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An Optimum Landmine Detection System Using Polyethylene Moderator and ^{241}Am-Be as a Neutron Source

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Abstract : In this paper an optimized moderating structure using an ^{241}Am-Be neutron source for detecting landmines (using the PGNAA method) has been investigated by experiment. The experimental set up composed of a Pb cylindrical shell enclosing the neutron source, embedded in a fixed size High-density polyethylene (HDPe) cylinder with the variable thickness of the upper and lower moderator. The optimizing approach applied in this work is straighter than the usual approach that is based on measuring the prompt gamma rays rate due to the Landmine nuclei. Methodologically, by using the concept of PGNAA method a novel approach was studied and some groups of experiment have been done to measure the several moderator configurations' responses.

Key words : Am-Be Neutron source; Landmine detection; Optimization; HDPe.

Introduction

The detection of landmines using classic technologies (Metal detector, prodding) is a time consuming, expensive and extremely dangerous procedure. Although metal detectors are very efficient in finding mines containing metal parts, but they are much less efficient in finding almost metal-free mines (Sieber, 1998). Several landmine detection methods based on nuclear techniques have been suggested in recent years (Cinausero *et al.*, 2004; Csikai, 2004; IAEA, 1999; Datema *et al.*, 2002; Gerl *et al.*, 2004; Knapp, *et al.*, 2000; Kuznetsov *et al.*, 2004; Lunardon *et al.*, 2004; Maucec and de Meijer, 2002; Nebbia *et al.*, 2005; Pazirandeh *et al.*, 2006; Viesti *et al.*, 2006). Although the nuclear approaches in landmine detection have their own limitations (Hussein and Waller, 2000; Viesti *et al.*, 2006), but some attempts have been done recently to resolve the technical limitations (Rezaei Ochbelagha et al., 2007). One of the proposed techniques to detect non-metallic landmine that has shown great potential, is using PGNAA method (Miri-Hakimabad *et al.*, 2007 a and c). The PGNAA Method is being actively investigated for finding mines (Report EUR 16 329 EN, 1995; Viesti *et al.*, 1999). In this method the landmine is excited with neutrons. The active landmine emits several prompt gamma rays with various intensions. Ordinarily, the energy spectrum of these gamma rays is the evidence of the elements contained in the landmine. In according to this fact that the PGNAA method is based on capturing thermal neutrons by sample nuclei, here landmine, Hence the optimum moderator geometry that causes to the maximum thermal neutrons flux, certainly improve the efficiency of this method (Miri-Hakimabad *et al.*, 2007c). The primary

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purpose of this paper is investigation the best and optimum structure of the moderated 241Am-Be source geometry to detect landmines. One way to obtain the optimum structure could be based on measuring the production rate of prompt gamma rays, but because of the disturbing effect of high-rate background gamma rays, this method for optimization is so hard to experiment. The problem was tackled in this way that instead of using a real landmine and detecting the ^{14}N prompt gamma rays, 10.8 MeV, a thermal neutron detector was replaced with the mine. So just, the variation of the near thermal and thermal neutron flux, produced by the source-moderator geometry, have been measured in the optimization process.

Experimental Approaches

By using the concept of PGNAA method and this fact that the production rate of prompt gamma rays is related directly to the thermal neutrons flux, so if we cause experimentally the maximum thermal and near thermal neutron rate on the sample position, the best moderator geometry can be obtained.

A BF_3 as a thermal neutron detector (Rezaei Ochbelagha, 2007) has been replaced with the mine to measure the thermal neutrons flux. By varying the upper and lower moderator thickness (polyethylene), the optimum moderator geometry based on the Maximum BF_3 Count rate, was obtained.

At first sight it may not justifiable and there is not any claim of similarity between a real situation and a simulated situation, because there is not any mine in the experimental procedure, while just only a BF_3 buried at the 3 cm lower from the level ground.

If we precisely consider to the procedure it can be seen that the ^{10}B reaction has a rather featureless cross section and obeys the 1/*v* law quite well even up to approximately the energy of approximately 0.5 MeV, like the general 1/*v* dependence exhibited by nitrogen nuclei (17-38% by weight in a usual mine) .

Also, since the most practical BF_3 counters are filled with pure Boron Trifluoride enriched to about 96% in ^{10}B, so the concern of the similarity about using a BF_3 tube instead of real explosive material vanishes.

The benefit of this approach is that there is a poor signal-to-noise ration because the BF_3 is less sensitive to the gamma-ray back ground. The work that we describe in this paper is an enhancement of the PGNAA method, made possible by using a BF_3 to detect the thermal neutron produced due to the applied source-moderator configuration.

Source-moderator Geometry Definition

The Landmine Detection System configuration is shown in Figure 1. The geometry of the land mine detection system is somewhat like to that used by Zuin, *et al* (2000). The PGNAA facility is composed of some parts. One part is including the cylindrical Pb shield and neutron source enclosed in the High Density Polyethylene (HDPe) moderator that is fixed (size/position) during the experiments. MCNP results show that the exterior radius of the HDPe cylindrical moderator shell do not strongly influence the thermal neutron fluence in the Landmine position, after a critical value of about 17-18 cm.

The cylindrical Pb is considered as a gamma shield. Such shielding material would act intrinsically as an external neutron reflector/moderator (Miri-Hakimabad *et al.*,

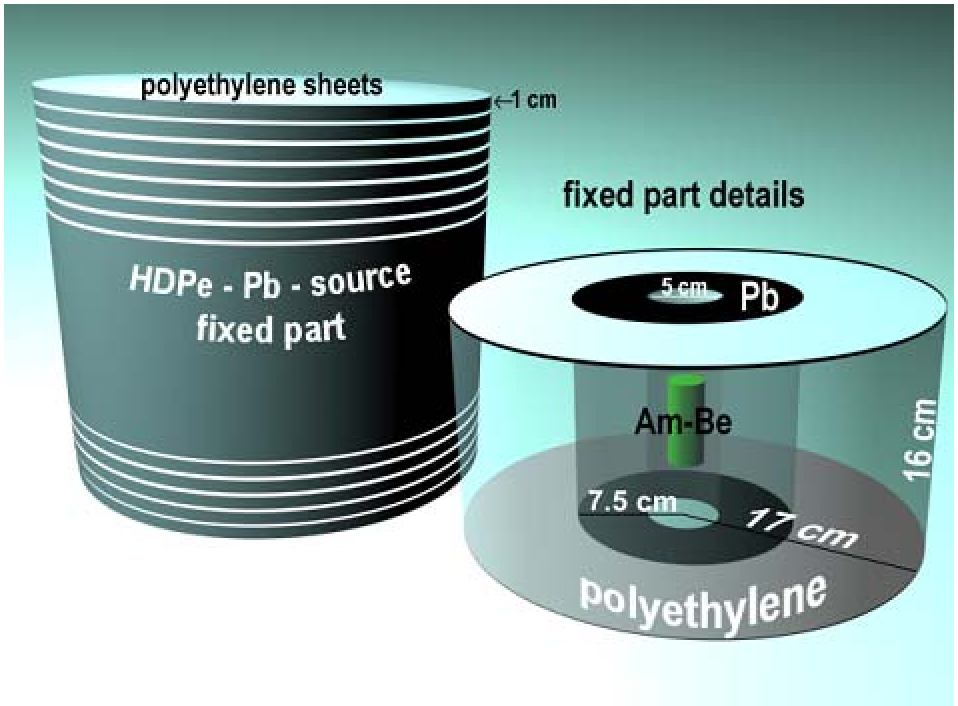

Fig. 1 : The Landmine Detection System details

2007 b and d). Also it protects the operator from the 4.438 MeV Am-Be primary gamma-rays. An ^{241}Am-Be neutron source with 5Ci activity contained in standard Amershan X.14 capsules format (code AMN24), was used in this Landmine Detection System. Since the risk of exposure to neutrons is more than the gamma rays so to protect personnel from biological effects of neutrons and specially to reduce background counts in an executive system using NaI detector, Figure 2, neutron shielding must be considered. Since high-speed neutrons are more difficult to shield, at first neutrons must be moderated by a hydrogenous material such as HDPe, although the Pb shield plays this role to some extent. In consequence, Because of Hydrogen has a great absorption Cross Section for thermal neutrons, hence the risk of neutrons for personnel vanishes. The other parts are the moderator sheets (1 cm thickness, polyethylene) which lie on/under the fixed part as a reflector/moderator. Note that the lower side of the fixed part has been fixed about 12cm above the level ground during the experiments.

Results and Discussion

According to what is mentioned before, an increase in the thermal neutron count rate is interpreted as that the setup goes to the optimum structure. Totally 56 kinds of configurations have been examined and the total experimental data were tabulated in Table 1. In this table the "bold" number is the maximum count and shows that, in its category it has the optimum structure between the others.

Table 1 lists the total experimental data obtained by varying the upper and lower polyethylene thickness. The percentage of the relative increase between the worst and the best configuration's count rate is about 20%. Results also show that the rate increases when the lower HDPe thickness increasing up to 5 cm. the number of capture events is very sensitive to the thickness of the lower HDPe part. A further increase of the HDPe thickness causes a significant reduction of the capture events in the detector. This effect is understood as due to the absorption of the thermalized neutrons in the hydrogen contained in the HDPe, which partially screens the detector from the thermal neutrons produced in the inner part of the structure. So the critical thickness of the lower HDPe part is the 5 cm. It is clear that with the 5 cm thickness of the lower part, the count rate will be increased, when the thickness of the upper HDPe part increasing. The maximum count rate in Table 1 is related to the best geometry which has 7cm thickness of HDPe above the fixed part.

Since by increasing the upper thickness of the reflector/moderator the rate of increasing is very slow, so the best thickness of the upper part, considered up to 7 cm thickness of polyethylene and the experiments didn't proceed more, taking

Table 1 : Total Thermal Neutron Flux in the 60 s of Detector Live Time

Thickness (cm) of upper Polyethylene Part								
	7	342434	338564	360652	371332	363846	341464	--------
	6	340879	337104	361161	370769	363214	340094	312234
	5	340585	337199	360925	371405	362180	341069	312386
	4	338772	336763	360440	370410	362993	340369	310912
	3	336836	335435	360217	369556	361996	340705	312469
	2	335601	334209	358347	369411	362481	339232	310732
	1	331365	332938	357049	367719	360418	337777	310216
	0	325894	328023	353303	365606	358939	337916	309136
		2	3	4	5	6	7	8
		Thickness of the polyethylene sheets (cm) lied under the fixed part						

Table 2 : Total Neutron and Gamma Dose Equivalent Rate (Sv h-1) Due to the Landmine Detection System

		Gamma	Neutron
Distance	2m	0.08	8.4
	4m	–	2.1

into account the total weight of the assembly.

Also in order to check the system safety and the radiation protection which is highly recommended, the neutron and gamma dose equivalent rates were measured experimentally at two different distances from the landmine detection system. Table 2 shows that the risk of exposure highly decreases when using a system holder with a long arm more than 4m.

Summary

The end goal of this paper which is finding the best geometry for a landmine detection system (using PGNAA method) was obtained. The critical thickness of the lower part is the 5 cm of HDPe while the upper side uses 7 cm thickness. The future work will be the gamma spectroscopy with the shielded NaI detectors by the optimum geometry to detect the landmines using PGNAA method, Figure 2. Also it is worthwhile to check the effects of using the other materials as moderator/reflector.

Fig.2 : The Optimum Landmine Detection System using PGNAA Method

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