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Portable Monitor for Special Nuclear Materials

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NEED FOR A PORTABLE MONITOR

The rise of world-wide terrorism brings with it the concern that a knowledgeable and well-organized group of terrorists might try to construct a nuclear bomb. Production of the special nuclear materials (SNM)* required for a nuclear bomb is very difficult; it requires a capability far beyond that of such a group. To make a bomb, terrorists must obtain SNM from supplies already produced or processed by such legitimate installations as the Energy Research and Development Administration (ERDA) and the companies and institutions working with it. To meet this threat, ERDA has strengthened security procedures at sites where appreciable quantities of SNM are kept. One procedure requires that all persons, packages, and vehicles leaving these sites be searched for SNM. Normally, searches are made by requiring that all outgoing pedestrians and packages pass through a doorway monitor and all vehicles through a gateway monitor. Each monitor produces an alarm to warn a guard if SNM is passing through it. Doorway and gateway monitors are effective, but they are large and permanently installed. Some searches call for a small, portable instrument, and for these, the Los Alamos Scientific Laboratory (LASL) has developed a hand-held SNM monitor.

This portable monitor is useful for supplementary searches when pedestrians or vehicles alarm a conventional doorway or gateway monitor, for temporary exits, and for exits where the traffic flow is too low to justify a permanent monitor. Considerable savings are realized by using it wherever appropriate because it costs 10 to 30 times less than a doorway or gateway device. LASL's monitor uses conventional techniques for SNM detection but incorporates a novel method of signal processing and alarm production that increases the probability of detection and adds to the ease of operation.

DETECTION OF SPECIAL NUCLEAR MATERIALS

Special nuclear materials emit gamma rays, which, like x rays, can penetrate materials. A gamma-ray detector can reveal hidden SNM because the emitted gamma rays penetrate

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*Plutonium and enriched uranium.

materials such as vehicle bodies with little loss of intensity. The search for SNM is complicated, however, by gamma rays produced by the earth's natural radioactivity. These background gamma rays are always present. The detectors used in SNM monitors cannot distinguish between gamma rays from SNM and those from natural radioactivity. To detect SNM we must first know the intensity of the background gamma rays and then rely on an increase in the intensity to indicate that an additional source of gamma rays, possibly SNM, is present.

One compact detector particularly sensitive to gamma rays consists of a sodium iodide crystal attached to the face of a photomultiplier tube. A light-tight container for the detector excludes external light. Gamma rays interact with the crystal to produce one small pulse of light for each interaction. The photomultiplier converts each light pulse to an electrical pulse. For each gamma-ray interaction in the crystal, one electrical pulse is produced, then amplified, and finally, counted and the number of counts displayed as a digital readout. The gamma-ray intensity is determined by how many counts occur during a set time interval. Thus, using only a simple system: detector, amplifier, pulse counter, and display, a search can be made for SNM.

To illustrate how the system works, presume that we must search two packages. First, we determine the background gamma-ray count per interval at the search position. Assume the *average* count per interval to be 30. The word *average* is emphasized because counting gamma-ray pulses is similar to tossing coins; both are examples of random behavior. If we put 100 coins in a jar, shake them, cast them on the floor, and count the number of "heads," we find that the average number of heads per toss is about 50 if we make a great many throws, but that an exact count of 50 occurs infrequently. Fluctuations in the background gamma-ray count are similar to the fluctuations in the number of heads per toss for the thrown coins. If gamma-ray counts are made during each of many intervals, the average count per interval in our example is very close to 30. Using statistical theory, we can calculate the probability that the count in an interval will exceed any given number when the average count per interval is known.

Once the background count has been determined, the first package is searched by moving the detector close to it and obtaining the count. The first package gives a count of 60. This is twice the normal background count so we can say that the package probably contains a source of gamma rays. A count of 60 per interval from random fluctuations in the background count alone is highly unlikely.

The second package gives a count of 42. Does this indicate that the package contains a gamma-ray source? Perhaps, but statistical theory calculations show a 2% chance that a count of 42 or greater can come from our average background count of 30. If four more counts for this package show 27, 33, 35, and 29, then probably, the first count of 42 was a large fluctuation of the background radiation, and probably, the package contains no gamma-ray source.

How can we decide whether a gamma-ray source has been detected? It is desirable to detect fractions of an ounce of SNM, but such small amounts are very weak sources of gamma rays. If it is decided that any count 40% or more above the background count means a source has been detected, then the alarm level is 42, that is, 30 + (40% of 30). With this low alarm level, the chance of producing an alarm by equaling or exceeding the level is 2% each time the background radiation is counted. Such an alarm would be false. The number of false alarms can be reduced by raising the alarm level, but this reduces the detector's sensitivity as well, because now more gamma-ray counts, hence a stronger source, are needed to produce an alarm. If the alarm level of 42 is retained, whether an alarm is real can be determined by several more counts of the package. Further alarms mean that the package probably contains a gamma-ray source.

The distance between a source of gamma rays and the detector affects the gamma-ray count. For instance, if the detector is 1 foot from a source and the average count per interval after subtraction of the background count is 100, then at 2 feet, the average count minus the background is 25; at 3 feet, it is 11-1/9; and at 4 feet, it is 6-2/3. The count equals 100 divided by the distance squared; at twice the 1-foot distance, the count rate is divided by 4 ($2^2 = 4$) and at three times the distance, by 9 ($3^2 = 9$). In other words, the smaller the distance, the weaker the source that can be detected.

When a person is searched, the operator holds the monitor at several locations 4 to 6 inches from the person's body and reads the counts per interval. If the first count is made at the top right front of the body, the next count down 6 inches, and the counts continued to the floor every 6 inches, then up the front left side to the top, and down, then up the back, a six-foot-tall person is covered completely by obtaining a count at each of 48 locations. A hidden source is never farther than 1 foot from at least one of the 48 locations; at this distance, the detector can discern a fraction of an ounce of SNM. We could have designed a detector system that produces clicks for the counts, but with this system it is difficult to distinguish between random changes in background rate and changes produced by small gamma-ray sources, especially in a noisy environment. We could have shown the count rate on a meter; this system suffers the same random-change difficulties as the above, but also, it is difficult for the operator to watch the meter while maintaining the correct distance between the detector and the person's body.

LASL'S PORTABLE MONITOR

The digital-readout system described above is effective, but searching extensive areas requires many separate counts; it is a tedious and time-consuming operation. The guards who perform SNM searches have little special scientific training. To make the searches easier, LASL has developed a monitor that determines and sets the alarm level at the press of a button and that sounds an alarm automatically.

LASL's semiautomatic monitor has the same detector, amplifier, and pulse counter described earlier. The counting interval is set within the monitor, usually at 0.3 second. The alarm level is usually 1.4 times the background count per interval, and it is set automatically when the operator, by pressing a button, stores the background count long enough to get a close approximation of the average counts per interval. If, for example, the stored count is 30 per 0.3-second interval, the alarm level is set at 1.4 times 30, that is, 42 counts per 0.3-second interval. With the alarm level set, the monitor is ready for the search, and it accumulates counts for 0.3 second. If the counts equal 42, the monitor sounds a tone that stays on for the remainder of the 0.3-second interval. Thus, if the average count per interval from the background plus that from the object being searched is 84, the tone comes on at about 0.15 second and lasts for 0.15 second, that is, until the end of the 0.3-second interval. Then the process is repeated. With the average count per interval equal to 84 and with the monitor held stationary at the same distance from the source, there is a series of tones that begin about every 0.3 second and last about 0.15 second. If the monitor is moved far enough from the source to reduce the count to 42, the tone lengths are reduced and some intervals have no associated tone because the count has fluctuated to less than 42.

To convey the simplification of inspection procedure, again presume the search of a person. The operator begins at the subject's head and while holding the monitor 4 to 6 inches away, sweeps it over the subject at the rate of about 20 inches per second. At this rate, the monitor sweeps about 6 inches during each 0.3-second interval, insuring that, if a source is present, at least one count during the search is made with the detector less than 1 foot from the source. The complete operation requires less than 30 seconds, but surveys all the count positions covered previously. Because he has no visual count readout to observe but merely listens for a tone, the operator can devote his full attention to the monitor's position relative to the subject's body.

False alarms present no problem, for when one occurs the operator merely moves the monitor back to the location where the tone sounded and holds it there for a second or two to hear whether the tone sounds again. If it does not sound, he assumes the alarm is false and continues his search.

Vehicles and packages are searched in a similar manner, by sweeping the monitor across the areas to be examined.

LASL's hand-held monitor is an 8- by 5- by 6-inch box with a handle. It weighs only 4 pounds and is easy to use. The electrical power is furnished by rechargeable, low-voltage batteries that operate for 100 hours between recharges. The high voltage needed for the photomultiplier is furnished by a converter that produces 720 volts from the battery's low-voltage output.

As the number of installations using SNM for legitimate purposes increases, the chance of theft of the material for subversive purposes also increases. The hand-held monitor, available commercially and now with improved efficiency, is an extremely useful tool for preventing the diversion of special nuclear material.

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Search of a vehicle with LASL's portable monitor.

Search of a person with the portable monitor after the doorway monitor in the background has produced an alarm.

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