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SNM Monitor Applications: Diversion Safeguards for Emergency Exits and Detection of Undeclared Feed in Enrichment Plants

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814

SNM MONITOR APPLICATIONS:
DIVERSION SAFEGUARDS FOR EMERGENCY EXITS AND
DETECTION OF UNDECLARED FEED IN ENRICHMENT PLANTS

by

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ABSTRACT

A new monitor for special nuclear material (SNM) uses wide plastic scintillators and digital logic to achieve a higher sensitivity for detecting uranium than is found in conventional personnel SNM monitors. With its detectors spaced 2 m apart, the new monitor meets the DOE requirement to detect a 10-g metal ^{235}U sphere of 93% ^{235}U whose total mass is 10.8 g. This capability suits the monitor to scan people who may have to pass quickly through emergency exits. In yet another application, the monitor meets detection goals for detecting freshly separated, natural UF_6 that is brought into enrichment plants through personnel portals. To determine the performance of the new monitor for these applications, laboratory source scans and measurements of the growth of uranium daughter activity in freshly separated UF_6 were used.

INTRODUCTION

An ongoing vehicle monitoring study investigates the sensitivity of different monitors to the presence of SNM. One part of that study calls for a monitor design that places wide plastic scintillators on each side of a vehicle to form a vehicle portal. After the monitor was constructed, a period of testing began to find and correct deficiencies. One of the tests compared the uranium detection sensitivity of the new detectors to that of previously tested detectors used in personnel SNM doorway monitors. The new detectors performed almost as well, spaced at 2 m, as other detectors spaced at 1.2 m or less. Thus, it seemed worthwhile to investigate the performance of the new monitor in two new applications of personnel monitors that require more sensitivity to uranium than is now available in commercial units.

One new application of the monitor addressed a problem at the DOE Y-12 plant in Oak Ridge. Material access areas where uranium is processed undergo emergency evacuation from time to time as practice evacuations or alarm sensor malfunctions occur. Each time an evacuation takes place, a

material inventory is required to verify that no SNM is missing. If SNM monitors were placed at the emergency exits they would eliminate the need for an inventory. The monitors would have to be capable of detecting 10-g quantities of uranium carried by people running through an exit. At Oak Ridge's request, the Los Alamos Detection and Verification group applied the recently developed vehicle monitor to the problem at the Y-12 plant. This application afforded an excellent opportunity to obtain valuable data on hardware performance for emergency exit applications.

In the second application, the vehicle SNM monitor also served as a personnel monitor, but in this case it was for detecting undeclared feed material entering an enrichment plant under International Atomic Energy Agency (IAEA) safeguards. A long-time source of information on the technical aspects of monitoring for UF_6 feed material, the Los Alamos Detection and Verification group assembled a data base during its early investigations¹ of perimeter safeguards techniques for enrichment plants. The new monitor offered an opportunity to expand the data base for UF_6 monitoring. The new information consisted of sensitivity data, measurements of ^{238}U daughter radiation build-up in a freshly separated UF_6 sample, and a determination of how well the transfer of UF_6 to a new container separates the UF_6 from uranium daughters.

STATIC MEASUREMENTS

One of the columns of a new monitor appears in Fig. 1 with its cover removed to expose the detectors. It has two detectors that consist of a Pilot F scintillator (30 cm wide by 3.8 cm thick by 91 cm long), a 23-cm-long light pipe, and a 3.8-cm Hamamatsu R580 photomultiplier. The two detectors placed in each column are positioned so that the photomultipliers and light pipes of the top and bottom detectors overlap. The sensitive area of each detector is unobstructed. When the column is erect, its total height is 226 cm (Fig. 2). In use, the detector columns face one another with the outside surface of each column shielded by 0.95 cm of lead to reduce background intensity.

To compare the new detector to others that we investigated,² we made similar measurements of the signal count obtained for a 10-g ^{235}U metallic sphere (total mass 10.8 g, 93% ^{235}U) as we varied the spacing between the columns. The source was positioned at the minimum sensitivity position in each case. The figure of merit used to compare detectors is the net 10-g source signal squared, divided by the background (S^2/B), where both signal and background counts are static (no source motion) and last about 200 s. This figure of merit is the square of the signal-to-noise ratio and needs to be about 40 to meet DOE detection requirements. The value of 40 includes a four standard deviation (4σ) above background alarm level and assumes that 60% of the static net signal would be detected when a person carrying the source walks through the portal. The collected results from this and earlier studies in Table I demonstrate a clear superiority of the new Pilot F detectors over most others. The NE-102 scintillators detailed in the table are a close second.

Fig. 1.

A detector column lies horizontally with its cover removed to expose the detectors. The arrangement is similar to an early Los Alamos personnel doorway monitor that overlapped the nonsensitive photomultiplier and light pipe regions.

MEASUREMENTS WITH MOVING SOURCES

The performance of an SNM monitor can be determined by appropriate tests. The results of a person carrying samples through the monitor, whether or not a detection is made, can be tabulated. This approach is useful to compare the performances of equipment designed for a specific purpose. However, in the case of new applications, we first need to establish the basic parameters, such as the optimum logic count time to monitor runners who pass through a very wide opening.

Accordingly, we carried out basic measurements of several sources in the new monitor, including source intensity scans, using the minimum sensitivity region. We made similar slow scans of people passing through the monitor to determine the background attenuation caused by the human body during passage. The measurements were performed on the 193-cm NE-102 scintillators (Table I), at 76-cm spacing, and on the new Pilot F detectors at

Fig. 2.

The erect detector columns are 2.26 m high, taller than conventional personnel monitors, which usually stand about 1.98 m. Panels on each column allow access to the detectors.

spacings of 76 and 203 cm. The dual measurements at the 76-cm spacing allowed us to verify the new technique by comparing its results with those that were determined earlier. The measurements also allowed us to determine the comparative performance of the new detectors for conventional-width personnel monitoring. The measurements at the 203-cm spacing provided the necessary information for investigating an emergency exit monitor.

The first step in testing the new monitor was to set appropriate gamma-ray energy windows in the detector electronics. The appropriate window³ for detecting unshielded ^{235}U is about 70-220 keV, which we used in the initial measurements. The minimum sensitivity point for the 193-cm-high NE-102 detectors was established earlier² as the foot region of the medial plane between the detectors. For the new detectors, a vertical, highly enriched uranium (HEU) source scan (Fig. 3) established a low sensitivity point in the head region of the medial plane. The reason for the difference in the low sensitivity points is that the top detectors in the column of the new monitor (Fig. 1) are about 5 cm farther away from a portal occupant.

TABLE I
RELATIVE PERFORMANCE OF
FIVE SNM MONITOR DETECTORS

Detector Separa- tion (cm)	Figure of Merit (S^2/B) for Different Detectors (counts/s) ^a				
	<u>NaI(Tl)^b</u>	<u>Liquid Scintillator^c</u>	<u>NE-110^d</u>	<u>NE-102^e</u>	<u>Pilot F^f</u>
61	---	192	---	---	---
69	73	---	---	---	---
76	63.5	---	64	219	256
84	49.8	---	---	---	---
91	35.9	---	---	---	---
102	24.4	---	---	133	169
107	17.8	43	---	---	---
122	---	---	---	47	80.4
183	---	25	---	---	---
203	---	---	---	28	43.9

^aThe source was a 10.8-g metallic sphere of 93% ^{235}U and the background intensity was $22\mu\text{R/h}$.

^bA total of eight 5-cm-diam by 2.5-cm-thick scintillators.

^cTwo 10-cm-diam by 208-cm-long scintillators.

^dFour 5-cm-diam by 91-cm-long scintillators with 12.5-cm-long light pipe.

^eTwo 30-cm-wide by 3.8-cm-thick and 193-cm-long scintillators.

^fFour 30- by 2.8- by 91-cm-long scintillators with 23-cm-long light pipe.

The response of the new detectors to an HEU source moving horizontally through the low sensitivity region of the new monitor was determined by a slow scan of a 3-g $^{235}\text{UO}_2$ powder sample traveling along a wire. We purposely selected an oxide source to provide a higher count rate that improved the counting statistics in scans.* The $^{235}\text{UO}_2$ source itself was compared in static measurements to the standard 10-g ^{235}U metal sphere, mentioned earlier, so that the scan results could be converted to sensitivity for the metal source. The scanning rate was slow, about 1 cm/s, and counts were multiscaled in 10-s counting intervals with a computer-controlled scaler. The net source count in each count interval appears in Fig. 4. A separate printout (not shown) gives channel values and cumulative values for each scan.

When a person carries a source through a monitor, the detected radiation from the source increases the monitor count rate. However, at the same time, the person's body shields parts of the detector from environmental

*Self-shielding is important in uranium. In the 10-g sphere, self-shielding reduces gamma-ray output by about 10. The powder oxide sample has little self-shielding, therefore the gamma-ray emission of the 3-g oxide sample is larger than the 10-g metal sample, even though the mass is smaller.

Fig. 3.
A vertical source scan using a 3-g $^{235}\text{UO}_2$ powder sample and a 76-cm detector spacing revealed the variation in sensitivity in the new monitor's medial plane. The lowest sensitivity is at the top because the upper detectors are farthest apart.

Fig. 4.
A horizontal source scan through the minimum sensitivity point in the medial plane of the new detectors at the 76-cm spacing. The scan shows the net response to a 3-g sample of $^{235}\text{UO}_2$. A fast walkthrough would result in about 13 channels of data.

radiation, which reduces the count rate slightly. We scanned the background count rate in the new monitor as several people, one at a time, walked through the monitor at a rate that covered the same distance per count interval that we used previously in the source scan. Figure 5 exemplifies the scan of one individual in the new detectors. The plot shows a decrease just as the individual moves into or out of the monitor, a position where his body provides the most effective shielding; his body and the exterior lead shielding almost entirely shield one end of the portal. At the center of the monitor, where he is completely inside the detector's environmental gamma-ray shield, there is a slight increase in response above the unoccupied background, possibly caused by scattered radiation from the body entering the detectors; this radiation would otherwise pass straight through the portal opening.

We needed to gather data for typical passage times in a free-flowing traffic monitor to convert the scanning data into results that would be seen while monitoring. We obtained the data by timing individuals as they walked or ran through a portal. Minimum sensitivity occurs for the fastest individual; therefore, to obtain a conservative performance estimate, we used the fastest walking time, 1.3 m/s, and the fastest running time, 3 m/s, in making performance calculations.

The performance calculations used a monitoring time per scanned data channel that was simply the scanned distance per channel divided by the maximum passage speed. The monitoring time values were 0.0823 s/channel for walkers and 0.035 s/channel for runners. The method used to establish the best performance was to choose a sampling time, say 0.8 s, and sum the net signal in the appropriate number, nine for instance, signal scan channels. The summed count (counts/s) was multiplied by the monitoring time per channel walking, 0.0893 s. The result was then multiplied by the ratio of response for the 10-g metal sphere

Fig. 5.

The presence of a person causes small changes in the new monitor's background count rate. As the person enters or exits, the main effect, signal depression, is caused by the shielding. When a person is in the center of the monitor, his body scatters radiation into the detector, giving a slight elevation. This radiation would otherwise pass through.

to the response for the 3-g oxide source to give the net detected source count for a normal passage. Background was the measured background count rate multiplied by the sampling time, which represented the background in the logic unit that would be obtained from prior unoccupied measurements.

The final step was to reduce the calculated source count by an amount representing the average background reduction caused by an individual passing through the monitor. This step represents what actually happens in monitoring: the count during occupancy increases from source counts, but at the same time, is reduced slightly by the body, which shields environmental radiation. Shorter and longer sampling times were calculated until a relative maximum figure of merit (S^2/B) was found. Table II gives an example of the calculations for three different sample times using data from the 193-cm NE-102 detectors. Case 2 has the best figure of merit and the count time is near the optimum count time of 0.8 s determined earlier in walkthrough testing (Ref. 2, p. 22). The ratio of the useful signal (signal minus background suppression) for Case 2 to the static source count for the Case 2 count interval is 0.60, the same value that we obtained earlier in walkthrough testing. These two results validate the scanning technique for performance testing. The performance figure of merit of 75 is better than in earlier tests of a commercial monitor that used these detectors; however, the commercial unit used different signal conditioning and analog logic.

The sample performance calculations for the new detectors are given in Table III for comparison to Table II and for use in a later section. The best figure of merit (Case 2) is somewhat higher, as expected, and, using a 1-s count-time logic unit, should provide excellent sensitivity. The figure of merit needs to be about 16 here (because S in these measurements is a dynamic count) to meet detection requirements (see Ref. 2, pp. 3-10). Hence, the monitor easily meets personnel monitoring requirements and has the potential for detecting a 3-g ^{235}U sphere 50% of the time.*

*Self-attenuation makes the uranium spheres act as surface area sources. Thus, if 38% of the signal is required, a mass of $10 \text{ g} \times 0.38^{1.5} = 2.7 \text{ g}$ provides it.

TABLE II
PERFORMANCE CALCULATION RESULTS FOR
THE 193-cm NE-102 SCINTILLATORS SPACED 76 cm APART

Case	Number of Data Channels Used	Integrated Signal Count ^a (counts)	Logic Count Time (s)	Logic Background ^b (counts)	Signal Minus Background Suppression ^c (counts)	Figure of Merit (counts)
1	7	12 197	0.576	2 299	399	69.2
2	11	16 291	0.905	3 613	519	74.6
3	15	18 993	1.235	4 930	585	69.4

^aThis sum is for a time period equal to the number of data channels used.

^bBackground intensity was nominally 22 $\mu\text{R/h}$.

^c $CS = \text{integrated signal count} \times 0.0823 \text{ s} \times (949/2090) - 0.025 \times \text{logic background}$.

TABLE III

PERFORMANCE CALCULATION RESULTS FOR
THE NEW DETECTORS SPACED 76 cm APART^a

Case	Number of Data Channels Used	Integrated Signal Count ^b (counts)	Logic Count Time (s)	Logic Back- ground ^c (counts)	Signal Minus Background Suppression ^d (counts)	Figure of Merit (counts)
1	9	23 237	0.741	5 014	727	106
2	13	28 904	1.070	7 243	889	109
3	15	30 911	1.235	8 360	942	106

^aTwo 91-cm Pilot F scintillators per column.^bThis sum is for a time period equal to the number of data channels used.^cNominal 22 μ R/h.^dS = integrated signal count $\times$ 0.0823 $\times$ (1331/3171) - 0.015 $\times$ logic background.

MONITORING OF EMERGENCY EXITS

Scans using the new detector columns spaced at 2 m included both the head region of the medial plane and also a plane near one column. The second position provides more signal, but also has larger background suppression during passage of a person; therefore, we needed to calculate both conditions. The outcome was that the medial plane was found to be the minimum sensitivity region: the source scan for the medial plane appears in Fig. 6 and the results of performance calculations are given in Table IV.

The results of this evaluation are that the figure of merit is just adequate to meet the personnel monitor performance specifications ($S^2/B = 16$). Some safety margin is usually necessary and could be obtained by using electronics that treat the lower and upper detectors in each column separately. This would increase the cost of the monitor slightly. The optimum count time for runners is about 1 s (Case 2); thus, conventional portal monitor logic count times can be used. The cost of the SNM monitor (in 1981) is about \$18,000. Part of the cost includes logic and communication functions not needed for the personnel monitor application; an \$18,000 estimate may be a reasonable upper limit for an emergency exit monitor.

Some differences between emergency exit monitoring and personnel monitoring require changes in the equipment or logic used. These changes entail some amount of test and evaluation, preferably at Oak Ridge, before they can be designed. Such changes as the following are involved.

- Open emergency exit doors can change the background and affect sensitivity. The monitor logic must compensate by adjusting its stored background whenever the doors open.

- A record of who was near the monitor when it alarmed must be obtained, possibly using photographic surveillance.

Fig. 6.

At 2-m spacing, the 3-g $^{235}\text{UO}_2$ horizontal scan is more spread out and the counting statistics are not as good. However, in this case, a runner covers 27 channels during the 1-s count and the precision of the figure of merit is about the same as for the narrower spacing.

TABLE IV

PERFORMANCE CALCULATION RESULTS FOR THE NEW DETECTORS USED AT EMERGENCY EXIT SPACING OF 2 m^a

Case	Number of Data Channels Used	Integrated Signal Count ^b (counts)	Logic Count Time (s)	Logic Background ^c (counts)	Signal Minus Background Suppression ^d (counts)	Figure of Merit (counts)
1	23	21 394	0.805	6 009	333	17.8
2	27	23 270	0.945	7 054	363	18.5
3	31	24 714	1.085	8 100	385	18.3

^aTwo 91-cm Pilot F scintillators per column.

^bThis sum is for a time period equal to the number of data channels used.

^cNominal 22 $\mu\text{R/h}$ background.

^d $S = \text{integrated signal} \times 0.035 \times (561/1260)$, there is no background suppression.

- The monitor is not observed continuously, hence random photographs may be useful to uncover any unusual behavior of individuals intent on subverting the monitor.

Two other questions require answers before emergency exit monitors can be designed.

- Is 10-g ^{235}U sensitivity required? Perhaps a quantity derived from an inventory limit-of-error mass divided by the average number of individuals exiting could be used. A larger detection goal will allow monitoring at locations that are closer to large quantities of stored material.

- Can another approach be used to eliminate the need for monitoring every exit? Perhaps an automatic inventory scheme or a reduced number of false alarms and a procedure of scheduling practice evacuation just before normal inventory would help reduce the needed number of monitors.

MONITORING FOR UNDECLARED FEED

A scenario of effective subversion of IAEA Safeguards at an enrichment plant may read as follows. Small containers, filled on the previous day with UF_6 , may be taken one at a time through personnel entrances of the plant. The containers may be shielded with 1.25-cm-thick lead.

A matrix of detection goals to counter such a scenario has been proposed for a single passage through a monitor (Table V). The indicated quantities are to be detected 95% of the time with 0.1% false-alarm rate in a 15- $\mu\text{R}/\text{h}$ background. The interpretation of these numerical parameters is a 3.16 σ alarm level to meet the false-alarm rate and a signal 1.65 σ above the alarm level to meet the detection requirement. A residence time of 2 s during passage through the monitor is assumed instead of the 0.6-s free flow count period.

An inexpensive way to provide the delay needed for a 2-s count is a BetaDoor (Fig. 7), available from Beta Tech* as an automatic darkroom door. The 1981 price of \$1150 buys an electrically operated double door with convenient side wells for detectors and a transit time of 2-3 s.

*Beta Screen Corporation, Carlstadt, NJ 07072.

TABLE V
95% DETECTION GOALS IN A 15- $\mu\text{R}/\text{h}$ BACKGROUND

<u>UF₆ Age</u>	<u>Quantity of Natural UF₆ (kg)</u>	
	<u>No Shielding</u>	<u>1.25-cm Lead Shielding</u>
24 h	1	10
50 days	0.1	1

The age of the UF_6 is important because uranium daughters that can be chemically or physically separated are responsible for emitting most of the detectable gamma radiation, particularly for shielded material. After separating the UF_6 from its ^{234}Th and ^{234}Pa daughters, as can be done by subliming the UF_6 into another container, the daughter radiation grows back into the gamma-ray spectrum with a half-life of 24.1 days.

To determine the completeness of separation and obtain response data for evaluation of the new detectors, we used 325 g of fresh UF_6 in a 1S container.* Periodically we measured the count rate of the container bare and in light lead shielding at several positions in the monitor. The energy window used for these measurements extended from 70 keV to about 1 MeV. The plot in Fig. 8 shows the activity measured at two positions over a period of 8 weeks. The measured points are shown along with a growth curve for the ^{238}U daughter, ^{234}Pa . P. E. Morgan of Los Alamos provided the growth curve, a solution of the Bateman equations for the ^{238}U decay chain. The relative growth data, C_{calc} , needed to be normalized to the observed points A_{exp} , including the offset from zero caused by other radiation (^{235}U gamma rays and x-ray fluorescence). The relationship

$$A_{\text{exp}} = a + b C_{\text{calc}}$$

and an approximate calculated value, C_{calc} , were fitted to the data using the linear least-squares method. Other curves for bare and lead-shielded cases (Fig. 9) were fitted in the same way. For instance, an estimate was made by multiplying the bare curve by the expected lead transmission and a final curve was obtained by determining the least-squares parameters a and b . This procedure provides reasonable assurance that the 1-day activity result is meaningful, tells how much of the observed intensity is soft radiation from ^{235}U and hard radiation from ^{238}U , and verifies the appropriate attenuation coefficient for lead in both thick and thin sections.

Fig. 7.
Installation of a BetaDoor with detectors in the side wells can provide the necessary 2- to 3-s delay for persons passing through the monitor.

*Standard sample containers referred to in this report, 1S and 2S, are described in Ref. 1, pp. 47-49.

Fig. 8.

The measured count rate points are fit with a calculated growth curve that includes a fixed ^{235}U offset and a ^{234}Pa contribution calculated from the Bateman equations. The more intense curve has the sample positioned upright at the maximum sensitivity point. The lower curve has the sample oriented sideways at the least sensitive point.

Fig. 9.

The effect of shielding the detector with lead was measured at the most sensitive location. The results verified earlier attenuation measurements with depleted and enriched uranium.

The fitted data for the minimum sensitivity case, when the source is 1 day old and located at the top center, oriented perpendicularly to the medial plane, must be reduced by a factor of 0.6 to calculate the signal detected from the container during a walkthrough. The response that would be obtained in a 2-s walkthrough is given in Table VI. The figure of merit obtained for our sample is too low for 95% detection* and an increase of 1.9 in detected signal is needed. If mass^{0.67} signal scaling** is used, the mass needed is about 859 g. This scaling law is appropriate for a spherical surface-area source. At the least sensitive position, the detector views the ends of the long, narrow container, which makes the container appear more spherical than cylindrical to the detectors. An experimental verification of this approach to scaling was obtained by measuring 1S (400-g) and 2S (2-kg) containers in the new monitor.

In the shielded case, a transmission of 0.155 for a 1.25-cm-lead shield is consistent with the fitted curves. Table VII gives the response results for the lead shielded case. A mass of 14 kg is needed for 95% detection. Table VIII gives the results for the aged (50-day) material.

Performance results for 95% detection of UF₆ in a 15-μR background are summarized in Table IX. The response of the new monitor is a bit less than desired for fresh shielded material, but could easily be improved to meet requirements by reducing the height of the monitor with a bridge at 212 cm above the ground. The 212-cm interior height would still exceed that of commercial monitors, which are about 198 cm. Conversely, increasing the minimum age requirement of the UF₆ to 2 days would also have the desired result. Both of the suggested modifications would yield a better performance for the unshielded case. A final consideration is that the standard container for quantities of UF₆ between 2 and 20 kg is the 5A. A 5A container is too

*S needs to be about 1.65 standard deviations above the 4σ alarm level. Thus, S²/B needs to be about 32.

**The radiation detected originates in the sample surface because self absorption removes radiation from the interior. Thus, the signal depends on the surface area that, for spheres, increases as the 0.67 power of the mass.

TABLE VI
NEW DETECTOR RESPONSE TO BARE, FRESH UF₆

Count Time (s)	Background (counts) ^a	Signal (counts) ^b	Figure of Merit (counts)
2	9 460	247	6.3

^a15 μR/h background.

^bS = graphed value at 1 day x walkthrough factor x count time; for example, S = 206 x 0.6 x 2 = 247.

TABLE VII
NEW DETECTOR RESPONSE TO FRESH UF₆
SHIELDED BY 1.25-cm LEAD^a

<u>Count Time (s)</u>	<u>Background (counts)^a</u>	<u>Signal (counts)^b</u>	<u>Figure of Merit (counts)</u>
2	9 640	38.3	0.152

^a15 μ R/h background.

^bS = $206 \times 0.6 \times 2 \times 0.15 = 38.3$.

TABLE VIII
DETECTOR RESPONSE TO AGED UF₆

<u>Shielding</u>	<u>Count Time (s)</u>	<u>Background (counts)^a</u>	<u>Signal (counts)^b</u>	<u>Figure of Merit (counts)</u>	<u>Required Mass of UF₆ (g)</u>
Bare	2	9 640	2 346	571	29
1.25-cm lead	2	9 640	364	13.7	482

TABLE IX
95% DETECTION MASSES IN 15- μ R/h BACKGROUND

<u>UF₆ Age</u>	<u>Quantity of Natural UF₆ (kg)</u>	
	<u>No Shielding</u>	<u>1.25-cm Lead Shielding</u>
24 h	0.860	14 ^a
50 days	0.030	0.480

^aThe quantity would be 10 kg with a reduced height monitor.

long (91 cm) to pass overhead through this 76-cm-wide monitor in the least sensitive orientation, with its long dimension perpendicular to the medial plane. Thus, a 5A container in a different orientation or a number of 2S containers would have to be used, making a smaller quantity of UF_6 detectable without any modification.

SUMMARY

The new monitor, when used for doorway monitoring, provides better sensitivity than commercial personnel monitors for SNM and natural UF_6 can provide. The new monitor has an efficient light collection system. A long light pipe on each scintillator gives uniform light collection, making the pulse height of the source the same for any point in the detector, which allows more efficient use of the energy window in the detection electronics.

Another advantage of the new monitor is that the scintillators are easy to calibrate. A variance-broadening found in longer detectors is not present above the 70-keV lower level of the energy window. The broadening effect, possibly caused by pulse pile-up in long detectors without a light pipe, requires monitoring count statistics as the lower level discriminator is raised until a variance-to-mean ratio near 1 is achieved. This effect, pointed out by L. Kruse of Sandia National Laboratories, Albuquerque, appears in the new detectors just below the optimum lower level discriminator setting.

A final advantage of the new monitor is that it is taller than existing personnel monitors. It can be made taller yet without reducing its mid-height response below the minimum response in Fig. 3.

ACKNOWLEDGMENTS

In addition to the growth curve provided by P. E. Morgan, E. L. Clark constructed hardware used for the scanning measurements, J. D. Atencio corrected deficiencies in the new monitor, and C. E. Moss measured gamma-ray spectra of the fresh UF_6 . J. L. Lyman provided the fresh sample and G. K. Anderson provided the 2S container. Tom Scurry Associates* constructed the new monitor.

REFERENCES

1. P. E. Fehlau and W. H. Chambers, "Perimeter Safeguards Techniques for Uranium Enrichment Plants," Los Alamos National Laboratory report LA-8997-MS (1981).
2. P. E. Fehlau, T. E. Sampson, C. N. Henry, J. M. Bieri, and W. H. Chambers, "On-Site Inspection Procedures for SNM Doorway Monitors," Nuclear Regulatory Commission report NUREG/CR-0598, Los Alamos Scientific Laboratory report LA-7646 (1979).

*Tom Scurry Associates, Boulder, CO 80306.

3. W. H. Chambers, H. F. Atwater, P. E. Fehlau, R. D. Hastings, C. N. Henry, W. E. Kunz, T. E. Sampson, T. H. Whittlesey, and G. M. Worth, "Portal Monitor for Diversion Safeguards," Los Alamos Scientific Laboratory report LA-5681 (1974).