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Determination of Am-Be Neutron Source used on Landmine Detection

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Abstract : For plastic landmine detection ^{252}Cf, D-D and D-T neutron sources are used. Present study indicates that Am-Be neutron source can also be used for this purpose. In order to apply this source, it is necessary to design suitable shield. In this work firstly we have experimentally shown that the gamma ray emitted from neutron source has no effect on BF3 detector counts. Secondly we have theoretically investigated the shield of Am-Be neutron source used on landmine detection then accomplished experiment to determine polyethylene(PE) shield thickness.

Keywords : Landmine, Am-Be Source, MCNP code, BF_3 Detector, Polyethylene, TNT.

Introduction :

Several landmine detection methods, based on nuclear techniques, have been suggested in recent years. One of the proposed techniques to detect non-metallic landmines shows great potential, using neutron backscattering. As the amount of hydrogen in a landmine, in most cases, is higher than that of the soil; the amount of thermalized neutrons, scattering back into a detector, can indicate the presence of a mine. The detection system was provided by the SHELL Nuclear Measuring Techniques Group. This group uses the system, for example, for the detection of oil, water, gas, and sand levels in large tanks (Datema *et al.*, 2002). They have Applied ^{252}Cf (Californium) as a neutron source. They have used carbon and borated paraffin, respectively, as neutron reflector and absorber.

According to investigations in all research works, performed to detect landmines ^{252}Cf, Pu -Be, D-D and D-T, have been used as neutron sources. In this work the Am-Be neutron source has been used to detect landmine buried; we have determined shield of neutron source to progress mine detection.

Theoretical basis :

Neutron sources have important role in landmine detection because, time to find a landmine, stand-off distance (distance between the detector and the soil) and depth of neutron influence are important parameters that depend on neutron source strength (Fioretto *et al.*, 2004).

There are three types of neutron sources that can be applied on commercial applications. One source is produced by the interaction of high speed ^{2}H ions with ^{3}H atoms in the target of a small accelerator. The source is almost isotropic and emits monoenergetic neutrons with energy of about 14MeV. A second source is spontaneously fissioning ^{252}Cf, which emits neutrons isotropically with an energy spectrum very similar to that of neutron-induced fission of ^{235}U. A third source is the

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form of ^{241}Am and beryllium. Alpha particles from decay of the former interact with the latter, yielding neutrons. Fig. 1 illustrates energy spectra for ^{252}Cf and 241Am-Be sources.

Mono-energetic neutrons with an energy between 10 KeV and 10MeV are emitted from these source. The results of investigations for a mine buried at 3 cm depth show that the optimum energy lies between 100 KeV and 1 MeV. At a greater depth a higher neutron energy is required to detect the mine with the best signal-to-background ratio. However, the sources with an average energy of a few MeV (californium, Am-Be) will probably perform better than a neutron generator based on the D–T fusion which produces neutrons with an energy of 14MeV.

There are two reasons for the presence of shield around the Am-Be neutron source: Firstly, application of shield around the neutron source causes most of neutrons to participate in mine detection and due to this the acquisition time is decreased or scanning speed is increased. Neutron source shield causes neutrons to scatter and their energies decrease. According to accomplished experiments neutrons with energies lesser than 1MeV have main role on landmine detection (Fig. 2). Secondly, it is necessary that users are protected from neutron radiation. The source strength that may be used in a prototype device needs to be as low as possible due to the radiation dose for the user. The yearly dose limit for a radiological worker is 20mSv. If one works 1000h per year, a dose rate of 20µSv/h is acceptable although a lower dose is preferred. But the lower limit of the source strength is limited by mine depth, soil humidity, stand-off distance, etc. Therefore we have to use source shield in order to reduce dose rate received by user. Some experiments and simulations have shown that the radiation dose can be reduced by a factor of 3-4 by using shielding materials like polyethylene (Datema *et al*., 2002). Therefore in this work we intend to determine the type and thickness of Am-Be neutron source shield in order to improve neutron contribution on detection process and reducing dose rate.

Monte Carlo Simulation :

According to accomplished investigations, due to presence of ^{10}B in borated complexes and 1H in hydrogenous material, borated complexes are suitable absorber and hydrogenous material are suitable moderators. Therefore, in this work, boric acid and polyethylene (PE) have been used as absorber and moderator, respectively (Hong *et al*., 2000; Coeck *et al*., 2002).

It has been assumed that an Am-Be neutron source, which has 4.7 cm diameter and 16 cm height, has been covered by two shield layers, polyethylene and boric acid. Two samples of TNT by 10×10×10 cm^3 dimension have been located under and next to the source by 5 cm distance from source and external shield. So neutron flux has been calculated on TNT samples by MCNP code (Fig. 4).

In the mine detection based on neutron back scattering, increasing of neutrons, received by TNT sample under the source facilitates detection process. Therefore, we must design shield around neutron source that causes decrease of neutron count in side source sample and increase in lower source sample. In order to show this point, we have accomplished calculations with boric acid

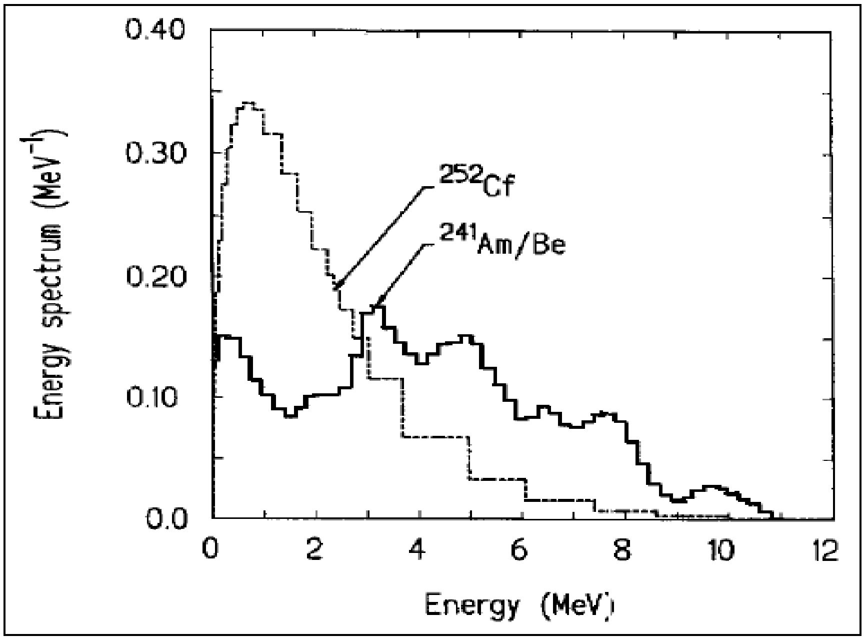

Fig. 1 : Neutron Energy spectra for ^{252}Cf and ^{241}Am-Be isotopic neutron source.

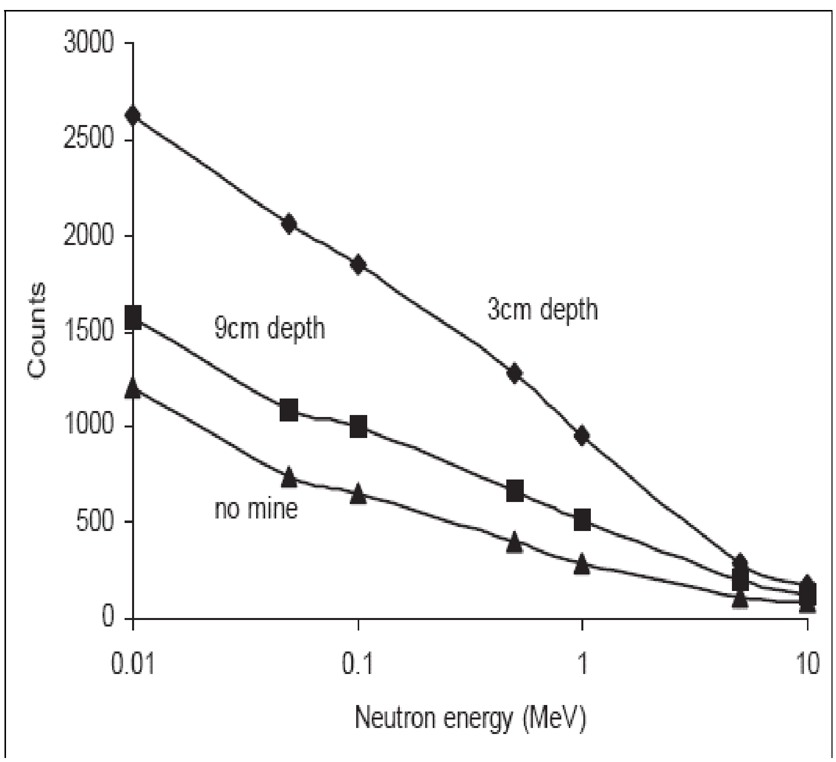

Fig. 2 : The number of counts for the mine at 3 and 9 cm depth as a function of the neutron energy.

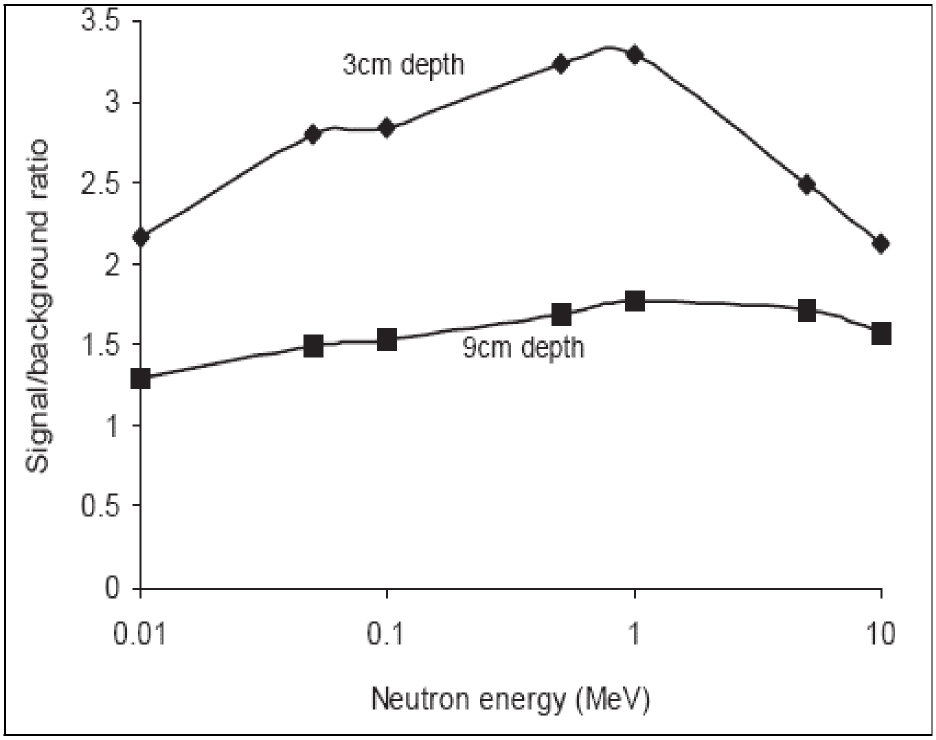

Fig. 3 : Signal-to-background ratio in the mine at 3 and 9 cm depth as a function of the neutron energy.

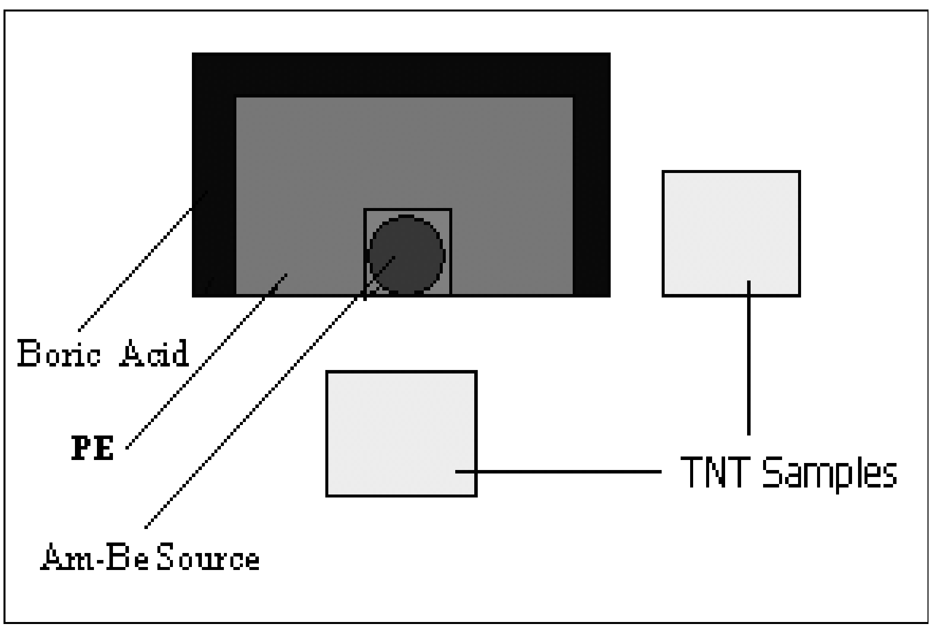

Fig. 4 : Locations of TNT samples, source and its shield with respect to each other in Monte Carlo simulation

and polyethylene shield separately; we have obtained neutron flux as a function of thickness in TNT samples for both shields. Figures 5 and 6 illustrate results of calculations.

It is seen in Fig. 5 and 6 that neutron fluxes, received by TNT samples, follow shield thickness. In other words neutron fluxes in lower and side source TNT samples have been increased and decreased, respectively. It means that neutron source shield causes most of neutrons to participate in mine detection. Comparing of the figures above, we understand that polyethylene as a neutron shield is more effective than boric acid. So it causes most of neutrons to arrive to lower source TNT sample. It must be remembered that if the thickness of each shield is about 10 cm the neutron counts will be saturated. Therefore, we can improve results by establishing 10 cm thickness of both shields. We have used polyethylene in the first layer because it is a good moderator and reflector and boric acid in the second layer because it has ^{10}B that absorbs thermal neutron received from background (Fig. 4). It must be determined how much shields thickness are used. We established 10 cm PE shield around the source and calculated neutron flux on TNT samples by decrease PE thickness and increase boric acid thickness. Calculation results have been shown in Fig. 7 and 8. According to Fig. 8 when PE (the first layer) and boric acid (the second layer) thicknesses are 9 cm and 1 cm respectively, neutron flux received by next the source TNT sample is at minimum rate. At the same time the neutron flux received by lower source TNT sample is almost at maximum rate. So it is the best shield for Am-Be source that is used on landmine detection.

Experimental results :

We designed two setups as figures 9 and 10. Detector used was BF_3 that had 28 cm length and 2.45 cm diameter. Neutron source used was Am-Be with 1.49E10^{11}Bq activity. Table 1 shows the intensity of particles that are emitted from the ^{241}Am–^{9}Be source (Mowlavi and Koohi-Fayegh, 2004). We have counted neutrons by BF_3 detector during 100s in all experiments. During the 100s, the number of neutrons can be estimated as (Knoll, 2000)

$$Sn = A(MB) \times \left(\frac{n}{MBq}\right) \times T(s) =$$

$$1.49 \times 10^{11} \times \left(\frac{70}{10^6}\right) \times 100 = 1.043 \times 10^9$$

Investigation of gamma effect in BF_3 detector : To investigate the gamma emitted by Am-Be source on BF_3 detector, we design a setup as Fig. 9. The neutrons emitted have been measured with and without lead cover by 5 cm thickness. In both setups detector distance to source was 7 cm.

Experimental results have been shown on table 2. As lead severely absorbs gamma ray, so it prevents arrival of the gamma ray in BF_3 detector. According to what is seen on table 2, the gamma emitted by source has approximately no effect in BF_3 detector count. The increase of neutron count is due to collision of neutron with lead atoms and its scattering and slowing down. As the lead cover absorbs only the gamma ray, so it can be used as shield for users.

PE effect on neutron count : We want to obtain optimum rate of PE shield thickness around the neutron source. In our opinion the optimum rate is acquired when the neutron flux on the lower source TNT