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MEASUREMENT OF DELAYED NEUTRONS AFTER INDUCED FISSION OF SPECIAL NUCLEAR MATERIAL

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Nondestructive measuring capabilities for the in situ detection and analysis of nuclear material are considered as possible measures to discover illicit trafficking of nuclear material and to prohibit nuclear proliferation. As e. g. pointed out by Shea [1] there is an increasing concern regarding the potential for thefts of nuclear weapons or weapons-useable nuclear material as a means through which states or sub-national organizations might acquire the components for nuclear weapons. This stolen nuclear material may be surrounded by additional shielding material to prohibit direct detection. Hence, gamma detection is not suited for measuring such items of dense material due to self-shielding effects. However, neutrons have a high probability to penetrate those materials. Whereas plutonium emits enough neutrons from spontaneous fission, which may be measured by passive methods, highly enriched uranium in casings can not be detected passively. So active techniques like neutron interrogation are needed. A clear proof of the existence of special nuclear material is the emission of delayed neutrons after induced fission by neutrons.

Therefore, we investigated the measurement of delayed neutrons in order to detect and identify hidden or shielded nuclear material in geometrical configurations which are not known in detail. Only about 1 % of the neutrons emitted from nuclear fission are delayed neutrons, all others are prompt. The absolute yields of the delayed neutrons as well as their yields as a function of the time after the neutron pulse vary significantly from fissionable isotope to isotope and thus constitute a clear signature of the isotopic composition [2]. We performed measurements on the time structure of the delayed neutrons. For the active nondestructive measurements we use a sealed tube 14 MeV neutron generator (d-T reaction) type Genie 26 manufactured by SODERN/France. This neutron generator is capable of producing $2x10^8$ n/s continuously or up to $2x10^{11}$ n/s in pulsed operation.

A block of depleted Uranium (size 5 x 5 x 4 cm^3) was irradiated repeatedly with our neutron generator for different time intervals, ranging from 3 to 60 seconds. The delayed neutrons emitted by the object were detected by slab counters. The distance from the neutron tube to the object was chosen to 8 cm, and the object and the neutron detector were placed close together. Each slab counter consists of 6 He-3 tubes embedded in polyethylene. The active length of the tubes is 33 cm and the diameter 2.54 cm. The front side of each slab counter is covered with a 0.8 mm thick Cadmium layer in order to obtain information on the thermalization of the neutron source and to reduce the thermal background of room return neutrons. The efficiency of each slab counter is 0.12 % for the detection of Cf-252 fission neutrons emitted from a point source in a distance of 100 cm from the center of the detector.

After the end of the interrogating neutron pulse we integrated the delayed neutrons in different time intervals, ranging from 3 s to 300 s. A MCS system (multi channel scaling) was used to record the „decay curves“ of the delayed neutrons. The electronic was triggered by the neutron generator in such a way that the neutron detector started counting after the end of the neutron pulse. For comparison we repeated the same measurements with the uranium replaced by lead

(Pb). To observe the influence of moderating material we surrounded the heavy metal by 5 cm polyethylene (PE). Some of the experimental results are shown in figure 1, where we have plotted the number of the measured neutrons as a function of composition of the irradiated object and as a function of the integration time.

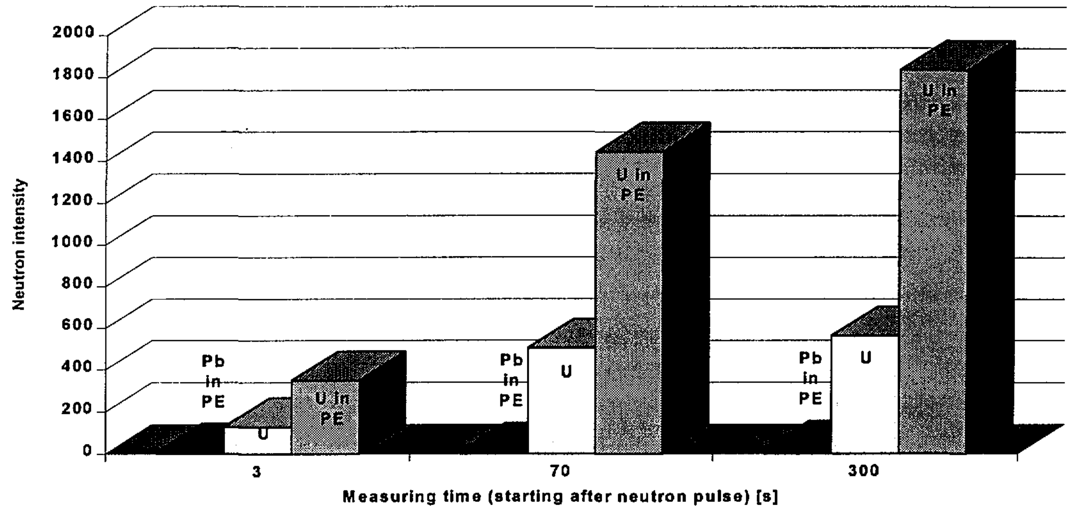

Figure 1: Intensity of the delayed neutrons in three time intervals (after induced fission)

Whereas with lead (with and without polyethylene casing) delayed neutrons could not be observed there is a good signal with the uranium in place. This countrate is enhanced further by the polyethylene casing around the uranium. Within the 300 s long measuring interval nearly all delayed neutrons are emitted and no significant additional information can be gained with longer counting intervals. The measured decay curves were fitted to the well known six groups of delayed neutrons. The relative strengths of the different groups were reproduced well for the measurements with the long irradiation time (60 s) and the long counting time (approx. 200s) for the delayed neutrons. For shorter irradiation or measuring times only some of the relations could be reproduced. As can be seen from figure 1, a shorter counting interval of approximately 70 s will already provide significant results. Further experiments will be performed with objects of different composition, size and additional shielding material. In this way the identification of the material in a suspect object will be possible by comparison of the measured results with previously gained data in the laboratory.

Thinking of verification of weapons materials this measurement method allows confirmation of fissile materials content without disclosing sensitive information (like geometry). These experiments show that fissionable material can be detected clearly and easily in a suspicious box with a pulsed neutron generator within a very short time (several minutes).

REFERENCES

[1] Shea, T.E.: The Evolution of IAEA Verification Responsibilities and Related Functions, IAEA Yearbook 1995, p. E17-E25, IAEA, Vienna, Austria, Sept. 1995

[2] Papadopoulos, N.N.; Xatzakis, G.E.; Tsagas, N.F.: Delayed Neutron Counting Decay Compensation for Improved Uranium Assay. In: International Nuclear Safeguards 1994: Vision for the Future: Vol. 2. Vienna: IAEA, 1994; p. 609 - 615