu-154	U-234	U-235	U-236	U-238	Pu-239+240	Pu-238	Pu-241
0 layer	$7,3*10^7$	$7,4*10^3$	$5,7*10^5$	$1,5*10^7$	-	-	$1,1*10^4$	$3,0*10^2$	$5,5*10^2$	$6,3*10^2$	$3,6*10^5$	$3,9*10^5$	$2,3*10^6$
1 layer	$8,3*10^7$	$1,9*10^4$	$7,0*10^4$	$8,5*10^6$	-	-	$5,0*10^3$	$1,5*10^2$	$1,1*10^2$	$2,6*10^2$	$4,3*10^3$	$8,0*10^2$	$1,1*10^4$
2 layer	$1,4*10^8$	$4,2*10^3$	$2,6*10^5$	$2,2*10^7$	-	$1,2*10^4$	$3,2*10^4$	$7,0*10^2$	$8,0*10^2$	$1,5*10^3$	$5,2*10^5$	$6,8*10^4$	$5,5*10^5$
6 layer	$8,9*10^7$	$3,0*10^4$	$9,9*10^5$	$5,8*10^7$	$1,6*10^5$	$4,3*10^4$	$6,0*10^4$	$1,6*10^3$	$3,0*10^3$	$3,6*10^3$	$1,6*10^6$	$5,8*10^5$	$4,0*10^6$
9 layer	$4,6*10^7$	$8,4*10^3$	$9,1*10^4$	$1,4*10^6$	$7,5*10^4$	-	$1,5*10^3$	40	90	90	$5,0*10^4$	$3,7*10^4$	$2,5*10^5$
12 layer	$8,5*10^6$	$6,9*10^3$	$7,9*10^4$	$5,0*10^6$	$6,8*10^4$	-	$6,0*10^2$	22	38	40	$2,3*10^4$	$2,3*10^4$	$8,0*10^4$
16 layer	$1,5*10^8$	$5,4*10^4$	$3,8*10^6$	$1,5*10^8$	$4,2*10^4$	$3,6*10^4$	$2,1*10^4$	$4,0*10^2$	$3,0*10^3$	$1,4*10^3$	$7,1*10^5$	$2,3*10^6$	$7,0*10^6$

From the results in Table 1 we can see that the radionuclides contaminations of the

graphite stack are almost uniformly along the depth. It was found the increasing of radionuclide concentrations near the reactor vessel bottom due to the complete destruction of the two bottom layers of graphite stack.

REACTOR VESSEL REMOVAL

After the graphite blocks removing and the reactor vessel bottom cleaning the exposure dose reached 5 mSv/h at the upper level of the reactor vessel and~ 40 mSv/h at the bottom. The results of dosimetric and spectrometric investigations of the reactor vessel are shown in figures 5 and 6.

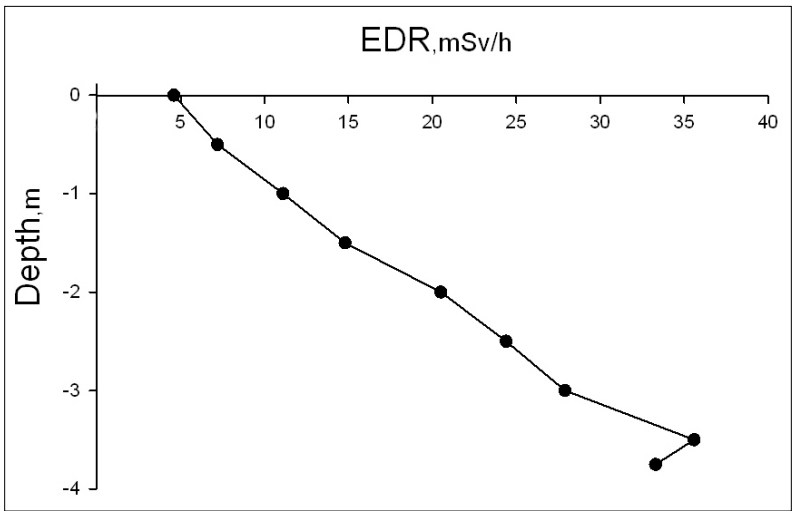

Fig.5. EDR distribution along the depth.

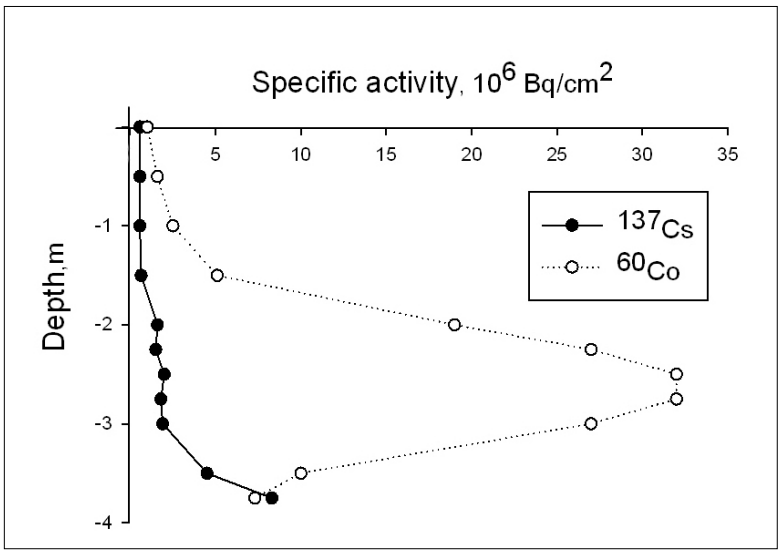

Fig.6. Specific activity ^{137}Cs and ^{60}Co distribution along the depth.

From the figure 6 this is followed that the main dose forming radionuclide is ^{60}Co and the activity of ^{137}Cs is order of magnitude lower. Dismantling of the reactor vessel was carried out by remote plasma cutting. The results of dosimetric and spectrometric investigations of the reactor pit after reactor vessel dismantling are shown in figures 7 and 8.

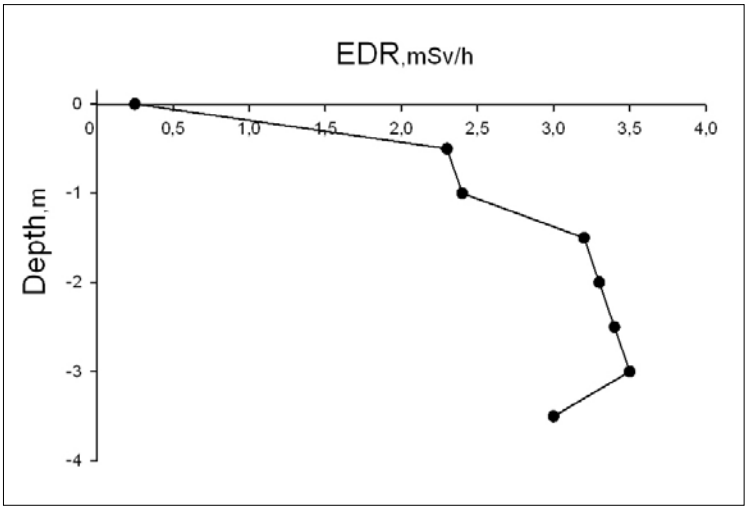

Fig.7. EDR distribution along the depth.

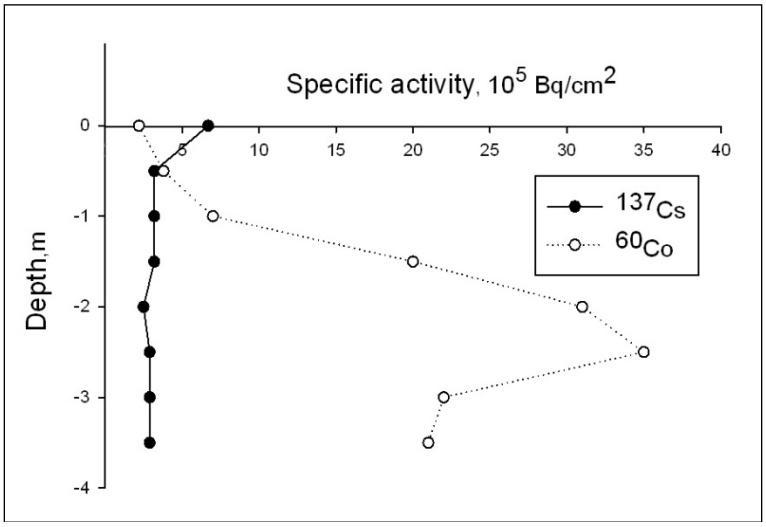

Fig. 8. Specific activity ^{137}Cs and ^{60}Co distribution along the depth,

The exposure dose rate reached 2 mSv/h at the upper level of the reactor vessel and~ 3 mSv/h at the bottom. EDR near the bottom in the reactor pit center was decreased an order of magnitude. Before and after removing reactor vessel ^{60}Co was the main dose forming radionuclide the most concentration of ^{60}Co was observed in active zone of the reactor that indicated to its activation nature. Activity of ^{60}Co

decreased an order of magnitude after the reactor vessel removing. The surface contamination by ^{137}Cs decreased 3 ÷ 7 times.

CONCLUSIONS

1. Distribution of fuel components and fission products in graphite stack was practically uniform.
2. The radionuclide ^{137}Cs was the main graphite stack contamination.
3. The reactor vessel and reactor pit were contaminated by ^{60}Co as a neutron activation product.
4. The main concentration of ^{60}Co was observed in the reactor active zone.

REFERENCES

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2. A. V. Stepanov, Yu. N. Simirskii, I. A. Semin, and A. G. Volkovich. «A Rapid Method for Analysis of Radioactive Waste for the Presence of Fuel Matrix Components» - Radiochemistry, 2016. Vol. 58. № 3. P. 302-304.