DISTRIBUTION NEUTRON AND GAMMA OF RADIATION IN THE PROTECTIVE COMPOSITE WITH VARIOUS CONTENT OF ATOMS OF BORON

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Results of calculations neutron and scale of fields are given in the filled polialkanimid with a variation of the content on atoms of boron in him, with the purpose of an assessment of extent of decrease in density of a stream of thermal neutrons and level of gripping gamma-radiation depending on atoms of boron additive. Dependence of spatial distributions of density of streams thermal and fast ($E > 2\,MeV$) neutrons and capacities of doses of neutrons and gamma-quanta in a layer of a polialkanimid 1 m thick are received at content on atoms of boron in him from 0 to 5%. The analysis of results of calculations has shown that the size of power of a dose of neutrons behind protection from a polialkanimid practically doesn't depend on an additive in his composition on atoms of boron. Extent of decrease in intensity of gamma-radiation depends on contents in atoms of boron polialkanimid not linearly. For practical purposes as rather optimum it is possible to consider on atoms of boron additive in polialkanimid in quantity up to 3% of masses. At configuration of protective composition of a boron-containing polialkanimid in combination with other materials it is necessary to consider that at significant increase in gamma-quanta from the previous layer influence of an additive on atoms of boron on deceleration of power of a dose of gamma-quanta behind protection from a polialkanimid with on atoms of boron falls.

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1. INTRODUCTION

In biological protection of nuclear reactors broad application was found by materials on the basis of polymers and, first of all, polyethylene and polypropylene. Thanks to the high content of hydrogen they effectively weaken neutron radiation. However at the same time have rather low temperature of operation which for polyethylene and polypropylene respectively, constitutes $80°C$ and $140°C$.

Search and implementation of the polymeric materials possessing more high thermal and radiation resistance has great practical value for the NPS (nuclear power stations) new projects.

The analysis of the developments performed in the field of creation of designs with high temperature of operation shows that as a polymeric basis of temperatures of fire-resistant polymeric materials combining high deformation and chemical stability in a wide interval poligeteroarilena can be effectively used. Limiting heat and thermal stability it is characteristic of poligeteroarilen which chains consist from continuously alternating aromatic and heterocycles.

And applied polipiromellitimida - poliimida in which receipt dianhydride of piromellitovy acid [1] participates are the most widely known. They contain hinged atoms and groups in a diamine a molecule fragment. Polipiromellitimida - strong and elastic, they have no expressed temperature interval of a softening.

Net aromatic poliimida having the greatest thermal stability (temperature of the beginning of decomposition is above $400°C$) and high heat resistance, provide long operability of products on their basis at temperatures up to $260...300°C$. But high heat resistance, i.e. inability to be softened, does not allow to perform conversion of poliimid from fusion [1, 2] therefore application of aromatic poliimid is limited to production of films and coverings.

A peculiar compromise between thermal characteristics and a possibility of technological processing is provided by the poliimida of fat aromatics called by polialkanimid which receive polycondensation of dianhydrides of aromatic tetracarbonic acids with aliphatic diamines. Polialkanimid as thermoplastic constructional materials are intermediate between aromatic polisulfona and the thermostablest, but expensive poliamidoimida, poliefirimida and poliefirketona [3].

Introduction in structure of polialkanimid of fillers on the basis of fibrous boron-containing hrizotil considerably improves their constructional and operational properties [4, 5]. At the same time use of the atoms of boron having the big section of absorption of neutrons in thermal and over thermal areas of a

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range is one of ways of improvement of protective characteristics of a composite.

Therefore in work results of calculations neutron and scale of fields are given in the filled polialkanimid with a variation of content of atoms of boron in it, with the purpose of an assessment of extent of decrease in density of a flow of thermal neutrons and level of gripping gamma radiation depending on atoms of boron.

2. MATERIALS AND TECHNIQUE

Composite materials received mixture of a powdery polialkanimid and fibrous boron-containing hrizotil of structure of $MgO : SiO_2 : B_2O_3 = 1.5 : 0.1 : 0.9$ (content of atoms of atoms of boron of 11.3 % of masses) with the subsequent processing by a molding method under pressure or hot pressing. The way of processing of compositions was determined by an indicator of fluidity of fusion proceeding from which samples from 30 % filling of polymer and more received by method of hot pressing. Respectively samples with filling of a polialkanimid a boron-containing hrizotil received less than 30 % of masses by a molding method under pressure. Content of atoms of atoms of boron in a composite at the same time varied from 0 to 5 % of masses. The nuclear composition of the materials used in calculation is presented in Table 1.

Table 1. *Nuclear structure of the filled polialkanimid with various content of atoms of boron, mass.%*

C	O	N	H	Mg	Si	B
69.11	16.75	7.33	6.81	-	-	-
62.82	19.86	6.66	6.20	3.28	0.18	1.00
50.28	26.04	5.34	4.96	9.84	0.54	3.00
37.70	32.28	4.00	3.72	16.4	0.90	5.00

For carrying out alternative calculations and receiving spatial and power distributions of streams of neutrons and gamma quanta in the considered materials of protection the compositions consisting of an active zone of the reactor, a reflector, constructional materials and a layer of the studied material 1.5 *m* thick have been used. Calculations were carried out according to the ANISN [6] program realizing the solution of the one-dimensional transport equation by method of discrete ordinates taking into account anisotropy of dispersion. The range of neutrons paid off for the 12th group splitting a power interval. The range of gamma quanta had the 6th group splitting. Geometry of a settlement task – flat [7-9].

Feature of calculations for this task is need to allocate from all potential generators of gamma-radiation (an active zone and materials of protective composition) influencing the size of a stream of gamma-quanta in the studied material, only own source of gripping gamma-radiation, having excluded or having reduced to a minimum formation of gamma-quanta from other layers of materials and from an active zone. Series of calculations for two compositions have been for this purpose carried out. In the first – before the studied material the layer of lead protection settled down as much as possible to weaken gamma-radiation from an active zone, intra reactor designs and the case of the reactor. In the second – the layer of lead was absent, the studied material settled down after the steel case of the reactor to establish effect of formation of gamma-quanta from an active zone and from a metalwork. For adequate comparison of results of calculations, the obtained data in each series were normalized at a size of density of a stream of fast neutrons on forward border of a layer for option of a polialkanimid without atoms of boron and further were submitted in relative units.

As the main characteristics of radiation protection (in this task with a variation of content of atoms of atoms of boron in a polialkanimid) when passing radiation on the studied materials were estimated:

– weakening of density of a stream of fast neutrons ($E_{and\,gt}$; $2\,MeV$);

– weakening of density of a stream of thermal neutrons;

– weakening of power of a dose of neutron radiation;

– weakening of power of a dose of gamma radiation.

3. RESULTS AND DISCUSSION

Result of calculation of distribution of functionalities neutron and gamma-radiations on thickness of a protective layer of 100 *cm* for two options of compositions (with lead and without lead) at the different content of atoms of boron in a polialkanimid are presented in Figs.1-8.

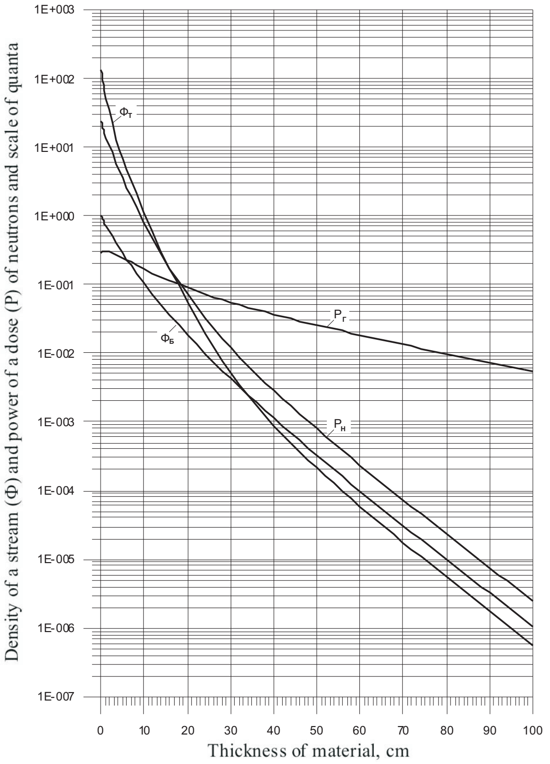

Fig.1. *Distribution of density of a stream of fast (F_f) and thermal (F_t) neutrons, capacities of a dose of neutrons (P_n) and gamma-quanta (P_g) in an initial polialkanimid behind a lead layer*

Values of ratios of functionalities for a polialkanimid with on atoms of boron and without on atoms of boron, the decrease in density of a stream of thermal neutrons showing frequency rate and the power of a dose of gamma-radiation depending on atoms of boron additive size are given in Figs.9-12.

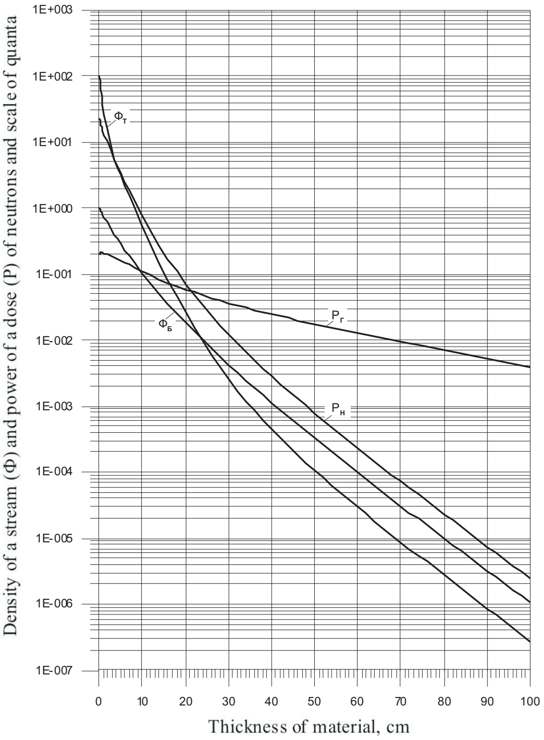

Fig.2. *Distribution of density of a stream of fast (F_f) and thermal (F_t) neutrons, capacities of a dose of neutrons (P_n) and gamma-quanta (P_g) in a polialkanimid with 1 % of masse. on atoms of boron a lead layer*

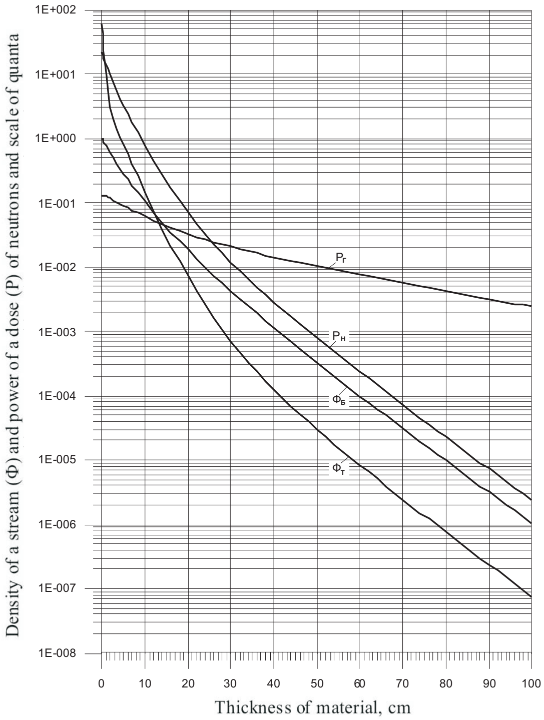

Fig.3. *Distribution of density of a stream of fast (F_f) and thermal (F_t) neutrons, capacities of a dose of neutrons (P_n) and gamma-quanta (P_g) in a polialkanimid with 3 % of masse. on atoms of boron a lead layer*

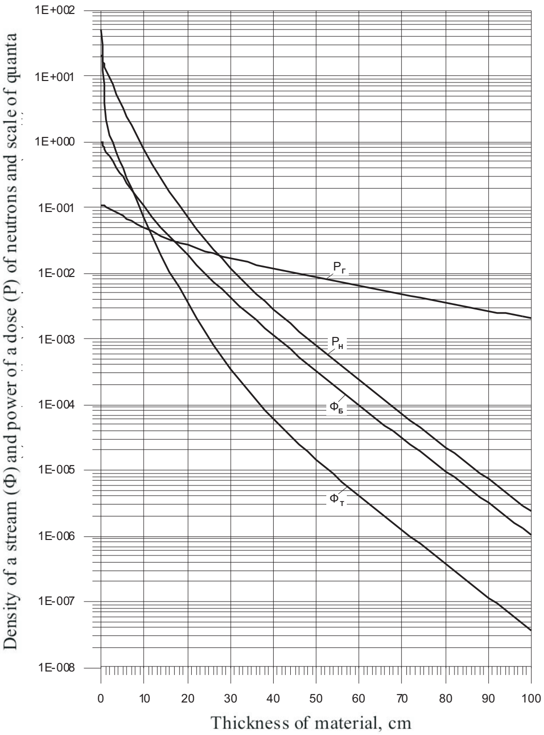

Fig.4. *Distribution of density of a stream of fast (F_f) and thermal (F_t) neutrons, capacities of a dose of neutrons (P_n) and gamma-quanta (P_g) in a polialkanimid with 5 % of masse. on atoms of boron a lead layer*

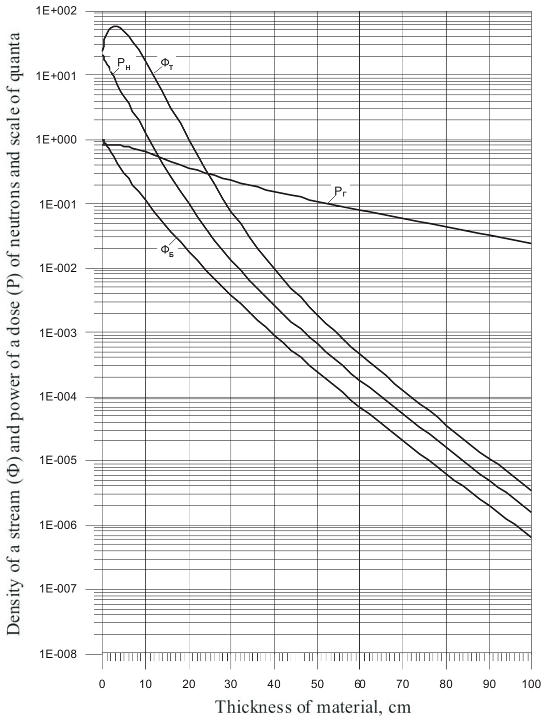

Fig.5. *Distribution of density of a stream of fast (F_f) and thermal (F_t) neutrons and capacities of a dose of neutrons (P_n) and gamma-quanta (P_g) in an initial polialkanimid behind a steel layer*

In the studied materials from the beginning of establishment of an equilibrium range (after layer thickness 30 *cm*) the atoms of boron additive practically doesn't influence distribution of density of a stream of fast neutrons and capacities of a dose of neutrons. At the same time the maximum relative

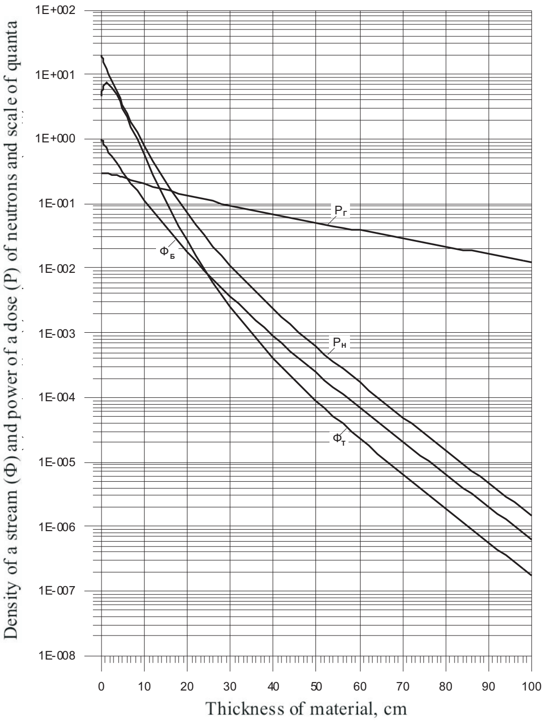

Fig.6. *Distribution of density of a stream of fast (F_f) and thermal (F_t) neutrons, capacities of a dose of neutrons (P_n) and gamma-quanta (P_g) in a polialkanimid with 1 % of masse. on atoms of boron a steel layer*

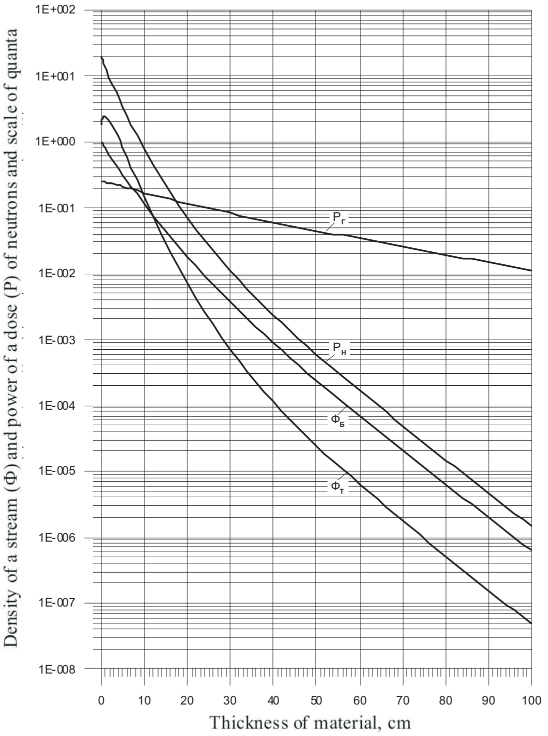

Fig.7. *Distribution of density of a stream of fast (F_f) and thermal (F_t) neutrons, capacities of a dose of neutrons (P_n) and gamma-quanta (P_g) in a polialkanimid with 3 % of masse. on atoms of boron a steel layer*

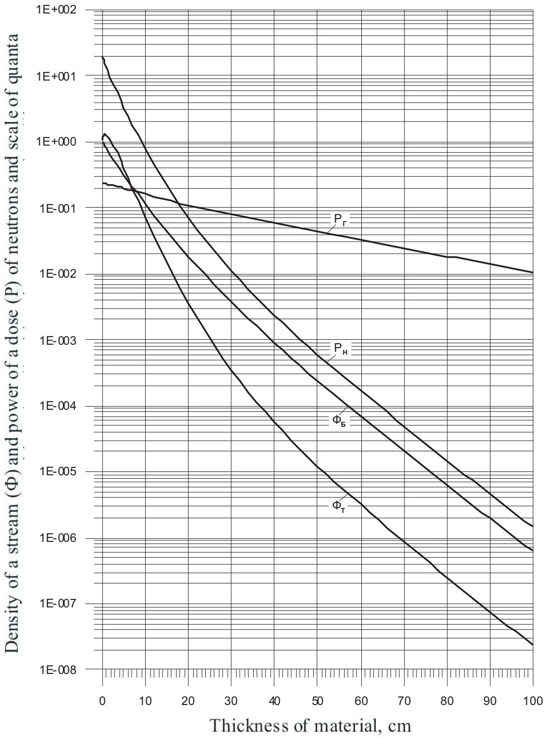

Fig.8. *Distribution of density of a stream of fast (F_f) and thermal (F_t) neutrons, capacities of a dose of neutrons (P_n) and gamma-quanta (P_g) in a polialkanimid with 5 % of masse. on atoms of boron a steel layer*

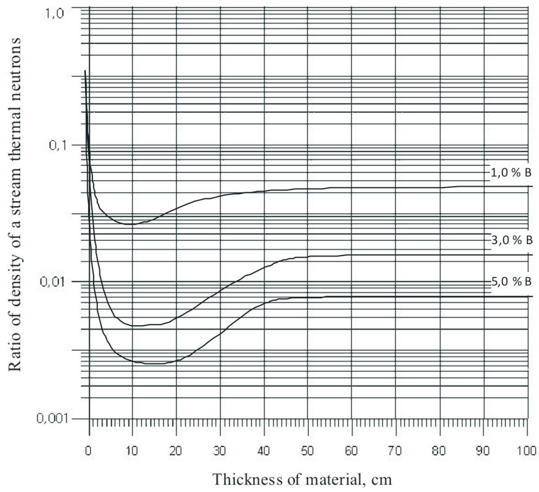

Fig.9. *A ratio of density of a stream of thermal neutrons for a polialkanimid with various content on atoms of boron and a polialkanimid without on atoms of boron in composition with lead*

difference for a polialkanimid with atoms of boron and without on atoms of boron makes 5...9 %. On the basis of received neutron and scale of fields sizes of lengths of a relaxation for density of a stream of fast neutrons and power of a dose of gamma quanta in a polialkanimid with various content on atoms of boron have been calculated. Results of calculation are presented in Tables 2 and 3.

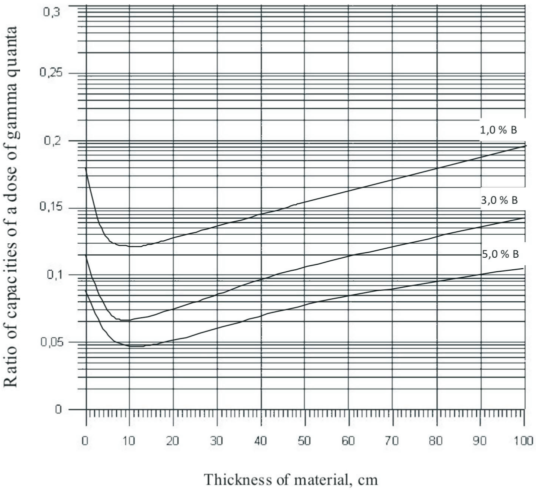

Fig.10. *A ratio of capacities of a dose of gamma-quanta for a polialkanimid with various content on atoms of boron and a polialkanimid without on atoms of boron in composition with lead*

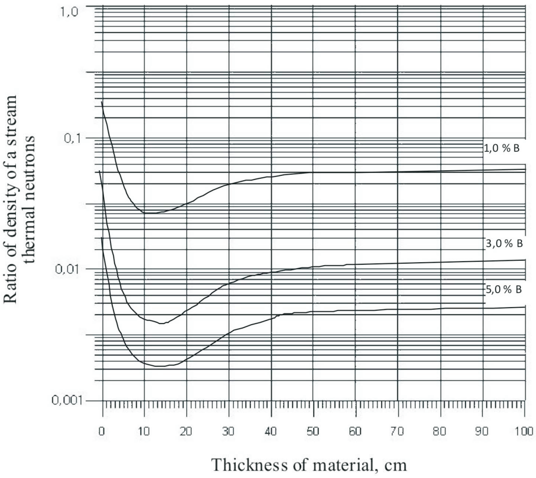

Fig.11. *A ratio of density of a stream of thermal neutrons for a polialkanimid with various content on atoms of boron and a polialkanimid without on atoms of boron in composition with steel*

Table 2. *Lengths of a relaxation of density of a stream of fast neutrons (λ_{fn}, cm) in the filled polialkanimid depending on thickness of his layer (T, cm)*

Content on atoms of boron, % of masse.	λ_{fn}, cm behind a steel layer			λ_{fn}, cm behind a lead layer		
	$T=$ 0... 30	$T=$ 30... 60	$T=$ 60... 100	$T=$ 0... 30	$T=$ 30... 60	$T=$ 60... 100
0	5.6	7.6	8.6	5.8	8.2	8.9
1.0	5.6	7.6	8.6	5.7	8.2	8.9
3.0	5.5	7.6	8.5	5.7	8.0	8.8
5.0	5.4	7.5	8.5	5.5	8.0	8.8

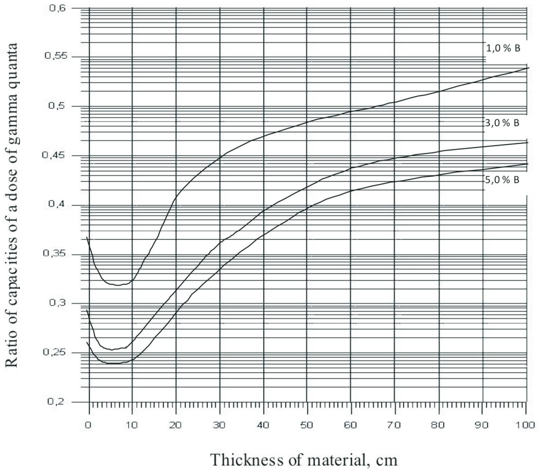

Fig.12. *Ratios of capacities of gamma-quanta for a polialkanimid with various content on atoms of boron and a polialkanimid without on atoms of boron in composition with steel*

Table 3. *Lengths of a relaxation of power of a dose of gamma quanta (λ_g, cm) in the filled polialkanimid of dependence on layer thickness (T, cm)*

Content on atoms of boron, % of masse.	λ_g, cm behind a steel layer			λ_g, cm behind a lead layer		
	$T=$ 0... 30	$T=$ 30... 60	$T=$ 60... 100	$T=$ 0... 30	$T=$ 30... 60	$T=$ 60... 100
0	23.4	28,3	33.4	20.1	25.0	29.9
1.0	25.9	33.0	36.1	17.5	28.3	33.4
3.0	27.3	33.7	36.2	16.7	29.8	35.0
5.0	27.6	33.7	36.1	16.2	30.4	35.5

Analyzing the obtained data, it is possible to note the following.

Availability of atoms of boron in a polialkanimid doesn't influence formation of a range of neutrons in fast area and, respectively, at length of a relaxation of density of a stream of fast neutrons.

With increase in thickness of a settlement layer of a polialkanimid of λ_{fn} increases owing to toughening of a neutron range. A little smaller λ_{fn} values for compositions with steel can be explained with the fact that after steel softer range for neutrons in the range of energiya higher than $2\,MeV$ in comparison with a range after lead therefore the group section of removal of fast neutrons will be more is formed, and relaxation length, respectively, is less.

As for gamma-quanta, the size λ_g with increase in a polialkanimid of content on atoms of boron increases owing to toughening of a range of neutrons in thermal and nadteplovy area, but at the same time there is a decrease in an absolute value of density of a stream of thermal neutrons to increase in content on atoms of boron. As a result the total effect gives noticeable deceleration of power of a dose of gamma quanta behind protection from a polialkanimid with on atoms of boron (1.0...5.0 %) in comparison with that for a polialkanimid without on atoms of boron (in compositions with lead – 4.8...15.5 degree for a layer of a polialkanimid 30 cm thick and 3.9...10.2 degree for a layer of a polialkanimid 60...100 cm thick; in compositions with steel – 2.1...2.9 degree for a layer of a polialkanimid 30 cm thick and 1.7...2.3 degree for a layer of a polialkanimid 60...100 cm thick). Some decrease in frequency rate of weakening of power of a dose of gamma-quanta in process of increase in thickness of a layer of a polialkanimid is a consequence of increase of λ_g with thickness of the studied material at any content on atoms of boron in him. The size λ_g in a polialkanimid at change of content on atoms of boron in him from 0 to 5 % increases on $\sim$ 15...20 %; on thickness of a polialkanimid from 30 to 100 cm the size λ_g increases: for compositions with lead in $\sim$ 2 times, for compositions with steel in $\sim$ 1.5 times.

The effect of decrease in total intensity of gamma-quanta depending on contents in atoms of boron polialkanimid in compositions with steel is less, than in compositions with lead. It occurs because in the first case from a steel structure on a layer of a polialkanimid the considerable education of gamma-quanta which weakening the additive on atoms of boron doesn't influence and which prevail over own gripping gamma-quanta in a polialkanimid takes place. Separately it is necessary to tell about nature of weakening of power of a dose of gamma-quanta in compositions with lead on the first 30 cm of protection from a polialkanimid. Here reduction of λ_g, with increase in an additive on atoms of boron is observed, on the contrary. The matter is that from lead the considerable education over thermal and thermal neutrons takes place. On thickness 30 cm there is their sharp easing, and that bigger, than the content on atoms of boron is more. With further increase in thickness of a polialkanimid thermal neutrons begin to reach balance with fast, and is terminated effect of education of thermal neutrons from lead. In general, the analysis of the data given on Figs.9-12 shows that introduction on atoms of boron in polialkanimid in number of more than 3 % doesn't lead to essential decrease in gripping radiation in material any more.

4. CONCLUSIONS

1. Calculations for definition of protective characteristics of a polialkanimid are executed, including, at introduction to his composition on atoms of boron for decrease in gripping radiation. Dependences of spatial distributions of density of streams thermal and fast ($E > 2\,MeV$) neutrons and capacities of doses of neutrons and gamma-quanta in a polypropylene 1 m thick layer are received at content on atoms of boron in him from 0 to 5%. For an assessment of own gripping gamma-radiation from a polialkanimid and influence of a range of the falling neutrons calculations were carried out for two types of compositions: before a polialkanimid composite were established or lead (the first type), or steel (the second type).

2. The analysis of results of calculations has shown that the size of power of a dose of neutrons behind protection from a polialkanimid practically doesn't depend on an additive in his composition on atoms of boron. Lengths of a relaxation of density of a stream of fast neutrons in the field of establishment of an equilibrium range (on thickness of a composite from 30 to 100 cm) make: for compositions of the first type (with lead) - 8.0...8.8 cm, the second type (with steel) - 7.5...8.5 cm.

3. Extent of decrease in intensity of gamma-radiation depends on contents in on atoms of boron polialkanimid not linearly. So, at sizes of an additive on atoms of boron 1, 3, and 5 of % deceleration of power of a dose of gamma-quanta behind protection with atoms of boron in comparison with that without atoms of boron makes of a polialkanimid, respectively, for a composite 30 cm thick layer: in compositions of the first type – 7.2; 12.6, and 15.5 degree; in compositions of the second type – 2.4; 2.8, and 2.9 degree; and for a layer of a polialkanimid 100 cm thick: in compositions of the first type – 5.4; 8.6, and 10.2 degree; in compositions of the second type – 1.9; 2.1, and 2.3 degree. From 0 to 5 % make lengths of a relaxation of power of a dose of gamma-quanta in a polialkanimid at change of content on atoms of boron in him, respectively, for a composite 30...60 cm thick layer: in compositions of the first type – 25.0...30.4 cm; in compositions of the second type – 28.3...33.7 cm degree; and for a layer of a polialkanimid 60...100 cm thick: in compositions of the first type – 29.9...35.5cm; in compositions of the second type – 33...36.1 cm.

4. For practical purposes as rather optimum it is possible to consider on atoms of boron additive in polialkanimid in quantity up to 3% of masses. At configuration of a polialkanimid with on atoms of boron in protective composition in combination with other materials it is necessary to consider that at a considerable education of gamma quanta from the previous layer influence of an additive on atoms of boron on deceleration of power of a dose of gamma-quanta behind protection from a polialkanimid with atoms of boron falls.

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РАСПРЕДЕЛЕНИЕ НЕЙТРОННЫХ И ГАММА-ПОЛЕЙ В РАДИАЦИОННО-ЗАЩИТНОМ КОМПОЗИТЕ С РАЗЛИЧНЫМ СОДЕРЖАНИЕМ БОРА

Р. Н. Ястребинский

Приведены результаты расчетов нейтронных и гамма-полей в наполненном полиалканимиде с варьированием в нем содержания бора, с целью оценки степени снижения плотности потока тепловых нейтронов и уровня захватного гамма-излучения в зависимости от добавки бора. Получены зависимости пространственных распределений плотностей потоков тепловых и быстрых (> 2 МэВ) нейтронов и мощностей доз нейтронов и гамма-квантов в слое полиалканимида толщиной 1 м при содержании в нём бора от 0 до 5%. Анализ расчётов показал, что величина мощности дозы нейтронов за защитой из полиалканимида практически не зависит от добавки в его состав бора. Степень снижения интенсивности гамма-излучения зависит от содержания в полиалканимиде бора нелинейно. Для практических целей достаточно оптимальной можно считать добавку бора в полиалканимид в количестве до 3 % масс. При компоновке защитной композиции борсодержащего полиалканимида в сочетании с другими материалами следует учитывать, что при значительном натекании гамма-квантов из предыдущего слоя влияние добавки бора на снижение мощности дозы гамма-квантов за защитой из полиалканимида с бором падает.

РОЗПОДІЛ НЕЙТРОННИХ І ГАММА ПОЛІВ У РАДІАЦІЙНО-ЗАХИСНОМУ КОМПОЗИТІ З РІЗНИМ ВМІСТОМ БОРА

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Наведено результати розрахунків нейтронних і гамма-полів у наповненому поліалканіміді з варіюванням в ньому вмісту бору, з метою оцінки ступеня зниження щільності потоку теплових нейтронів і рівня загарбного гамма-випромінювання в залежності від добавки бору. Отримано залежності просторових розподілів щільності потоків теплових і швидких (> 2 MeB) нейтронів і потужностей доз нейтронів і гамма-квантів у шарі поліалканіміда товщиною 1 м при вмісті в ньому бору від 0 до 5%. Аналіз результатів розрахунків показав, що величина потужності дози нейтронів за захистом з поліалканіміда практично не залежить від добавки в його склад бору. Ступінь зниження інтенсивності гамма-випромінювання залежить від вмісту в поліалканіміді бору нелінійно. Для практичних цілей достатньо оптимальною можна вважати добавку бору в поліалканімід у кількості до 3 % мас. При компонуванні захисної композиції поліалканіміда, який містить бор в поєднанні з іншими матеріалами, слід враховувати, що при значному натіканні гамма-квантів з попереднього шару вплив добавки бору на зниження потужності дози гамма-квантів за захистом з поліалканіміда з бором падає.