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AUTHOR(S): Lloyd Oscar Lindquist

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University of California

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POTENTIAL NUCLEAR SAFEGUARDS APPLICATIONS FOR NEUTRON GENERATORS

L. O. Lindquist
International Safeguards Group (Q-5)
Los Alamos Scientific Laboratory, Los Alamos, New Mexico

Summary

Many nuclear safeguards inspection instruments use neutron sources to interrogate the fissile material (commonly ^{235}U and ^{239}Pu) to be measured. The neutron sources currently used in these instruments are isotopics such as Californium-252, Americium-Lithium, etc. It is becoming increasingly more difficult to transport isotopic sources from one measurement location to another. This represents a significant problem for the International Atomic Energy Agency (IAEA) safeguards inspectors because they must take their safeguards instruments with them to each nuclear installation to make an independent measurement. The purpose of this paper is to review the possibility of replacing isotopic neutron sources now used in IAEA safeguards instruments with electric neutron sources such as deuterium-tritium (D-T, 14-MeV neutrons) or deuterium-deuterium (D-D, 2-MeV neutrons). The potential for neutron generators to interrogate spent-light water reactor fuel assemblies in storage pools is also reviewed.

Introduction

The International Atomic Energy Agency (IAEA) has the responsibility to conduct nuclear safeguards measurements in many nations. The purpose of these inspections is to detect possible diversion of nuclear material from peaceful activities such as nuclear power generation or education.

The IAEA inspectors will potentially make inspections at nuclear power plants, uranium enrichment plants, fuel fabrication plants, nuclear fuel reprocessing plants, research reactor facilities, and other facilities. In each of these environments, the inspector may, with the appropriate facility attachment, use an IAEA device to verify the operator-declared values of selected nuclear materials. An example might be to verify the quantity of ^{235}U in a bulk sample of U_3O_8 or UO_2. This is material which is stored in quantity at light water reactor (LWR) fuel fabrication plants. The IAEA inspector will have several instruments which use neutrons to interrogate the fissile material.

Current Safeguards Instruments Using Isotopic Neutron Sources

The current devices available (or to be delivered in the near future) for safeguards measurements are the High-Level Neutron Coincidence Counter (HLNCC),[1] in the active mode, the Active Well Coincidence Counter (AWCC),[2] the neutron Coincidence Collar (CC),[3] the random Driver (RD),[4] the Californium Shuffler,[5] and the Neutron Collar.[6] All of these devices assay the fissile content of nuclear material by using an isotopic neutron source to interrogate.

Isotopic Neutron Sources Utilized in Current Safeguards Measurement Equipment

The neutron sources in the HLNCC, AWCC, CC, RD, and Neutron Collar emit neutrons randomly in time. The neutrons are not time-correlated as are fission neutrons. A typical source is Americium-Lithium (AmLi) with a neutron output[7] of $1 \times 10^4 - 5 \times 10^5$/s. A replacement neutron generator for the isotopic source should have similar output characteristics. The average neutron energy (0.3 MeV) of the AmLi neutron spectrum is below the fission threshold for ^{238}U. Isotopic neutron sources for safeguards applications are very compact, lightweight, and thus highly portable. The difficulties associated with transporting and storing them is becoming a real concern. If an electric neutron source is to replace the isotopic source, it should be highly portable, simple to operate, and not intrinsically radioactive.

Neutron Generator Requirements for Substitution of Isotopic Neutron Sources

The neutron generator should emit neutrons continuously on demand. The two common neutron energies from generators are 2 MeV (from deuterium-deuterium interactions) and 14 MeV (from deuterium-tritium interactions). Either of these energies are greater than AmLi, but it is possible to moderate the neutrons to reduce the neutron energy below the fission threshold of ^{238}U.

The neutron generator must be simple to operate and have high reliability. For the IAEA portable applications, the weight and size requirements are approximately 30 kg maximum and and the volume of a large suitcase, respectively. The generator should be designed and built to withstand the rigors of airline conveyor belts. It should be D-D type to eliminate radioactive transport problems. The output characteristics should be continuous, nonpulsed, > 100-hour lifetime, and have a neutron output of 10^4-10^5/s.

Neutron Generator Use in Unattended Material/Equipment Portal Application

G. W. Smith[7] (Sandia National Laboratory) has developed an unattended material/equipment portal using active interrogation by 14 MeV neutrons from a small, high output, rapid-pulse neutron generator. This type of pass-thru system has been proposed for future international safeguards applications where nuclear fissile material must be identified without the aid of an inspector. The neutron generator to be used for this application must have reliable operating characteristics with a lifetime > 100 hours.

Potential Neutron Generator Applications for Spent LWR Fuel Assembly Safeguards Verification

Active neutron interrogation of spent LWR fuel stored in spent-fuel storage pools is a potential activity for nuclear safeguards research and development. The D-T or D-D neutron pulsed or D.C. generators offer the possibility of high neutron penetration into the LWR fuel assembly. Since the spent-fuel assemblies continuously emit neutrons [by (α,n) and spontaneous fission of plutonium], the pulsed or D.C. neutron source strength must exceed this neutron background from the fuel assembly. The neutron source strength should be $> 10^8$ neutrons/second (average).[9]

The neutron generator used for this application should ideally be watertight (to a depth of ~ 20 meters) with suitable component design to operate in 100 percent humidity, 30°C environments. The system should be designed for rugged use in an industrial environment. It should be reliable with a minimum of operator training or knowledge required. The lifetime should be > 100 hours.

Conclusions

Isotopic neutron sources for nuclear safeguards instrumentation are becoming increasingly difficult to transport. Development of lightweight, portable, nonpulsed, electric neutron sources to replace the isotopic sources is a desirable development.

Pulsed or D.C. neutron generators could potentially be used for active neutron interrogation of spent LWR fuel assemblies. The design and construction of such a generator must accommodate the aqueous environment in which spent LWR fuel assemblies are stored.

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