Homeland Security
Science and Technology

TechNote

Neutron Detection Instruments

Neutrons are uncharged particles with the same mass as a proton, and are found in the nucleus of an atom. Free neutrons are generated by the impact of high energy charged particles (cosmic rays) on atoms high in the atmosphere, and are a part of the natural background radiation. Neutrons are also generated in industrial neutron sources which use alpha particles emitted by a radioactive element, usually americium, to bombard beryllium. Californium (Cf-252) is also used as a neutron source; it can decay by splitting apart (fissioning) spontaneously, emitting three or four fast neutrons as well as x-rays and gamma rays. Such sources are used for well logging, moisture gauges, and industrial process control, and are shielded to reduce gamma and neutron emission.

Plutonium, used in atomic weapons, also decays by spontaneous fission and has low level neutron emission (as well as x-ray and gamma emission); thus, detection of neutrons above background levels might indicate the presence of plutonium (a Special Nuclear Material, SNM).

Neutron detectors are sometimes incorporated in hand held radioactive isotope identifiers that might be carried in emergency vehicles and used by emergency responders to make follow-up measurements after a radiation pager alarm or portal monitor alarm (designed to screen trucks or cargo for radiation). The ability of neutron detectors to screen for SNM depends on the detector sensitivity, distance from the source, measurement time, and shielding. For example, equipment built in conformance with ANSI Standard N42.34 (2006) or ASTM Standard ASTM C1237-99 will state sensitivity to neutrons at a specified distance (25 cm) from unshielded standard SNM neutron and gamma sources.

Neutron Detection Technologies

Since neutrons are uncharged particles, they do not interact strongly with matter. One way to detect fast neutrons is to allow them to pass through a material like polyethylene that has a large proportion of hydrogen in its chemical composition. Because neutrons and hydrogen nuclei (protons) have nearly the same mass, any fast neutrons give up much of their energy in neutron-proton collisions. The resulting slow neutrons can then be absorbed, or captured, by certain elements, such as boron, lithium, or helium (helium-3, ^{3}He), which then decay by emission of fast charged particles. These charged particles can easily be detected since they ionize the material through which they pass.

Detectors based on neutron capture and charged particle emission use a chamber filled with either gaseous boron trifluoride (BF_3) or ^{3}He as the detection medium; these are called proportional counters since the output signal generated is proportional to the number of incoming neutrons.

Another technique is to detect the high energy protons that result from head-on fast neutron-proton collisions. The neutron gives up most of its energy to the stationary proton, which is then detected in a solid-state detector. Such an instrument is sensitive only to fast neutrons, and only over a narrow angle and direction. The advantage of this method is its low cost; the disadvantages are very limited sensitivity and utility.

One of the most recently developed neutron detection technology is based on glass fibers that emit light when bombarded by neutrons. Glass fiber based detectors can provide large area neutron detectors at relatively low cost. They are,

U.S. Department of Homeland Security

SAVER

System Assessment and Validation for Emergency Responders

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions.

Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercial equipment and systems and provides those results along with other relevant equipment information to the emergency response community in an operationally useful form. SAVER provides information on equipment that falls within the categories listed in the DHS Authorized Equipment List (AEL).

The SAVER Program is supported by a network of technical agents who perform assessment and validation activities. Further, SAVER focuses primarily on two main questions for the emergency responder community: “What equipment is available?” and “How does it perform?”

For more information on this and other technologies, contact the SAVER Program Support Office.

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however, significantly more sensitive to gamma radiation than gas proportional counters. While both types of detectors can give false neutron alarms due to high levels of gamma radiation, the greater gamma sensitivity of the glass fiber based detector might be a considerable disadvantage under some circumstances.

Detection Limitations

As with other types of radiation sources, neutron sources can be shielded to reduce emission to very low levels; in particular properly shielded neutron emitters such as plutonium are extremely difficult to detect.

Since neutron sources also emit x-rays and gamma rays (high energy x-rays), several different layers of shielding are needed. Normally the neutron source is surrounded by a layer of heavy material such as steel or lead to attenuate the gamma rays, then by a layer of boron-polyethylene or lithium-polyethylene to slow down and absorb the neutrons, finally by a layer of steel to absorb any gamma radiation from the neutron capture (absorption) reactions.

Commercial Neutron Detectors

Stand-alone neutron detectors are used where neutron exposure might be of concern, such as in nuclear fuel reprocessing plants, nuclear fuel refining and fuel rod fabrication plants, nuclear weapons fabrication facilities, nuclear accelerators, and medical facilities using neutron radiation therapy. The capabilities of these detectors and their technical characteristics are described in their instrument manuals. They detect neutrons over a broad energy range and are used to monitor the radiation dose from neutrons. They typically are based on ^{3}He or BF_3 proportional counter technology, and use appropriate moderators and attenuators to assure linearity and accuracy. Such detectors might also be used by specialized national security/DOE response teams to deal with nuclear weapons or radioactive waste accidents.

Neutron detectors are often combined with x-ray/gamma detectors in handheld monitors or in radioactive isotope identifiers, sometimes denoted as RIIDs. The neutron detector technology is either a proportional counter or a solid state detector.

Portal monitors examine neutron and gamma ray emission from vehicular and personnel traffic into or out of critical facilities (e.g. scrap metal yards, container terminals, nuclear power plants) to insure that radioactive material is not being moved without permission. Most neutron detectors in portal monitors are based on proportional counter technology.

Conclusions

The technology for neutron detection and shielding is well understood, and sensitive instruments and shielding materials are available commercially. Neutron detectors tested in accord with ASTM (American Society for Testing and Materials) or ANSI (American National Standards Institute) standards are available for use by emergency responders. The results of these tests and the instrument technical characteristics should be included in the instrument manuals. Agencies providing funding for detector acquisition should strongly encourage a careful detector selection process. In addition, funding Agencies should promote a rigorous training program that instructs users in detector operation as well as the limitations of neutron detectors (and radiation detectors in general) with regard to intercepting special nuclear materials.

Resources

Delaney, C.F.G., and Finch, E.C., Radiation Detectors: Physical Principles and Applications, Clarendon Press, Oxford, 1992.

ASTM C1237-99 (Re-approved 2005): Standard Guide to In-Plant Performance Evaluation of Hand Held SNM Monitors (www.astm.org).

ANSI N42.32: Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security

ANSI N42.34-2006: Performance Criteria for Hand-held Instruments for the Detection and Identification of Radionuclides

ANSI N42.35: Evaluation and Performance of Radiation Detection Portal Monitors for Use in Homeland Security (www.ansi.org).

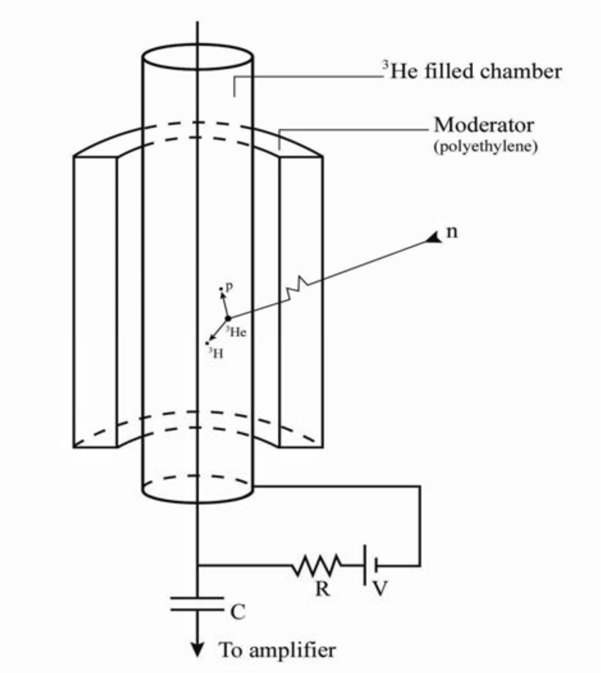

Figure 1. Proportional counter showing the ^{3}He filled cylinder inside a moderator (polyethylene), and the ^{3}He-neutron (n) reaction, with reaction products of a proton (p) and a tritium (^{3}H) nucleus. These ionize the gas; the burst of charged particles is detected as a voltage pulse across a resistor (R) - battery (V) by an amplifier beyond the blocking capacitor (C).