Transport Calculations of photons and neutrons in different shielding materials

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Abstract:-

Transport calculations of photon and neutron fluxes and doses were made. The Monte Carlo multigroup experimental transport code MORSE-CG [1] was used for these calculations with its modified version [2].

Distributions of gamma ray fluxes through the shield of a pressurized water reactor were obtained. The shield was represented by layers of water, steel and lead; it was a semi realistic representation of a working reactor.

A simulation was made for the total dose that could be received by a person living near a very active radiating source of neutrons or photons.

The obtained results were compared with experimental referenced data which shows a very good agreement.

Introduction:-

The environmental effects associated with the operation of a nuclear plant fall into two main categories; thermal and radiological. All nuclear plants discharge a certain amount of heat to the environment, like steam-electric generating plants. The problems associated with thermal effect are not unique to nuclear plants. The procedure used for discharging waste heat to the environment must take some considerations [3]. The radiological problems associated with the radiation emitted from nuclear plants constitute a serious health hazard. Special precautions must consequently be taken both to protect workers from radiations and to limit the release of radioactivity to the environment. All the areas around a nuclear plant and its associated equipments and laboratories are surveyed regularly to measure the radioactivity deposited on surfaces and the amount of activity in the air.

Radiation exposures to the general public are controlled by strictly limits the levels of radioactivity from the nuclear plant to protect workers inside the plant, however, special physical means of protection are required, which is usually shielding to attenuate the radiation level. The reactor vessel and all other vessels that carry radioactive materials are surrounded by suitable shielding.

The first unit used to measure radioactivity was the roentgen, which is equivalent to the quantity of gamma radiation that produces a total charge of $2.58 x 10^{-4}$ coulomb in one kilogram of dry air. The amount of energy absorbed by a material from radiation is called the radiation dose. The absorbed dose unit is called rad, which is defined as the radiation that deposit 10^{-2} joule of energy per kilogram. The rad is applicable to all kinds of radiations. It can be used to indicate energy deposition in both living tissues and non living matters.

The biological effect of ionizing radiation depends not only on the energy absorbed but also on other factors. The effect of radiation on a human tissue expressed by a unit called rem (radiation equivalent man). This unit is equivalent to rad multiplied by two factors, a minor factor depends whether the radiation source is outside or inside the human body, and a major factor which allows the effects of radiation on the different tissues of human body. The unit rem makes the values of different kinds of radiations to be additives, so that it gives the overall biological effect.

Calculation Details:-

MORSE code was used in the calculations; it solves the multigroup Boltzmman transport equation by Monte Carlo method for photons and neutrons radiations. This code uses the energy group cross sections which represent the probabilities of all kinds of interactions of radiation with materials. These cross sections were taken from RSIC library and from ENDF/B library [4]. The calculated radiation flux was converted to dose rate by employing the dependent slandered reference of neutron flux to dose rate factors ANSI/ANS[5].

Although transport calculations of neutrons and photons through air is not usually an important consideration in the design of the shield for fixed power plants, it is an important shielding consideration for any portable or mobile system [6]. Laboratory experiments involving reactors, isotopes, or accelerators frequently requires some assessment of air transport. In our calculations air was considered to be made of oxygen and nitrogen with total density of 1.29 gram/letter.

The dose rates from a point source emitting gamma rays of energies 4.5-5.5 MeV in an infinite air media were obtained. The geometry considered in these calculations were a concentric spherical shells of air surrounding the source. A simulation was made for the radiation dose rate received by a person living near a nuclear plant or near a very active neutron source. A 48 cm thickness of concrete was placed between the neutron source and the person to simulate conservatively the total dose that will be received.

Calculations were made for the distribution of gamma ray fluxes in the shield surrounding a 70 Mega Watt reactor. The geometry of the core and shield of the reactor were a semi realistic representation of them. The shield considered was several layers of water, steel, and lead. The core of the reactor was considered as a point source of radiation once and as a sphere of a certain radius in the second time.

Results and Discussion:-

The dose rates of neutrons from a very active fission neutron source of strength 10^{17}neutrons/second through air were calculated. Two cases were considered. In the first case a free source was used, while in the second case a shielded source was considered. The shield considered was a 48 cm of concrete surrounding the source. The results of these calculations are shown in table 1. This table shows that the dose rate decreases by a factor of 15 times when a shield is used. The table also shows that the dose rate decreases with distance from the source. If we knew that the whole body dose of radiation required to kill half a human population is abut 400 rads, this means that 600 meter from a free source still in the dangerous area. While for a shielded source moving away a distance of 200 meter made the person in a safe place.

The dose rate of gamma rays from an active source of strength 1.2×10^{15} Photons/second with energies of 5.5 MeV in an infinite air was calculated. The results of these calculations are represented in table 2.

This table also shows a comparison between these results and referenced results [7]. The comparison indicates a good agreement between the two results. Comparing the results of table 1 with table 2 we get that the effect of neutron radiation on human body is much higher than that from gamma radiation.

The results of calculations of gamma ray distributions through the shield of a pressurized water reactor operating at a power of 70 Mega watts are represented in figure 1. The shield was represented by serious layers of water, steel, and lead. Three distributions are shown in the figure. The one in the middle represent an experimental data of the working reactor, the lower distribution for considering the core of the reactor as a point source, and the upper distribution for using a spherical geometry as the core. The figure shows that considering the core as a spherical shape is more reliable than a point source because it is a closer representation to the real geometry. It also shows that the gamma flux decreases steadily with distance and the attenuation of radiation in steel is more than in water as was expected.

References:-

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