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REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 5.27

SPECIAL NUCLEAR MATERIAL DOORWAY MONITORS

A. INTRODUCTION

Paragraph (b), "Exit Requirement," of § 73.60, "Additional Requirements for the Physical Protection of Special Nuclear Material at Fixed Sites," of 10 CFR Part 73, "Physical Protection of Plants and Materials," requires that individuals exiting from material access areas be searched for concealed special nuclear material (SNM). This guide describes means acceptable to the Regulatory staff for employing SNM doorway monitors to comply with that requirement.

B. DISCUSSION

Special nuclear material doorway monitors provide an efficient, sensitive, and reasonably unobtrusive means of searching individuals exiting from a material access area for concealed SNM. With proper installation and operation, gram quantities or less of SNM can be detected with a high level of reliability while maintaining a low false alarm rate.

1. Theory of Operation

The doorway monitor is composed of a detector unit(s), associated electronics, and alarm logic. The detector unit(s) is sensitive to the radiations which emanate from the SNM and responds to these radiations (usually gamma rays) by generating current pulses. These pulses are amplified, filtered, and fed to alarm logic which interprets the number (or rate) of pulses in some period of time, for example, one second. The alarm logic may be either a digital or analog system; in either case, if the number (or rate) of pulses exceeds a set level, an alarm condition ensues.

2. General Characteristics

Typically, the detectors of a doorway monitor are NaI(Tl) scintillators or solid or liquid organic scintillators. Geiger-Mueller detectors have also been used in this application, although the lower intrinsic efficiency of these detectors renders them less suitable than scintillation detectors.

Detectors are arranged such that a detection area is defined by a plane perpendicular to the line of passage of individuals through the doorway monitor. Various arrangements of the detectors are possible; however, specific placement of detectors is usually dictated by the need to eliminate dead spots.

Some commercially available doorway monitors are equipped with an automatic background updating system. The automatic background updating system periodically monitors and averages the background. A doorway monitor equipped with an automatic background updating system is also provided with a treadle pad or beam-break system to indicate that the sensitive area is occupied. When the sensitive area is occupied, the radiation level detected by the doorway monitor is compared with the mean background. If the level is "significantly" greater than the mean background, an alarm condition ensues. Significance is usually determined by comparing the radiation level when the sensitive area is occupied with the mean background plus some multiple of the square root of the mean background*

*The square root of the mean of a Poisson-distributed quantity is the unbiased estimate of the standard deviation of that quantity.

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Thus the condition for an alarm can be written as

$$G > B + n\sqrt{B},$$

where B is the mean background, G is the radiation level with the sensitive area occupied, and n is a multiplier, usually an integer between 4 and 10.* The value of n directly affects the false alarm rate, and the combination of B and n affect the sensitivity.

Although the automatic background updating system allows unattended use of the doorway monitor, for technical reasons, the system may be less effective in certain situations. Techniques to prevent this are described in the Regulatory Position.

Doorway monitors not equipped with an automatic background updating system either must rely on the inherent sensitivity of the instrument and low background variation to ensure that concealed SNM will be detected or must be attended so that a measurement of background can be taken immediately prior to use and the alarm level set to maintain the desired sensitivity to concealed SNM. As with the doorway monitor equipped with an automatic background updating system, a doorway monitor not so equipped compares the activity with the detection area occupied with some set value, usually the measurement of background taken just prior to use. In any case, the expression above can be used as a condition of alarm by replacing $B + n\sqrt{B}$ with the set level.

Whether or not a doorway monitor is equipped with an automatic background updating system, high background activity will decrease sensitivity. Measuring activity for longer periods will somewhat compensate for high background; however, longer measurement periods will make use of the doorway monitor less convenient.

C. REGULATORY POSITION

1. Minimum Qualifications for SNM Doorway Monitors

a. General

(1) SNM Doorway monitors should be used in conjunction with a metal detector and should be installed in a passageway (see Regulatory Guide 5.7, "Control of Personnel Access to Protected Areas, Vital

*Note that, in general, for a count rate system, the condition for alarm should be modified to account for the response time of the instrument as follows:

$$G > B + n\sqrt{B}(1 - e^{-t/\tau})$$

where t is the counting time and τ is the time constant of the instrument. If, as should be the case, $t/\tau > 5$ the added factor is essentially unity.

Areas, and Material Access Areas,") in such a manner that objects cannot be passed over, around, or under the detection area.

(2) The detector elements should be designed and positioned so that detection sensitivity is as uniform as possible over the detection area; in no case should any areas where SNM is not detectable be permitted.

(3) Power, sensitivity, and other controls of the doorway monitor should be tamper-secured when unattended.

(4) Signal lines connecting alarm relays to the alarm monitor should be supervised.

(5) Some doorway monitors may require an individual to occupy the detection area for a specified time, longer than a normal walking pace would provide. If this is the case, the doorway monitor should be provided with a treadle pad and a "clock" device to assure that the detection area is occupied for the requisite time. An aural and visual indication should be given if an individual being searched does not occupy the area sufficiently long.

b. System Specification

(1) *Plutonium-239*. A doorway monitor used to detect plutonium should be capable of detecting a minimum of 0.5 gram of plutonium-239 encased in a minimum of 3 mm of brass at a 90% confidence limit. The false alarm rate should be less than 0.1% (Appendix C).

(2) *Uranium-233*. A doorway monitor used to detect uranium-233 should be capable of detecting within 4 hours of purification* a minimum of 1 gram of uranium-233 containing between 7 and 10 ppm of uranium-232 encased in a minimum of 3 mm of brass at a 90% confidence limit. The false alarm rate should be less than 0.1% (Appendix C).

(3) *Uranium-235*. A doorway monitor used to detect uranium-235 should be capable of detecting a minimum of 3 grams of uranium-235 contained in uranium enriched to 20% or more in the uranium-235 isotope encased in a minimum of 3 mm of brass at a 50% confidence limit. The false alarm rate should be less than 0.1% (Appendix C).

2. Use of Doorway Monitors

In general, doorway monitors should be used in locations of minimum background and minimum background fluctuation. If circumstances dictate use of a doorway monitor in an area of high background, sufficient shielding should be provided to maintain necessary sensitivity.

a. Attended Doorway Monitor

(1) If the doorway monitor is attended during use, it need not be equipped with an automatic

*Purification means removal of all decay products.

background updating system, although such capability is preferred.

(2) Prior to each use* of a doorway monitor not equipped with an automatic background updating system, a measurement of background should be taken, and the alarm threshold should be set to the proper value listed in Table I for the measured background and the proper n value as determined in Appendix B. Each individual to be checked should, in turn, enter the detection area and be required to remain sufficiently long for the device to operate properly. During use, the background should be checked and the alarm threshold reset at least each 15 minutes.

(3) With the individual being checked in the detection area, an alarm should sound if the activity in the detection area exceeds the alarm threshold T , as such a situation would indicate the presence of SNM.

(4) The doorway monitor should be equipped with a high-background alarm which will sound if the measurement of background exceeds the appropriate maximum permissible background level listed in Table II as determined in Appendix C. The doorway monitor should not be used during such periods of high background.

b. Unattended Doorway Monitor

(1) If the doorway monitor is unattended, an automatic background update system should be incorporated into the doorway monitor electronics and alarm logic. The control circuitry, if possible, should be located at the central alarm station (or other monitoring point).

(2) Door interlocks and closed-circuit TV in combination with beam breaks, motion detectors, and/or treadle pads, should be employed to:

(a) Indicate to the person manning the central alarm station that an individual has entered the secure access passageway and/or is approaching the doorway monitor,

(b) Allow observation of the individual approaching the doorway monitor,

(c) Preclude a slow approach to the sensitive area of the doorway monitor, and

*By use is meant an individual or several individuals, each, in turn, being checked for SNM by the doorway monitor. The maximum period between threshold sets while the doorway monitor is in use is determined by the stability of local background and may necessarily be more frequent than every 15 minutes.

(d) Activate the electronics and alarm logic when an individual is within the detection area and initiate operation of the doorway monitor.

(3) An alarm should sound in the central alarm station if, when occupied, the activity in the detection area exceeds the internally set threshold level (the mean background plus some multiple times the square root of the mean background), as such a situation would indicate the presence of SNM upon the individual being checked.

(4) The doorway monitor should be equipped with a high-background alarm which will sound if the average background at the location of the doorway monitor exceeds the appropriate maximum permissible background level listed in Table II as determined in Appendix C. The doorway monitor should not be used during such periods of high background. Other monitored exits should be used.

3. Testing and Calibration

a. Testing

Doorway monitors should be tested by passing an appropriate source of the amount and isotope specified in Regulatory Position C.1.b. through the doorway monitor no less frequently than once per day.* In addition, a functional performance test should be carried out at least once per week. An acceptable functional performance test procedure is discussed in Appendix A of this guide

b. Calibration

Doorway monitors should be calibrated with a source of the amount, configuration, and variety of SNM to be detected (e.g., 0.5 gram Pu in 3 mm of brass). Calibration should be carried out according to a procedure such as that in Appendix B.

c. Operating Instructions

Operating instructions should be posted near the doorway monitor, if attended, or at the monitoring point if the doorway monitor is unattended. The instructions should clearly indicate the procedure for use of the doorway monitor and the procedure for setting thresholds, if appropriate. In addition, the operating instructions should indicate what corrective action is to be taken and who is to be notified in the event of a malfunction.

*Doorway monitors used to search for concealed U-233 should be tested according to §6 of Appendix A.

TABLE I
ALARM THRESHOLD

T								
B	n =	4	5	6	7	8	9	10
100		140	150	160	170	180	190	200
120		164	175	186	197	208	219	230
140		187	199	211	223	235	246	258
160		211	223	236	249	261	274	286
180		234	247	260	274	287	301	314
200		257	271	285	299	313	327	341
220		279	294	309	324	339	353	368
240		302	317	333	348	364	379	395
260		324	341	357	373	389	405	421
280		347	364	380	397	414	431	447
300		369	387	404	421	439	456	473
320		392	409	427	445	463	481	499
340		414	432	451	469	488	506	524
360		436	455	474	493	512	531	550
380		458	477	497	516	536	555	575
400		480	500	520	540	560	580	600
420		502	522	543	563	584	604	625
440		524	545	566	587	608	629	650
460		546	567	589	610	632	653	674
480		568	590	611	633	655	677	699
500		589	612	634	657	679	701	724
520		611	634	657	680	702	725	748
540		633	656	679	703	726	749	772
560		655	678	702	726	749	773	797
580		676	700	724	749	773	797	821
600		698	722	747	771	796	820	845
620		720	744	769	794	819	844	869
640		741	766	792	817	842	868	893
660		763	788	814	840	866	891	917
680		784	810	836	863	889	915	941
700		806	832	859	885	912	938	965
720		827	854	881	908	935	961	988
740		849	876	903	930	958	985	1012
760		870	898	925	953	981	1008	1036
780		892	920	948	975	1003	1031	1059
800		913	941	970	998	1026	1055	1083
820		935	963	992	1020	1049	1078	1106
840		956	985	1014	1043	1072	1101	1130
860		977	1007	1036	1065	1095	1124	1153
880		999	1028	1058	1088	1117	1147	1177
900		1020	1050	1080	1110	1140	1170	1200
920		1041	1072	1102	1132	1163	1193	1223
940		1063	1093	1124	1155	1185	1216	1247
960		1084	1115	1146	1177	1208	1239	1270
980		1105	1137	1168	1199	1230	1262	1293

TABLE I (Cont'd)

ALARM THRESHOLD

B	T							
	n =	4	5	6	7	8	9	10
1000		1126	1158	1190	1221	1253	1285	1316
1200		1339	1373	1408	1442	1477	1512	1546
1400		1550	1587	1624	1662	1699	1737	1774
1600		1760	1800	1840	1880	1920	1960	2000
1800		1970	2012	2055	2097	2139	2182	2224
2000		2179	2224	2268	2313	2358	2402	2447
2200		2388	2435	2481	2528	2575	2622	2669
2400		2596	2645	2694	2743	2792	2841	2890
2600		2804	2855	2906	2957	3008	3059	3110
2800		3012	3065	3117	3170	3223	3276	3329
3000		3219	3274	3329	3383	3438	3493	3548
3200		3426	3483	3539	3596	3653	3709	3766
3400		3633	3692	3750	3808	3866	3925	3983
3600		3840	3900	3960	4020	4080	4140	4200
3800		4047	4108	4170	4232	4293	4355	4416
4000		4253	4316	4379	4443	4506	4569	4632
4200		4459	4524	4589	4654	4718	4783	4848
4400		4665	4732	4798	4864	4931	4997	5063
4600		4871	4939	5007	5075	5143	5210	5278
4800		5077	5146	5216	5285	5354	5424	5493
5000		5283	5354	5424	5495	5566	5636	5707
5200		5488	5561	5633	5705	5777	5849	5921
5400		5694	5767	5841	5914	5988	6061	6135
5600		5899	5974	6049	6124	6199	6273	6348
5800		6105	6181	6257	6333	6409	6485	6562
6000		6310	6387	6465	6542	6620	6697	6775
6200		6515	6594	6672	6751	6830	6909	6987
6400		6720	6800	6880	6960	7040	7120	7200
6600		6925	7006	7087	7169	7250	7331	7412
6800		7130	7212	7295	7377	7460	7542	7625
7000		7335	7418	7502	7586	7669	7753	7837
7200		7539	7624	7709	7794	7879	7964	8049
7400		7744	7830	7916	8002	8088	8174	8260
7600		7949	8036	8123	8210	8297	8385	8472
7800		8153	8242	8330	8418	8507	8595	8683
8000		8358	8447	8537	8626	8716	8805	8894
8200		8562	8653	8743	8834	8924	9015	9106
8400		8767	8858	8950	9042	9133	9225	9317
8600		8971	9064	9156	9249	9342	9435	9527
8800		9175	9269	9363	9457	9550	9644	9738
9000		9379	9474	9569	9664	9759	9854	9949
9200		9584	9680	9775	9871	9967	10063	10159
9400		9788	9885	9982	10079	10176	10273	10370
9600		9992	10090	10188	10286	10384	10482	10580
9800		10196	10295	10394	10493	10592	10691	10790

TABLE II

MAXIMUM PERMISSIBLE BACKGROUND

 $\alpha = 0, \quad P_{\alpha} = 50\%$

B

G	n =	4	5	6	7	8	9	10
100		67	61	55	50	46	42	38
120		83	76	70	64	59	54	50
140		100	92	85	78	72	67	62
160		117	108	100	93	86	80	74
180		134	124	116	107	100	93	87
200		151	141	131	123	114	107	100
220		168	157	147	138	129	121	113
240		186	174	163	153	144	135	127
260		203	191	180	169	159	150	141
280		221	208	196	185	174	165	155
300		238	225	213	201	190	179	170
320		256	242	229	217	205	194	184
340		274	259	246	233	221	210	199
360		292	277	263	249	237	225	214
380		310	294	280	266	253	240	229
400		328	312	297	282	269	256	244
420		346	329	314	299	285	272	259
440		364	347	331	316	301	287	274
460		382	365	348	332	317	303	290
480		400	382	365	349	334	319	305
500		418	400	383	366	350	335	321
520		436	418	400	383	367	351	337
540		455	436	417	400	383	367	352
560		473	454	435	417	400	384	368
580		491	471	452	434	417	400	384
600		510	489	470	451	433	416	400
620		528	507	488	468	450	433	416
640		546	525	505	486	467	449	432
660		565	543	523	503	484	466	448
680		583	562	541	520	501	482	464
700		602	580	558	538	518	499	481
720		620	598	576	555	535	516	497
740		639	616	594	573	552	532	513
760		657	634	612	590	569	549	530
780		676	652	629	607	586	566	546
800		695	671	647	625	603	583	563
820		713	689	665	643	621	600	579
840		732	707	683	660	638	617	596
860		750	725	701	678	655	633	613
880		769	744	719	695	673	650	629
900		788	762	737	713	690	667	646
920		806	780	755	731	707	685	663
940		825	799	773	748	725	702	679
960		844	817	791	766	742	719	696
980		863	835	809	784	760	736	713

TABLE II (Cont'd)

MAXIMUM PERMISSIBLE BACKGROUND				$\alpha = 0, P_{\alpha} = 50\%$			
B							
G	n = 4	5	6	7	8	9	10
1000	881	854	827	802	777	753	730
1200	1069	1039	1009	981	953	926	900
1400	1258	1225	1193	1161	1131	1101	1073
1600	1448	1412	1377	1343	1310	1278	1247
1800	1638	1600	1563	1527	1491	1457	1423
2000	1829	1789	1749	1710	1673	1636	1600
2200	2020	1978	1936	1895	1855	1816	1778
2400	2212	2167	2124	2081	2039	1998	1958
2600	2404	2357	2312	2267	2223	2180	2138
2800	2596	2548	2500	2453	2407	2363	2318
3000	2789	2738	2689	2640	2593	2546	2500
3200	2982	2929	2878	2828	2778	2730	2682
3400	3175	3121	3068	3016	2964	2914	2865
3600	3368	3312	3258	3204	3151	3099	3048
3800	3561	3504	3448	3392	3338	3284	3232
4000	3755	3696	3638	3581	3525	3470	3416
4200	3949	3888	3829	3770	3713	3656	3600
4400	4143	4081	4020	3960	3900	3842	3785
4600	4337	4273	4211	4149	4088	4029	3970
4800	4531	4466	4402	4339	4277	4216	4155
5000	4725	4659	4593	4529	4465	4403	4341
5200	4919	4852	4785	4719	4654	4590	4527
5400	5114	5045	4977	4910	4843	4778	4713
5600	5309	5238	5169	5100	5032	4966	4900
5800	5503	5432	5361	5291	5222	5154	5087
6000	5698	5625	5553	5482	5411	5342	5274
6200	5893	5819	5745	5673	5601	5531	5461
6400	6088	6012	5938	5864	5791	5719	5648
6600	6283	6206	6130	6055	5981	5908	5836
6800	6478	6400	6323	6247	6172	6097	6024
7000	6673	6594	6516	6438	6362	6286	6212
7200	6868	6788	6709	6630	6552	6476	6400
7400	7064	6982	6902	6822	6743	6665	6588
7600	7259	7176	7095	7014	6934	6855	6777
7800	7455	7371	7288	7206	7125	7045	6965
8000	7650	7565	7481	7398	7316	7234	7154
8200	7846	7760	7674	7590	7507	7425	7343
8400	8041	7954	7868	7782	7698	7615	7532
8600	8237	8149	8061	7975	7889	7805	7721
8800	8433	8343	8255	8167	8081	7995	7911
9000	8628	8538	8449	8360	8272	8186	8100
9200	8824	8733	8642	8553	8464	8376	8290
9400	9020	8928	8836	8745	8656	8567	8479
9600	9216	9122	9030	8938	8848	8758	8669
9800	9412	9317	9224	9131	9039	8949	8859

TABLE II (Cont'd)

MAXIMUM PERMISSIBLE BACKGROUND B					$\alpha = 1.3, P_{\alpha} = 90\%$			
G	n =	4	5	6	7	8	9	10
100		57	51	46	42	38	34	31
120		72	65	59	54	49	45	41
140		87	80	73	67	62	57	52
160		103	95	87	81	75	69	64
180		119	110	102	95	88	81	76
200		135	126	117	109	101	94	88
220		151	141	132	123	115	107	100
240		168	157	147	138	129	121	113
260		185	173	163	153	143	135	127
280		201	189	178	168	158	149	140
300		218	206	194	183	172	163	154
320		235	222	210	198	187	177	167
340		252	239	226	214	202	191	181
360		270	255	242	229	217	206	196
380		287	272	258	245	233	221	210
400		304	289	275	261	248	236	224
420		322	306	291	277	263	251	239
440		339	323	308	293	279	266	254
460		357	340	324	309	295	281	268
480		374	357	341	325	311	297	283
500		392	374	357	342	326	312	298
520		409	391	374	358	342	327	313
540		427	409	391	374	358	343	329
560		445	426	408	391	374	359	344
580		463	443	425	407	391	375	359
600		480	461	442	424	407	390	375
620		498	478	459	441	423	406	390
640		516	496	476	457	439	422	406
660		534	513	493	474	456	438	421
680		552	531	511	491	472	454	437
700		570	549	528	508	489	470	453
720		588	566	545	525	505	487	469
740		606	584	562	542	522	503	485
760		624	602	580	559	539	519	500
780		642	619	597	576	555	535	516
800		660	637	614	593	572	552	532
820		679	655	632	610	589	568	549
840		697	673	649	627	605	585	565
860		715	690	667	644	622	601	581
880		733	708	684	661	639	618	597
900		751	726	702	679	656	634	613
920		770	744	720	696	673	651	630
940		788	762	737	713	690	668	646
960		806	780	755	731	707	684	662
980		824	798	773	748	724	701	679

TABLE II (Cont'd)

MAXIMUM PERMISSIBLE BACKGROUND $\alpha = 1.3, P_{\alpha} = 90\%$

G	n =	4	5	6	7	8	9	10
1000		843	816	790	765	741	718	695
1200		1027	997	968	940	913	887	861
1400		1212	1180	1148	1117	1088	1059	1030
1600		1398	1363	1329	1296	1264	1232	1201
1800		1586	1548	1512	1476	1441	1407	1374
2000		1773	1734	1695	1657	1620	1584	1548
2200		1962	1920	1879	1839	1800	1761	1724
2400		2151	2107	2064	2022	1980	1940	1900
2600		2340	2294	2249	2205	2162	2119	2078
2800		2530	2482	2435	2389	2344	2300	2256
3000		2720	2670	2622	2574	2527	2481	2435
3200		2911	2859	2808	2759	2710	2662	2615
3400		3101	3048	2996	2944	2894	2844	2795
3600		3292	3238	3183	3130	3078	3027	2976
3800		3484	3427	3371	3317	3263	3210	3158
4000		3675	3617	3560	3503	3448	3393	3340
4200		3867	3807	3748	3691	3634	3577	3522
4400		4059	3998	3937	3878	3819	3762	3705
4600		4251	4188	4126	4066	4006	3946	3888
4800		4443	4379	4316	4253	4192	4131	4072
5000		4636	4570	4505	4442	4379	4317	4256
5200		4828	4761	4695	4630	4566	4502	4440
5400		5021	4953	4885	4819	4753	4688	4624
5600		5214	5144	5075	5007	4940	4874	4809
5800		5407	5336	5266	5196	5128	5061	4994
6000		5600	5528	5456	5386	5316	5247	5180
6200		5793	5720	5647	5575	5504	5434	5365
6400		5987	5912	5838	5765	5692	5621	5551
6600		6180	6104	6029	5954	5881	5808	5737
6800		6373	6296	6220	6144	6070	5996	5923
7000		6567	6488	6411	6334	6258	6184	6110
7200		6761	6681	6602	6524	6447	6371	6296
7400		6955	6874	6794	6715	6636	6559	6483
7600		7148	7066	6985	6905	6826	6747	6670
7800		7342	7259	7177	7096	7015	6936	6857
8000		7536	7452	7369	7286	7205	7124	7044
8200		7731	7645	7561	7477	7394	7313	7232
8400		7925	7838	7753	7668	7584	7501	7419
8600		8119	8031	7945	7859	7774	7690	7607
8800		8313	8225	8137	8050	7964	7879	7795
9000		8508	8418	8329	8241	8154	8068	7983
9200		8702	8611	8521	8433	8345	8257	8171
9400		8897	8805	8714	8624	8535	8447	8360
9600		9091	8998	8906	8815	8725	8636	8548
9800		9286	9192	9099	9007	8916	8826	8737

APPENDIX A

PROCEDURE FOR TESTING SNM DOORWAY MONITORS FOR FUNCTIONAL PERFORMANCE

Doorway monitors should be tested by employing a test source of the same isotope of SNM the doorway monitor is used to detect as follows:

1. With the detection area unoccupied, measure and record background.
2. Determine alarm threshold T from Table I (see Appendix B).
3. Place a test source in the detection area of the doorway monitor. The test source should be such that the activity in the detection area slightly exceeds the T level.* The doorway monitor should go into an alarm condition if operating properly.
4. Remove test source to its original location and measure background once again. If the measurement of

*The test source may be improvised by partially shielding the calibration source.

background taken immediately after the test varies by more than $2\sqrt{B}$ from the background taken before the test, the test should be repeated, for such a difference indicates nonrandom fluctuations of the background or equipment malfunction. The probability of such an occurrence due to the randomness of the background is less than 8%.

5. A calibration source (Appendix B) should be carried repeatedly to various places within the detection area of the doorway monitor in simulation of actual use to verify that the SNM can be detected everywhere within the detection area and to assure proper operation of treadle pads, beam-break, or similar devices if the doorway monitor is so equipped.

6. Doorway monitors used to search for concealed uranium-233 should be tested with each uranium purification run, but no more frequently than daily. The test source should be freshly purified uranium-233 (within four hours of removal of decay products).

APPENDIX B

PROCEDURE FOR DETERMINING MAXIMUM PERMISSIBLE BACKGROUND

Background should be measured over several workshifts to determine the setpoints for alarm threshold (with or without automatic background updating) to assure that normal operation will be minimally affected by alarms due to high background.

The doorway monitor should be calibrated with the amount of the appropriate isotope specified in Regulatory Positions C.1.b(1), (2), or (3) of this guide (e.g., 0.5 gram plutonium-239 in 3 mm of brass).

The calibration procedure described below is essentially a means of determining maximum permissible background for effective operation of the doorway monitor.

1. Place a calibration source variously about the detection area and take readings to determine the least sensitive point. This location of minimum sensitivity should be maintained as the calibration point.

2. Measure background over several workshifts to determine the periods of high background and the range of background. A minimum of 20 measurements should be taken. The variance of the background is given by

$$\text{Var } B = \frac{1}{N-1} \sum_{i=1}^N (B_i - B)^2 \quad (1)$$

where N is the number of measurements, B is the mean of the background measurements, and B_i is the i^{th} background measurement.

3. With the calibration source at the calibration point, the mean gross counts G should be determined during a period of high background to establish the upper operating range of the doorway monitor. Table II lists various maximum permissible background levels for a given value of G for values of the parameters n and α . During periods when the background exceeds the value

found from Table II, the sensitivity of the doorway monitor will generally be below that specified as minimum in Regulatory Position C.1.b of this guide.

The parameter n is a function of the background variation and the permissible false alarm rate and is calculated from

$$n \geq 3.1 \left(\frac{\text{Var } B}{B} \right)^{1/2} \quad (2)$$

Generally, n is taken as an integer. If n satisfies the above expression, the expected false alarm rate (Appendix C) due to background fluctuations should be less than 0.1%. Larger values of n will decrease the expected false alarm rate; however, the maximum allowable background for a given G will also decrease.

4. For doorway monitors equipped with automatic background updating systems, the alarm threshold is

$$\text{Counts} > B + n\sqrt{B}, \quad (3)$$

where n should be derived from expression (2), and the instrument set accordingly.

5. The high-background alarm should be set at the B value given in Table II for the measured G and calculated n values.

6. For doorway monitors not equipped with an automatic background update, the value of n determined above should be employed in the use of the doorway monitor according to Regulatory Position C.2.a.

*The false alarm rate is estimated by the probability that an observation of a quantity distributed normally about some value X will exceed X by $n(\text{Std. deviation of } X)$. The factor 3.1 limits the false alarm rate to 0.1%, while the factor $(\text{Var } B/B)^{1/2}$ compensates for observed deviations in the background distribution from Poisson.

APPENDIX C

DETECTION CONFIDENCE LIMITS, THRESHOLDS, AND MAXIMUM PERMISSIBLE BACKGROUND

With a calibration source at the calibration point, the condition for an alarm is, in general,

$$g > T = B + m\sqrt{\text{Var } B} \quad (1)$$

where g is a single measurement of G (the mean radiation level with the source), B is the mean background, and m is some multiplier. The detection confidence limit is the probability that with the calibration source at the calibration point, any single determination of G will exceed a threshold T , i.e., the above inequality will be satisfied. For any given probability P_α , there exists a value α such that

$$g > G - \alpha\sqrt{\text{Var } G} \quad (2)$$

with a probability of P_α , where g is any single measurement of the quantity G . Hence the condition for a detection confidence limit of P_α is

$$G - \alpha\sqrt{\text{Var } G} > T = B + m\sqrt{\text{Var } B}. \quad (3)$$

For a given value of G , solving (3) gives the maximum permissible B at which the doorway monitor will detect the source with a confidence P_α . For $P_\alpha = 90\%$, $\alpha = 1.3$, and for $P_\alpha = 50\%$, $\alpha = 0$.

The condition for a false alarm* is written as

$$b = B + \beta\sqrt{\text{Var } B} > T \quad (4)$$

where b is a single measurement without the source and β is a number corresponding to a false alarm probability P_β . For $P_\beta = 0.1\%$, $\beta = 3.1$. Hence the necessary condition for maintaining a false alarm rate below P_β is

$$b = B + \beta\sqrt{\text{Var } B} < B + m\sqrt{\text{Var } B}. \quad (5)$$

However, the doorway monitor actually compares b with $B + n\sqrt{B}$, hence the condition on n becomes

$$\beta\sqrt{\text{Var } B} < m\sqrt{\text{Var } B} = n\sqrt{B} \quad (6)$$

or

$$n > \beta \left(\frac{\text{Var } B}{B} \right)^{1/2} \quad (7)$$

In Table I threshold values of T were determined by substituting equation (6) into equation (3):

$$T = B + n\sqrt{B}$$

The values of B in Table II were then calculated for $\alpha = 1.3$ and $\alpha = 0$ from equation (3) assuming that, for the determination of G , the background should be reasonably stable and therefore $\sqrt{\text{Var } G} \sim \sqrt{G}$.

*False alarm means an alarm condition generated by statistical fluctuations in the background radiation or by instabilities of the electronics which appear as background fluctuations when the detection area is occupied.