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Study of Neutron and Gamma Radiation Protective Shield

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ABSTRACT: Due to the development of nuclear technology and use of these technologies in various fields of industry, medicine, research and etc, protection against radioactive rays is one of the most important topics in this field .The purpose of this is to reduce the dose rate from radioactive sources. The sources in terms of components are emitted various types of nuclear radiation with different energies. These radiations are involving of alpha particles, beta, and neutron and gamma radiation. Given that alpha and beta particles can be fully absorbed by the shield, the main issue in the debate protection radioactive rays is stopping of gamma rays and neutrons. Accordingly in shield design usually two types of radiation should be considered. First, X-rays and gamma rays, which have great influence, and by the mass of any suitable material, can be more efficiently attenuate the higher the density, the better the potential attenuation effect against gamma rays and the required shielding thickness decreases. The second type of radiation is neutrons. Often a combination of three materials is desirable that include heavy metals, light metals, and neutron-absorbing material to omit the slow neutrons through adsorption to the neutron shield. There are different materials that can be used to shielding against radioactive rays. The main materials that are used in protection include: water, lead, graphite, iron, compounds that contains B, concrete, and polyethylene. Accordingly, the main objective of this paper is evaluating the kind of shield against gamma and neutrons rays.

KEYWORDS: Neutrons, Gamma rays, Protective shield, Gamma absorbing, Radioactive sources.

1 INTRODUCTION

Due to the development of nuclear technology and using this technology in various fields of industry, medicine, research, etc, protection against radioactive radiation is the most important aspect in this context in order to minimizing the radiation rate of radioactive sources. The sources in terms of components are emitted different types of radiation with different energies. These radiations are involving of alpha particles, beta, and neutron and gamma radiation. Radioactive rays protection is a physical barrier that is placed between the radioactive ionization source and the object or purpose of the protection to reduce the amount of radiation exposure in the safeguard place. In order to protect of nuclear radiation maybe

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a variety of materials such as lead, iron, graphite, water, polyethylene or concrete are used. Among these materials, Concrete is one of the best and most widely used materials for manufacture of Gamma and neutron radiation shield, because in addition to having the proper Structural properties of the material, there are variety choice of the materials used to build it, that lead to manufacture of concrete with different densities and different combinations. . Ease of fabrication, low cost for the construction and maintenance of concrete are another advantage. In fixed installations and large nuclear power plants, Such as power plants, medical centers and nuclear particle accelerators of concrete are used to protect against nuclear radiation. Given that alpha and beta particles can be fully absorbed by the shield, the main issue in the debate of protecting of radioactive rays, is stopping of gamma rays and neutrons ,because with increasing thickness of the absorbent material can only be reduced gamma rays and neutrons. Accordingly in shielding design usually two types of radiation should be considered. First X-rays and gamma rays, which have great influence and by using the mass of any suitable material they can be more efficiently attenuation good. Most materials can attenuate gamma-ray and photon energy in effect of Compton scattering. Attenuation of operating efficiency, which is roughly proportional to the mass of the material, is exposed in radiation path. Since the photon attenuation function is not affected by the type of material, so different materials with the same mass, has virtually identical ability to protect against X-rays and gamma rays .The higher the density of the shielding material, the ability to better attenuation effect against gamma rays and reduces the thickness of required shielding. Therefore, in cases where there is limited space, we can use the heavy concrete instead of ordinary concrete to reduce thickness of required shield largely. The second type of radiation is neutrons. Designing an effective neutron shield is very complex. A good shielding for neutrons should contain a heavy material such as iron, barium or elements with higher atomic number. These heavy elements reduce fast neutrons through inelastic collisions. Light elements is desirable to reduce the moderately fast speeds of neutrons through inelastic. In this context, the presence of hydrogen is very effective because its mass is about the mass of the neutron. Finally, removal of the slow neutrons through the absorption operation is necessary. Hydrogen is effective at absorbing neutrons, but with absorption of neutrons by hydrogen- gamma rays with the energy 2/2 million electron volts (secondary gamma) are produced, these radiations due to the high permeability of the material will increase the thickness of the shield [5], [1].

Among the neutron absorber material, boron element not only contains high neutron absorption, but after absorbing neutrons produces secondary gamma rays with energies 378/0 of millions of electron volts, which have a lower permeability (compared to secondary gamma radiation of neutron absorption in other shielding materials). For this reason, materials containing boron are used often in neutron shields. It should always be considered in the protection discussion that a material efficiency in protection is determined by the effectiveness of it in attenuation per unit thickness .view of this, that the weight and volume of maintenance are surrounding a radioactive system ,Approximately increases with third exponent of the shield thickness and dependent on other factors such as increasing the total cost (both in material and in cases where the amount of savings), Particularly is easy to understand the important of using protection with excellent efficiency. Accordingly, the main objective of this article is choosing the best protection for mixed fields of neutrons and gamma rays.

2 TYPES OF NUCLEAR RADIATION

Alpha radiation, beta and gamma rays and neutrons are the most particles that may be emitted in nuclear reactions. Alpha particle is a helium nucleus that consisting of two neutrons and two protons. It is based on two positive charges and as the particle is relatively large, has a little bit of range in target material so easy to stop. For example, it stops an ordinary sheet of paper of alpha particles that is emitted from a radioactive element. Beta particle is high-energy electrons that are thrown out of the nucleus. It is believed that a neutron at the nucleus is changed into a proton and an electron and an electron is thrown out with considerable kinetic energy. Because beta particle is much smaller than the alpha and contains only one negative charge that permeability of it in the material is more than alpha. Permeability depends on the energy of the beta, but to stop a beta particle with an average energy, aluminum plates of thickness less than six - seven millimeters is sufficient. Gamma ray is High-energy photons; the nuclear gamma-ray emission is just very rare. What usually happens is that when a nucleus emitting alpha or beta particles maybe radiation one or more photons of gamma. Because gamma photons have no electric charge and mass so the permeability of it is much higher than beta particles. Permeability of gamma photons in the material depends on its energy. To stop gamma photons with average energy is needed elements with mass numbers up to several centimeters in thickness such as pieces of lead. Gamma radiation can directly or indirectly impact on the body and can cause serious risks both internal and external. Gamma irradiation plant is found in machine containing radioactive material around each nuclear power and in most plant the workers exposed to radiation, Thus, in plants everywhere which there is the possibility of gamma-ray radiation ,the proper shields are embedded into alignment that to reduce radiation to a safe level [3].

3 GAMMA PHOTONS COLLIDE WITH MATTER

How gamma rays dealing with the matter are different in compared with alpha and beta particles. So that the alpha and beta can be absorbed in substance completely so they have certain range, but gamma-rays cannot be absorbed completely, But with increasing thickness of the absorbent material can only reduce the radiation intensity. Since gamma rays have no mass and charge the Probability of collision or in other words cross sections dealing with the matter is much lower in contrast to alpha and beta particles. Therefore, the influence of gamma radiation, are much more penetrating power than alpha and beta particles and it is to some extent to which high-energy photons can penetrate the material without loss of energy from several centimeters to few meters . The initial collision of a photon with material occurs in orbital electrons. During the collision, Part of the photon energy is converted into kinetic energy of fast electrons and other part is removed from material as scattered radiation. Express electrons in its path, causing ionization, excitation of atoms and breaking of molecular bonds. It may some of the express electrons in dealing with material can cause brake beams. The beam and the scattered photons with matter can be treated with material as having the primary photons. Gamma rays or X-rays collide with matter is in several different ways. As one of the most important encounters of gamma with material are photoelectric effect, Compton scattering, Thomson scattering and ion production. Photoelectric effect: on the phenomenon of photoelectric effect, a photon includes energy deal with an atom [2]. The result of this collision is sala, following the collision with the electrons that come out of atoms are called photoelectrons.

4 PHOTOELECTRONS WITH KINETIC ENERGY

Leaves atom in this regard, Eb, is the binding energy of the orbital. However, when the electrons are replaced by electrons from higher orbits one or more photons are emitted from the atom. On the photoelectric effect, the probability of photon collision with electrons that are closest to the nucleus is higher. If gamma rays have enough energy, in 80% of cases with electrons of K orbit collide. The collision of electron orbits in M, L and N is also possible. Based on the photoelectric effect, the photon absorption coefficient that known as the photoelectric coefficient strongly dependent on the photon energy and absorber atomic number (Z). Although there is not the simple correlation that expressed coefficient of the photocurrent variation with respect to all of the energy levels, however, we can use the following approximate relation for the photoelectric coefficient [6].

In this regard, changes in n and m can be expressed as follows:

In the above equation, based on the Mev and a is equal with

9-10×1.25

From this relationship can be derived that the heavy material is capable of absorbing photons of low energy as well and this has led to this lead is used as the best protection against low energy gamma rays. Compton scattering: the phenomenon of Compton scattering, photons may deal with any of the orbital electrons. In fact, this phenomenon can be assumed that the elastic collision is carried out between a photon with and a free electron at rest energy. From a practical standpoint, if the photon energy is MeV1 R 0, the orbit electrons in comparison with photon energy are assumed release. In phenomenon Compton, unlike photoelectric effect transferring all the energy of the photon to released electron is not possible, because that according to The principle of conservation of energy and angular momentum it requires that after the electron left the atom, continuing the movement with the speed of light is impossible. Thus, the Compton scattering process, only part of the photon energy is converted to the free electron kinetic energy [7].

Probability of collision between a photon and a free electron in the Compton effect is anticipated by using the equations that proved by Nyshyn and Klasn proved. Based on this equation, the probability of a photon collision with orbital electrons regardless of the binding energy of nuclear are equal. In other words, the coefficient of Compton scattering, depends solely on the number of electrons in the absorption material and, therefore, is independent of the atomic number of the absorber material. The Compton scattering coefficient decreases with increasing photon energy, but the rate of decline compared with the photoelectric effect, is much slower. In general, it is very important that the probabilities of Compton collision at energies which have declined the photoelectric absorption coefficient are more important [9], [12].

Thomson scattering: In this phenomenon, photons with energy collision with a free electron and with no loss of energy, only to be deflected from its original path. Pair production: when a photon passes near the nucleus of an atom, it disappears and instead a positron and an electron are created. Therefore, this phenomenon is called pair production. Therefore, because the phenomenon occurs, it is necessary that at least the energy of the photon be equal with mass energy of an electron and a positron in the rest. Contrast phenomena photoelectric and Compton, pair production cross section is increased by increasing the photon energy. Also, due primarily to the phenomenon of pair production occurs naturally influenced by atomic absorption with increasing atomic number, the probability of pair production increases. Attenuation coefficient of the photons collide with matter, each process photoelectric Compton scattering, Thomson scattering and pair production may occur, but one process can only happen in every encounter, whereas in multiple interactions may occur in the whole process. It is evident that the probability of each of these processes is proportional to the surface area. In any case, the probability of a photon collision is equal to the total cross section of the process. Neutron-proton mass is nearly equal mass but no charge [11]. Therefore, unlike charged particles neutrons are not able to loss their energy during a series of closely ionizations. Moreover, the neutron was not component of the electromagnetic wave and based on this will not have collision with absorbent electron. After the neutrons penetrate into matter, continue their path to collision with the nucleus of an atom generally, this is the kind of elastic scattering and inelastic or absorption. Neutrons collision probability (cross-section) are not only material, but also strongly depends on the neutron energy. So, it is performed collisions of neutrons with matter to be discussed with respect to energy of this particle. The neutron energy is divided into the following groups:

A – Fast neutrons: they have the addition of 1/0 millions of electron volts of energy. In this energy range, the neutron collision is mainly dispersion and absorption cross section of the material is much lower than scattering cross section.

B - Thermal neutrons: that the energy of them are an electron volt or less (Often 025/0 eV). These neurons, like gas molecules cuffed in thermal equilibrium with its environment and finally absorbed or in short duration (minutes) are analyzed to the proton.

C – Neutrons that their energy is located between fast neutrons and thermal neutrons, to these neurons are given different topics such as medium, slow and near thermal neutrons. In this energy range, neutron can create varied reactions.

5 Attenuation and Absorption of Neutrons

Attenuation of neutron in a material that occurs by the absorption and scattering phenomena is as the exponential function: In which is the microscopic cross sections of neutron collides with the nucleus of an atom per cm, N the number of absorbent atoms on cm3 and X is adsorbent material thickness in terms of cm. Fast neutrons, usually during Elastic collisions with surrounding atoms, rapidly lose their energy and change into thermal neutrons or near heat. As the neutron loss energy, the probability of its absorption is increased by the absorbent material core. In the case of many-core, neutron absorption cross section with low energy is proportional to the neutron velocity inversely. Scattering of neutrons: neutron collision with a nucleus can be elastic or inelastic collision. In an elastic collision, the maximum neutron loses its energy during a collision with a hydrogen nucleus. In general, elastic scattering is the most likely type of collisions between fast neutrons and light absorbing materials. During an inelastic collision, part of kinetic energy of the neutrons has been transferred to the hit nucleus, effect arousing the nuclear. Aroused nucleus then emitted the extra energy as gamma rays [5].

6 Biological Effects of Radiation

Radiation emitted from radioactive materials or which are produced in radiation generating devices, in collision with the human body put extra energy, that this energy, has deleterious effects on living body tissue. Physical radiation effects are different in partial and temporary disruption of some physical exercise and also some serious consequences such as shortening life expectancy, decreased body resistance against diseases, reduced reproductive output cataract and leukemia and other cancers and damage to a developing fetus. Extent of the damage is a function of radiation dose and is different about different people. Local exposure (to a small area of the body) basically affects only the exposed tissues, but the whole body irradiation cause the general reaction of the body. It is possible that the light shine on it from outside or from within the body. External dose can be limited by reduceing the exposure time, distance from the radiation source, and finally protection. Generally emission of alpha particles and emitted beta slow energy particles are not dangerous from outside to the body, they are not usually dangerous, but if the particles are absorbed into the body, their energy is transferring to the sensitive tissues of a living organism during short distance. If energetic particles shine from outside on the body can enter a huge dose to the skin. X-rays and gamma rays have high permeability and can affect the entire body from the inside and outside [7].

7 Protection against Radiation

In summary, two important factors in the proper radiation protection are: distance, shielding or absorbent material that in this regard a brief study of the topic will be discussed. Distance from the source: the distance makes us this sure that the person is not exposed unnecessary radiation source .For example, while distribution of radioactive material in the laboratory, we should not use the fingers, but must use tools such as pliers, scissors or tweezers. This is kind of protection method using the distance. With increasing distance from the source of radiation, the beam decreases. The relationship is inverse-square law, which states that track radiation is proportional to the inverse square of the distance from an exposure point source. By simple calculations we found that imagine of this point is wrong that rapid transport of radioactive material by hand (in a very short time) to the more time which is consuming their transform by the help of long-handled tools (to keep away of the body)which significantly this will reduce radiation dose. It should be noted that when calculating the radiation we must considered together the attenuated inverse square rule and the exponential attenuation of absorbent barrier.

Protecting: One of the most important ways to protect against nuclear radiation is using suitable protective material between the radiation source and human or environmental protection. Materials used in nuclear reactors protection must have the property of making neutrons slow and can make gamma rays in order to attenuation. To slow the neutrons that are used usually from the layers of graphite, beryllium and water and for the attenuation of gamma rays are used heavy metals and concrete. In addition to that concrete is capable to attenuation the gamma radiation is very important at slowing and absorbing neutrons of thermal neutrons. Hence concrete with high availability, low cost and its effects suppressive properties are of great use in protecting, especially in the outer shield [7].

Protecting materials: Making an appropriate and effective shielding against neutrons and gamma of a nuclear facility requires proper selection of materials and thickness. Choosing the right material for making protective shield interconnected optimality analysis are the weight, volume and cost considerations such as these. It is possible that these considerations affect the choice of materials and consequently affect on the final design. However, cannot usually design protection that to ensure the entire above range. Usually, for practical purposes, one of the above cases is considered as main goals and the other goals are settings in order to be optimal. Most important characteristic of a material protection is its ability in attenuation of neutron and gamma radiation. In general, lighter materials have higher ability in attenuation of neutrons and heavy materials have higher ability in attenuation of gamma rays. The use of only one material is impossible for shielding source of gamma and neutron. Meanwhile, heavy materials often activated by absorbing neutron and irradiation secondary gamma that should be considered in shielding design. In practice an appropriate protection forms from the combination of different layers of hevy and light materials to control neutron, gamma and secondary gamma. Different materials are that can be used for protecting against radioactive rays. The main materials that are used in protecting include: water, lead, graphite, iron, boron, concrete, and polyethylene. However, experience has proven that the use of appropriate concrete has a lot of advantages compared to other materials. Boron (usually in addition to other materials such as polyethylene and concrete) has many applications in protecting. The use of this is due to primarily higher neutron absorption cross sections. Particularly this particle interesting is because of its dominant reaction that results in complete inhibition of neutrons and does not produce any secondary particles with high penetration [3].

8 WATER AS THE SHIELDING

Water due to the high hydrogen content and the availability and cheap is useful shield for neutrons. However, due to the low atomic number of the constituent nuclear of water are not acceptable against the gamma rays. There are Issues over the use of water as the shielding that is hard case for storage, corrosion problem, purified, corrosion problem and removing stiffness. Another problem of using water as a shield against neutron sources (reactors are widely used around the blue shield) is neutron absorption in oxygen and producing of excited.

Lead as shielding: Lead is the most common substance for the attenuation of gamma rays. Lead's blocks with relatively high prices can provide good attenuation of gamma rays. The power of gamma rays Attenuation in the lead back to its proper density and high atomic number. Pieces of Lead Because of the softness and flexible are suitable for filling pore in the doors and fittings. Lead is not satisfactory and cannot creat acceptable neutron attenuation in neutron field. Lead by absorbing the neutron is emitting 7.4 Mev that cause it to worse the neutron properties. The impurities in commercial sorbs can have activation gamma with full energy.

Graphite as shielding: Graphite is good retarders for neutron and in the types of reactors used as retarders. Neutron absorption cross section is low in graphite and hence (as the possibility of the comfortable production of highly pure) problem of secondary Gama is largely absent. Like Water graphite is not proper attenuation for gamma. Graphite has good thermal properties which can also be involved in its use as a shield. Iron as shield, iron in the form of steel has widely used in the shielding against radioactive sources. In addition to the shield in front of radiation iron is also used as a heat shield. Of course, iron in effect of absorption of neutrons is emitted Gammas impart maximum MeV10 energy. Iron contains attenuation effect somewhere between carbon as low and tungsten as high against gamma. Isotopes readily activated with absorbing of thermal neutrons and isotope with half-life of the - 59 days and Gama with 1.5 MEV energy is producing.

Concrete as a barrier: Most commonly employed shield in different sectors of the nuclear is shield of concrete. It is cheap and has features that are used as building materials. Concrete is known and this case facilitates its making and using. Because concrete is a mixture of several different materials (in any combination may be highly variable) its composition is not constant. Even two of the same type of concrete with depending on the materials have used very different in composition. So when referring to concrete as shielding material, the material used in its composition should be told correctly. Generally concrete are divided to batch "ordinary" and "heavy". Common concrete density was2/2 up to 2/4 gr / cc and the most common substances has found in it is oxygen and depending on the material used for heavy making concrete is silicon or calcium (or both). Usually granite, sandstone or limestone is used for this purpose. The heavy concrete with a density of 3 to 6 gr / cc as heavy concrete iron ore, barite (barium sulfate), steel balls, steel punch or other additives are used.

Typically, the concrete is as mix of cement, water (water in which the matter is considered too heavy concrete) and the reinforcement of concrete .As stated, by vary of the reinforcement material can be prepared by various concrete types. Various additives to improve the attenuation of neutrons or gamma rays, or increasing the hydrogen content of concrete can be used to better mental health [10].

9 CONCLUSIONS

By the study of nuclear radiation such as alpha, beta, gamma and neutron we conclude that, by given that alpha and beta particles can be fully absorbed by the shield, the main issue in the debate of radioactive rays shielding is stopping of gamma rays and neutrons. Accordingly, in designing of the shield, usually two types of neutron and gamma radiation should be considered. With examining of with these two types of radiation and processing of the prevention of these radiation with different materials can be examined types of shield against these radiations. Protective material between the source of radiation and humans must have the slowing property of neutrons and be able to attenuate gamma radiation. Making protective and affective shield against neutron and the gamma of a nuclear facility requires choosing the right material and considering the required thickness for them. Choosing right materials for making shield are interconnected with optimality analysis of the weight, volume and cost and considerations such as these. It is possible that these considerations affect the choice of materials and consequently on the final design. However, usually we cannot design shield that to satisfy all cases highly and will be optimal from all sides. Usually, for practical purposes, one of these cases is considered as main goals and other purposes besides it are being regulated to the optimum. Most fundamental characteristic of a sconce or protection material is its ability in attenuating of gamma and neutron radiation. Accordingly types of protection can be designed. Design a shield against nuclear sources requires highly accurate dose and effective intensity of nuclear radiation in the total generated dose is in the out of shield. Often the computational methods used to obtain this information. All calculation methods can be evaluated in two ways certainty and probabilistic methods. Simple equations for describing the behavior of functions in certain ways (such as flux or neutron radiation) are introduced and the coefficients are determined by methods. In short, semi-empirical methods based on predetermined rules of radiation change are determined in protection. Accordingly, we can be summarized shielding design methods in a more accurate classification in the following three categories [9]:

- Experimental methods
- Methods for solving the transport equation
- Monte Carlo methods

Monte Carlo method is the statistical simulation of the parameters of probabilistic nature. Nature is the examining quantitative in statically protection of issues that means quantitatives such as flux is determines by the average performance of very large number of neutrons. Based on this it is expected that by Using statistical methods can be calculated common amounts such as flux and rates of dose and this is the basis of Monte Carlo method. The ultimate goal of the Monte Carlo method is determining the neutron flux, the rate of varies reaction, dose rate and also identifying the critical state of the system. Issues considered in the Monte Carlo method (in the field of reactor physics) can be classified in two categories: constant source issues and critical issues. Our next article (if God willing) will investigate the problems of constant source (or guards problems) [8].

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