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STUDY OF THE CHARACTERISTICS OF NEUTRON AND GAMMA RADIATION ATTENUATION COMPOSITIONS BASED ON TITANIUM HYDRIDE

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Assess the potential of composite materials based on titanium hydride in biological protection of nuclear power plants. Theoretical calculation and experimental research of characteristics of neutron and gamma radiation attenuation compositions based on titanium hydride. On the basis of neutron and gamma values calculated length field relaxation to fast neutron flux density and dose rate of gamma-quanta in the studied materials for areas with established equilibrium range. The multiplicity of weakening of neutron and gamma radiation spectra are dependent on the anterior border of the investigated material. These spectra are formed by material structures in front of the studied materials.

INTRODUCTION

A characteristic feature of nuclear-powered submarines (NPS) is a new generation power plant of a new type, having an integral monoblock design in which the reactor itself and its first cooling circuit are mounted in a single package. This ensures low-noise submarines and increases the overall efficiency of the nuclear power plant (NPP). Such steam supply system is much more compact than the previous generation, easier to maintain, more safe and secure. At the same time, the integration of all the systems and units of the reactor in a single housing adversely affects the maintainability of the installation due to their low availability. Difficulties related to radiation safety NPS, due to low strength and performance design of biological protection, molded and complexity of installation technology, which increases its cost

In biodefense reactors transport NPS, including reactors, nuclear submarines, have found wide application materials based on polymers and, primarily polyethylene. Due to the high content of hydrogen, it effectively reduces the neutron radiation. However, it has a relatively low operating temperature (60…80 °C).

Polypropylene has a higher heat resistance and strength compared with polyethylene. Polypropylene is more resistant to water, its water vapor permeability and water absorption lower than that of polyethylene. In contrast to the latter it, according to the literature [1] can be used for a long time at temperatures of 130…140° C. Known composition of polypropylene filled with powdered graphite [2, 3], the composition of polypropylene and propylene-ethylene copolymer filled with boron nitride BNS-17-1, BNS-17-2, BNS -18-1, BNS- 18-2 [TU 2243 -032-05796653-97]. However, the operating temperature data composites limited to 230 °C, which does not satisfy the conditions of operation of transport NEI, where the operating temperature of the reactor protection is 300…350 °C. In addition, polypropylene is rather complicated in processing.

Known foreign counterparts on the basis of polyethylene (HDPE) with 5% elemental boron content (Quadrant Engineering Plastic Products (city Tilt, Tielt, Belgium)). This material provides protection from ionizing radiation, however, subject to significant thermal aging in the range of 250…300 °C. LNP Thermo comp HSG compounds based on nylon-6 reinforced with tungsten (company GE Plastics (Niderldand)) have high levels of stiffness and impact resistance. Thus compounds do not satisfy the conditions of operation of transport NPS due to the presence of structural defects and gassing with prolonged exposure.

In this regard, search and implementation of protection materials having a high thermal and radiation stability is of great practical importance for new developments (projects) NPS NPS [4].

Hydride of the titan is the most promising material transport biological protection of nuclear power plants (NPP) thanks to a new generation of high performance protective with respect to neutron radiation [5]. In comparison with filled polymers titanium hydride has a higher operating temperature and the permissible neutron fluence.

On the basis of titanium hydride is currently developed and commercialized four materials: briquetted titanium hydride powder, titanium hydride, baby titanium hydride and compact titanium hydride. Briquetted titanium hydride and titanium hydride chips have low operating temperature (200 °C), which limits their use in protecting the NPU. Used compact titanium hydride (CTH), obtained by the through saturation of titanium billets hydrogen has a high thermal and radiation stability. However, it cannot be machined, resulting in the formation of the protection units is necessary to fill the gaps and voids formed on the basis of pictures of titanium hydride crumbs and a binder of Portland cement (PC). The resulting composition (CTH-PC) contains up to 5% of a fine dust fraction (less than 0.2 mm), which is flammable and explosive, as well as the main source of hydrogen evolution at high operating temperatures of operation.

Therefore, the authors have developed a structural material based on the fraction of titanium hydride (MFTH) to enable easier mounting technology to protect nuclear installations, to improve the quality and reduce the cost. Tests have shown that titanium hydride as a fraction more robust, has no microcracks not crack during the operation, does not form a fine fraction and the explosive has a higher operating temperature. Thermal stability fractions allow to use the materials on the basis of biological protection MFTH in the conditions of temperature 300…350 °C, directly next to the reactor pressure vessel. Modification fraction boron materials to allow their vitrification on the surface will improve the thermal stability of the composites and provide better protection tough operating conditions at a temperature of 450…500 °C [6].

Purpose of the work was to evaluate the possibility of using the materials developed in biodefense transport NPS. Theoretical calculations and experimental studies of attenuation characteristics of neutron and gamma radiation compositions based on titanium hydride.

THE EXPERIMENTAL PROCEDURE

In real arrangements, protection hydrogenous materials often preceded by materials based on lead or steel. In this regard, consider two types of compositions.

In the compositions of the first type before the test material is steel. The compositions: the active zone (85 cm), zhelezovodny reflector (20 cm) steel reactor vessel (12.5 cm), the test material (150 cm).

In the compositions of the second type before the test material is lead. Up to and including the reactor vessel, the compositions of the second type is similar to the composition of the first type. Further, after the reactor body is placed a water tank (15 cm) and the protection of the lead (30 cm), and then the test material (150 cm).

Consideration of the composition of two types allows us to estimate the effect of the spectra of neutrons and gamma rays coming from the direction of the core to the protection of the test material, the formation of a neutron and gamma its fields and dose distributions. In the first type of compositions have the presence of gamma rays from the core internals and the reactor shell. In the second type of compositions, due to lead shielding, this effect is absent (or reduced to a minimum) that allows you to select from all potential generators of gamma radiation (active zone and construction materials) that affect the flux of gamma rays in the material, only their own source capture gamma radiation.

The data obtained for all types of compositions presented in relative units. Thus, although the results are presented in relative form, dimension values neutron flux density (1/(sm^2·s)) and dose rate of gamma rays (mk3v/h) are in the ratio of the absolute.

RESULTS AND DISCUSSION

On the basis of neutron and gamma fields were calculated quantities relaxation lengths for fast neutron flux density and dose of gamma rays in the material for areas with an equilibrium spectrum.

The calculation results are presented in Table 1 and Table 2.

The relaxation length of fast neutrons depends on the content of the fraction in the composite material of titanium hydride. The values for materials λ_{bn} CTH and CTH-PC (density, respectively, 3,325 and 3,320 g/cm^3) with a maximum of fractions of titanium hydride (proper compaction of the fraction) 3…8% compared with the materials of the CTH and CTH-PC -higher density (density 3.8 and 3.4 g/cm^3).

Table 1

Relaxation length of fast neutron flux density (λ_{fn} cm) with energy E > 2 MeV in the material according to the thickness of the material layer (h, cm)

Material	λ_{fn}(h) for layer steel/lead, cm		
	h=0…30	h=30…60	h=60…100
CTH	4.2/4.3	5.3/5.7	6.2/6.4
CTH-PC	4.6/4.7	5.8/6.2	6.8/7.0
FTH	6.7/6.7	7.9/8.4	9.2/9.7
MFHT	5.0/5.1	6.0/6.4	7.0/7.2
MMFTH	5.0/5.0	6.0/6.3	6.9/7.1

Where CTH – compact titanium hydride; CTH-PC – material based on crumbs from the compact titanium hydride (CTH) and portland cement (PC); FTH – fraction of titanium hydride of 0.6…2.2 mm and a bulk density of 2.6 g/cm^3; MFHT – material based on the fraction of titanium hydride and portland; MMFTH – material based on a modified fraction of titanium hydride and portland cement.

Table 2

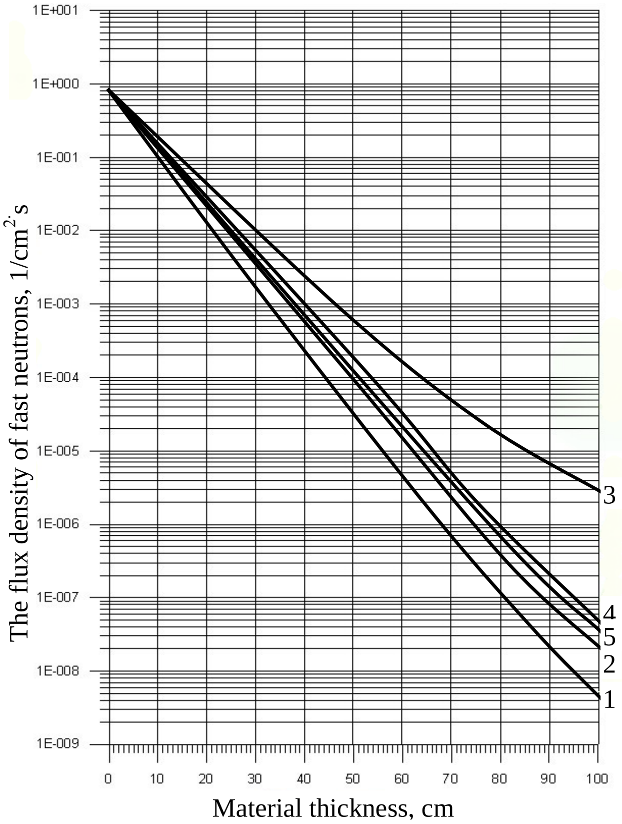
Relaxation length of gamma rays (λ_g, cm) in the material depending on the material thickness (h, cm)

Material	λ_g(h) for layer steel		λ_g(h) for layer lead	
	h=30-60	h=60-100	h=30-60	h=60-100
CTH	8.7	9.2	8.7	9.2
CTH-PC	9.6	10.2	9.6	10.2
FTH	13.5	14.8	13.5	14.9
MFHT	9.9	10.6	9.9	10.7
MMFTH	10.3	10.6	10.1	10.7

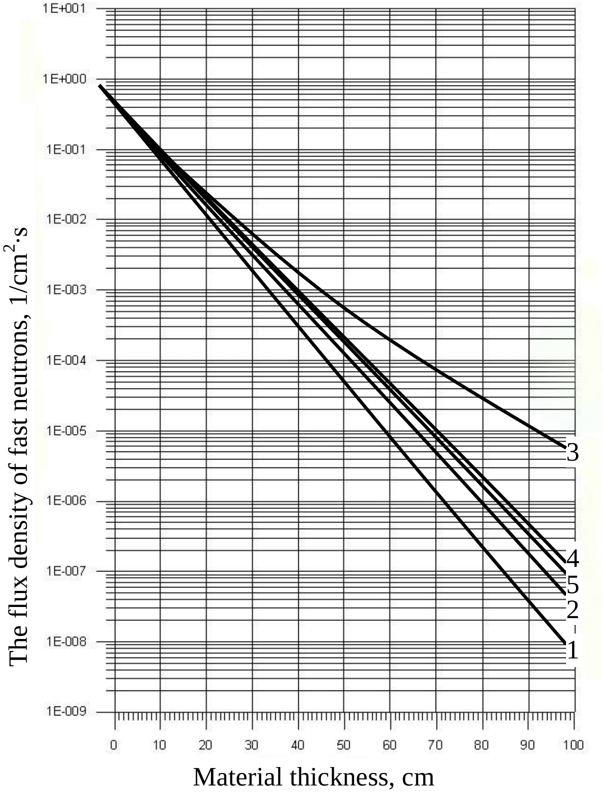
In the material, hydrogen is present due to the basics – titanium hydride. Addition of hydrogen by mixing water that may remain in the mixture after drying at least an order of magnitude lower and plays a minor role. Therefore, composite materials CTH-PC after heat treatment at 300 °C (under the assumption that all the mixing water out), their properties are not inferior materials MFHT and MMFTH in which some part of the mixing water remains.

As can be seen, with increasing thickness of the design layer increases the value of the test material λbn. This is due to the tightening of the neutron spectrum in thickness. A somewhat lower values λ_{bn} for compositions with steel can be explained by the fact that after the steel a softer spectrum for neutrons in the energy range above 2 MeV in comparison with the spectrum after the lead, so the group removal cross section of fast neutrons will be more, and the relaxation length, respectively, downward (Figs. 1 and 2).

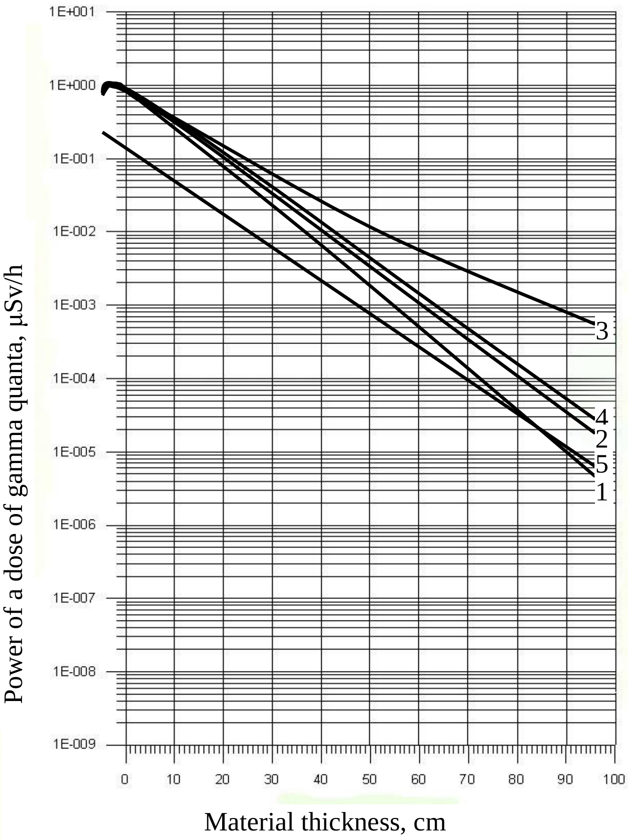
As for the gamma rays, the value of λ_g in the materials in the compositions to steel and lead to practically identical (pic. 3, 4). This indicates that the distribution of gamma rays (MDH) in thickness and the amount of the protection MDH impingement define the front wall and capture gamma rays in the initial material layer thickness of a few centimeters. And in this case, the first component is less than the second, except material MMFTH (by layer steel).



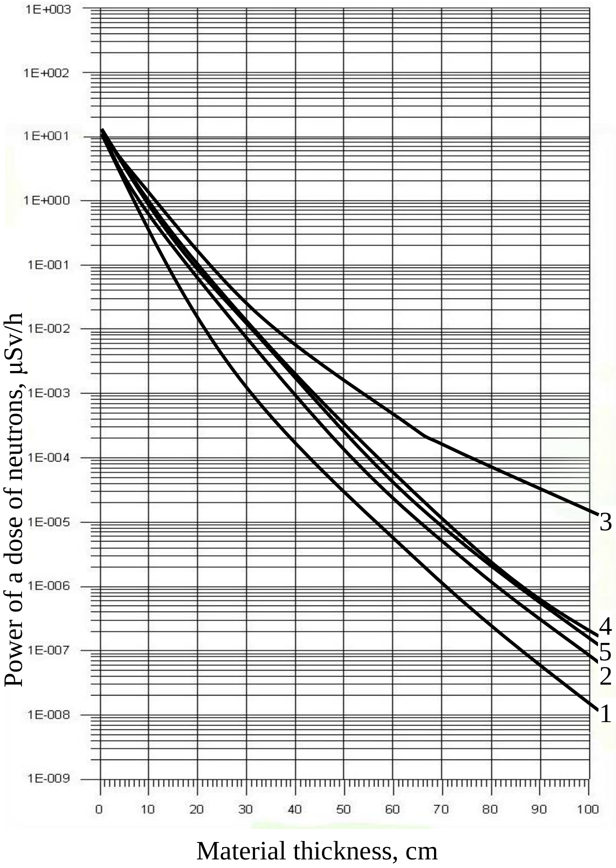
Pic. 1. Distribution of fast neutron flux density in the materials of the layer are: 1 – CTH; 2 – CTH-PC; 3 – FTH; 4 – MFTH; 5 – MMFTH



Pic. 2. Distribution of fast neutron flux density in the materials of the layer of lead: 1 – CTH; 2 – CTH-PC; 3 – FTH; 4 – MFTH; 5 – MMFTH



Pic. 3. Distribution of gamma rays in the materials of the layer are: 1 – CTH; 2 – CTH-PC; 3 – FTH; 4 – MFTH; 5 – MMFTH



Pic. 4. Distribution of neutron dose in the materials of the layer of lead: 1 – CTH; 2 – CTH-PC; 3 – FTH; 4 – MFTH; 5 – MMFTH

In support of this conclusion says the following. Since in these materials gamma rays are attenuated less than thermal neutrons ($\lambda_g > \lambda_t$), then with increasing thickness of the material decline in the initial gamma rays (impingement or formed in the initial layer) will be less than the return of new capture gamma rays due to thermal neutrons, which are attenuated more strongly and is unable to give a significant addition to the total amount of MDH. Therefore, the value of the material is determined by the MDH gamma-ray source located either in his initial layer, or in front of him, and the formation of their own capture gamma rays in the rest of the material, and the material MMFTH (after steel) in general in all the stuff does not matter .

The relaxation length of gamma rays in hydrogen materials also varies depending on the content of titanium hydride fraction, steady but the spectrum is independent of standing in front of the material. The values of λg for materials and MFTH and MMFTH more than the materials of the CTH and CTH-PC by 5%.

Thus, the multiplicity of attenuation of neutron and gamma radiation depends on their spectra on the front edge of the test material. These spectra are formed structural materials, located in front of the investigated materials.

CONCLUSION

The results of these studies define the prospects for the use of construction materials on the basis of the fraction of titanium hydride for biological protection of transport NPS. Using a modified fraction of titanium hydride improve the barrier properties of the composite (MMFTH) in thermal and epithermal neutron spectrum areas. The use of these materials will facilitate mounting technology to protect nuclear installations, to improve its quality and reduce the cost.

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ИССЛЕДОВАНИЕ ХАРАКТЕРИСТИК ОСЛАБЛЕНИЯ НЕЙТРОННОГО И ГАММА-ИЗЛУЧЕНИЙ КОМПОЗИЦИЯМИ НА ОСНОВЕ ГИДРИДА ТИТАНА

Р.Н. Ястребинский, В.И. Павленко, Н.И. Черкашина, О.В. Куприева

Дана оценка возможности применения композиционных материалов на основе гидрида титана в биологической защите транспортных ядерных энергетических установок. Проведены теоретические расчеты и экспериментальные исследования характеристик ослабления нейтронного и гамма-излучений композициями на основе гидрида титана. На основании полученных нейтронных и гамма-полей рассчитаны величины длин релаксации для плотности потока быстрых нейтронов и мощности дозы гамма-квантов в исследуемых материалах для областей с установившимся равновесным спектром. Установлено, что кратности ослабления нейтронного и гамма-излучений зависят от их спектров на передней границе исследуемого материала. Эти спектры формируются материалами конструкций, находящимися перед исследуемыми материалами.

ДОСЛІДЖЕННЯ ХАРАКТЕРИСТИК ОСЛАБЛЕННЯ НЕЙТРОННОГО ТА ГАММА-ВИПРОМІНЮВАНЬ КОМПОЗИЦІЯМИ НА ОСНОВІ ГІДРИДУ ТИТАНУ

Р.М. Ястребинський, В.І. Павленко, Н.І. Черкашина, О.В. Купрієва

Дана оцінка можливості застосування композиційних матеріалів на основі гідриду титану в біологічному захисту транспортних ядерних енергетичних установок. Проведено теоретичні розрахунки та експериментальні дослідження характеристик ослаблення нейтронного і гамма-випромінювання композиціями на основі гідриду титану. На підставі отриманих нейтронних та гамма-полів розраховані величини довжини релаксації для щільності потоку швидких нейтронів та потужності дози гамма-квантів у досліджуваних матеріалах для областей зі сталим рівноважним спектром. Встановлено, що кратності ослаблення нейтронного та гамма-випромінювань залежать від їх спектрів на передній межі досліджуваного матеріалу. Ці спектри формуються матеріалами конструкцій, що знаходяться перед досліджуваними матеріалами.