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NEVADA TEST SITE

February — May 1955

Project 39.1

GAMMA- AND NEUTRON-RADIATION MEASUREMENTS

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Report to the Test Director

GAMMA- AND NEUTRON-RADIATION MEASUREMENTS

By

L. J. Deal

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Division of Biology and Medicine
U. S. Atomic Energy Commission
Washington, D. C.
May 1957

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ABSTRACT

(Supp. to JTR 1174)

This report contains the results from film dosimeters and gold and sulfur threshold detectors used to measure gamma radiation and neutron fluxes. The bulk of the data reports the results of measurements in various shelters and homes. The data are presented in tabular form by project number and shot name in Appendix A. >

> The report also contains results of cooperative studies with Projects 39.6 and 39.7 on the effects of neutrons on film dosimeters. The data from Wasp, Hornet, Moth, Bee, and Wasp Prime shots were in regions where the neutron fluxes were sufficient to cause effects on the film that cannot be explained at this time; hence the film results will not necessarily be in agreement with other systems of gamma-radiation measurement. >

> Appendix B contains a discussion of the advances in mass processing of films as developed by Edgerton, Germeshausen & Grier; and Appendix C contains the results of certain calibrations and laboratory studies carried out by the National Bureau of Standards. (10 71)

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PREFACE

Previous experience has demonstrated that certain functions, such as radiation measurements, are common to many projects and can be coordinated through a central pool of instruments. Because of the varied nature of the Civil Effects Test Group programs, lack of experience on the part of many of its project people in handling radiation, and the specialized nature of radiation measurements, such devices as film dosimeters and gold and sulfur threshold detectors were made available through a single project. This report contains the results of these measurements; it also reports the raw data of certain other inconclusive experiments on neutron effects on film dosimeters.

The gamma and neutron data reported here are essential to round out the studies of the many Civil Effects Test Group projects that are concerned with the effects of nuclear explosions on structures, foodstuffs, drugs, and other items.

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ACKNOWLEDGMENTS

The successful conclusion of this project could not have occurred without the assistance of all Civil Effects Test Group project personnel who made use of the film dosimeters and neutron detectors. The author gratefully acknowledges this assistance. This project could not have made neutron detectors available on such a broad scale without the splendid cooperation of T. D. Hanscomb of the Naval Research Laboratory. Also the Evans Signal Laboratory Group and Ross Larraic gave invaluable assistance by providing Co⁶⁰ calibration films for test runs.

Special credit is due C. Wyckoff of Edgerton, Germeshausen & Grier, who was responsible for devising a mass-production procedure for processing and reading the films and supplying results in record time. Also the cooperation of Margarete Ehrlich and H. O. Wyckoff of the National Bureau of Standards was essential to providing standard calibrations; without their assistance the final results would be far less meaningful.

Many other persons assisted in the performance of this project, and among those who deserve special noting are

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CHAPTER 1

OBJECTIVES

The objectives of Project 39.1 were to ensure that the various Civil Effects Test Group (CETG) projects were able to obtain and document adequate radiation measurements in an economical and coordinated manner. These data were essential to the completion of many of the project studies that were concerned with the effects of nuclear explosions on items varying from foodstuffs to structures.

In addition to the strictly service functions of supplying data to others, this project carried out studies on the performance of film dosimeters in high gamma and high neutron fluxes. The results of these studies demonstrated that much was still to be learned about the measurement of gamma doses from atomic weapons. The experience and data are believed to be of great value in the planning of future studies.

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CHAPTER 2

BACKGROUND

2.1 NEED FOR COORDINATED RADIATION-MEASUREMENT PROGRAM

Prior to Operation Upshot-Knothole, weapon effects tests were limited primarily to essential studies of a military nature; however, during that test series full-scale civil effects tests that were aimed at providing data for use in civil defense planning were performed.

One of the major problems facing civil defense is protection against radiation; therefore, to be complete, any studies of a civil defense nature must have data on the radiation dose. Since many of the project personnel for Operation Teapot were not familiar with the complexities of measuring radiation and since experience during Operation Upshot-Knothole had emphasized the need for a coordinated program of radiation measurement, this project was established to supply radiation measurements and to coordinate the results of such measurements.

These data are necessary in order to allow an over-all evaluation of the effects of atomic weapons on such varied items as foodstuffs, drugs, automobiles, and shelters. Because radiation data were needed by almost every CETG project, it was only prudent that one project be made responsible for providing such data on a coordinated basis.

2.2 NEUTRON MEASUREMENTS

Neutron-flux measurements were made with gold and sulfur threshold detectors. These are not dosimeters; however, they provide a satisfactory index of the number of neutrons per square centimeter for energy regions up to 4 ev and above 3 Mev. The neutron measurements reported here were furnished to Project 39.1 through the courtesy of the Naval Research Laboratory (NRL), Washington, D. C.

2.3 GAMMA MEASUREMENTS

Film dosimeters have been used for obtaining a large number of measurements of prompt-gamma dose from nuclear explosions. The dosimeters used for Operation Teapot, with the exception of the film holders, which were modified, were the types developed by the National Bureau of Standards (NBS) for Operation Greenhouse. These dosimeters are fully described in Report WT-81.

2.4 SPECIAL STUDIES ON EFFECTS OF NEUTRONS ON FILM DOSIMETERS

The work at Operation Greenhouse showed that, in the region where the neutron dose is low compared to the gamma dose (of the order of 10^9 to 10^{10} neutrons/cm²), the effects of neutrons on film dosimeters are not significant. During Operation Upshot-Knothole film dosimeters were placed inside 7-in. lead hemispheres, where the ratio of neutron to gamma

dose is quite high. The results obtained were not consistent with expected gamma doses and were not in agreement with biological determinations of gamma dose. During Operation Teapot it was planned to study this further to see if additional data that would add to a better understanding of the problem could be obtained. Field experiments are necessary because in the laboratory it has not been possible to obtain neutron fluxes high enough to cause significant effects on the film.

2.5 REFINEMENTS IN FILM DOSIMETRY

Prior to Operation Teapot all film processing and reading had been carried out by the methods and procedures developed for Operation Greenhouse (Report WT-81). During the early planning phases of Operation Teapot, it became evident, from the large number of dosimeters required, that some system would have to be provided for the mass handling of film during processing and reading. It was recognized that the processing methods, although standard for x-ray film, were subject to refinements. These refinements in processing techniques, handling of film, etc., are described in Appendix B, and the results are described in Chap. 4. This phase of the project was done by Edgerton, Germeshausen and Grier, Inc. (EG&G).

CHAPTER 3

OPERATIONS

3.1 ADVANCE DETERMINATION OF REQUIREMENTS

In order to make advance plans for the instrument requirements of the CETG, a canvass of projects was made in the fall of 1954. The results of this study provided information that was invaluable in the planning of the over-all instrument requirements.

3.2 INSTRUMENT SUPPLY

Arrangements were made with EG&G to reengineer and procure the film-dosimeter holders to specifications provided by NBS. These film-dosimeter holders are fully described in Report WT-81 and in Appendix B. Through the courtesy of NRL the gold and sulfur requirements were supplied out of the detectors procured for the Military Effects Test Group.

3.3 DISPENSING AND COLLECTING INSTRUMENTS

Supplies of dosimeters were maintained in the CETG quonset area for use by the various projects. With the exception of the studies made by Projects 39.1 and 39.7 on scattering experiments, all placement and recovery of dosimeters and neutron detectors was handled entirely by the project using the instruments; therefore, results reported by location are in terms of the location specified by the using project.

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CHAPTER 4

DISCUSSION

4.1 NEUTRON-FLUX DATA

The results of the neutron measurements with gold and sulfur threshold detectors are shown in Tables 4.1 and 4.2. These data were furnished through the cooperation and courtesy of NRL of the Military Effects Test Group. The detectors used are fully described in Report WT-1116 on Project 2.2.

4.2 GAMMA MEASUREMENTS

The gamma measurements reported here are the results of the film-dosimeter readings supplied by EG&G. In regions where the neutron fluxes were of the order of 10^9 to 10^{10} neutrons/cm², there is substantial disagreement between the results of film dosimeters and chemical dosimeters. The results of field tests on Operation Teapot did not provide sufficient information to resolve this discrepancy. Subsequent laboratory studies have explained some of the anomalies observed.

The contribution of EG&G to the project is described in Appendix B; it should be noted that this work represents a major endeavor in film dosimetry. An evaluation of the radiation doses as given in Appendix C indicates that the over-all error in dose interpretation is ± 30 per cent.

The useful range of the dosimeter is from 0.1 to 70,000 r, provided there is no significant neutron contribution, as mentioned previously. For practical purposes the range of the dosimeter under conditions of Operation Teapot was from 0.1 to 5,000 r, except in cases in which the dosimeters were used in areas where the neutron-gamma ratio was considerably increased, i.e., in lead hemispheres.

Table 4.1 — APPLE I NEUTRON MEASUREMENTS

Gold		Sulfur	
Sample No.	Flux (integrated), neutrons/cm ²	Sample No.	Flux (integrated), neutrons/cm ²
500	6.75×10^{12}	367	2.64×10^{11}
501	9.35×10^{12}	368	1.71×10^{11}
502	2.12×10^{12}	369	5.61×10^{10}
503	9.76×10^{12}	370	3.22×10^{11}
504	1.15×10^{13}	371	3.41×10^{11}
505	6.87×10^{12}	372	2.18×10^{11}
506	1.15×10^{13}	373	2.28×10^{11}
507	1.07×10^{13}	374	2.02×10^{11}
508	1.72×10^{13}	375	3.62×10^{11}
509	7.59×10^{12}	376	1.55×10^{11}
510	5.58×10^{10}	377	2.02×10^9
511	5.54×10^{10}	378	2.77×10^9
512	4.92×10^{10}	379	1.64×10^9
513	3.15×10^{10}	380	1.74×10^9
514	4.34×10^{10}	381	2.19×10^9
515	5.57×10^{10}	382	2.17×10^9
516	9.21×10^{10}	383	3.74×10^9
517	9.82×10^{10}	384	3.14×10^9
518	3.40×10^{13}	385	6.90×10^{11}
519	2.25×10^{13}	386	3.06×10^{11}
		389	7.08×10^8
		390	1.72×10^8

Table 4.2—APPLE II NEUTRON MEASUREMENTS

Sample No.	Flux (integrated), neutrons/cm ²	Sample No.	Flux (integrated), neutrons/cm ²
Sulfur			
123	8.26×10^8	157	4.01×10^8
124	6.75×10^7	158	5.43×10^{10}
125	3.55×10^{11}	159	4.36×10^{10}
126	2.99×10^{11}	160	1.30×10^{11}
127	7.72×10^9	161	1.41×10^{10}
128	3.28×10^{11}	162	3.47×10^{11}
129	5.25×10^{11}	163	2.39×10^8
130	3.02×10^{11}	164	1.44×10^8
131	3.63×10^{11}	165	1.96×10^{11}
132	4.81×10^{11}	166	7.39×10^{10}
133	1.90×10^8	167	1.04×10^{11}
134	1.55×10^{10}	168	6.78×10^{10}
135	9.55×10^8	169	3.60×10^{10}
136	4.08×10^9	170	2.26×10^{10}
137	1.03×10^{11}	171	5.88×10^{10}
138	4.69×10^{10}	172	1.43×10^{11}
139	5.37×10^{10}	173	1.05×10^{11}
140	1.36×10^{10}	174	3.71×10^{10}
141	2.77×10^{10}	175	4.05×10^{10}
142*	2×10^6	176	5.83×10^{10}
143	6.35×10^{11}	178	3.25×10^{10}
144*	2×10^6	179	2.06×10^{10}
145	6.43×10^{11}	180	4.31×10^7
146	6.07×10^{11}	181	5.03×10^9
147	3.23×10^{11}	182	5.42×10^{10}
148	7.14×10^{11}	183	2.77×10^{10}
149	1.96×10^{11}	184	1.63×10^{10}
150	2.94×10^7	185	1.02×10^{10}
151	5.72×10^{10}	186	4.99×10^9
152	1.62×10^9	187	3.47×10^9
153	9.71×10^{10}	188	2.10×10^9
154*	2×10^6	189	1.24×10^9
155	1.92×10^{10}	190	7.18×10^8
156	3.76×10^{10}	191	4.08×10^8
Gold			
247	1.09×10^{10}	263	2.62×10^{12}
249	1.78×10^{13}	264	5.05×10^{11}
250	1.24×10^{13}	265	1.89×10^{13}
251	7.03×10^{11}	266	8.85×10^8
252	1.48×10^{13}	267	2.21×10^{13}
253	1.67×10^{13}	268	2.75×10^{13}
254	1.45×10^{13}	269	2.45×10^{13}
255	1.64×10^{13}	270	5.02×10^{13}
256	1.72×10^{13}	271	5.50×10^{13}
257	2.75×10^9	272	4.99×10^{13}
258	1.51×10^{12}	273	2.98×10^8
259	3.46×10^{10}	274	1.18×10^{12}
260	1.01×10^{11}	275	3.05×10^9
261	5.25×10^{12}	277	2.02×10^{12}
262	5.16×10^{12}	279	1.03×10^{11}

*Sample had no significant activity above background.

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Table 4.2—(Continued)

Sample No.	Flux (integrated), neutrons/cm ²	Sample No.	Flux (integrated), neutrons/cm ²
Gold (Continued)			
280	2.00×10^{12}	312	2.33×10^8
281	1.92×10^{11}	313	5.98×10^{11}
282	1.23×10^{12}	314	3.31×10^{11}
283	2.01×10^{12}	315	1.78×10^{11}
284	4.20×10^{12}	316	9.02×10^{10}
287	1.29×10^{12}	317	4.86×10^{10}
288	3.30×10^9	318	3.09×10^{10}
289	1.76×10^{11}	319	1.85×10^{10}
290	3.47×10^{12}	320	1.11×10^{10}
293	6.39×10^{12}	321	5.86×10^9
294	1.40×10^{12}	322	2.72×10^9
295	8.47×10^{11}	323	1.42×10^9
296	3.97×10^{11}	324	8.76×10^8
297	3.63×10^{11}	325	7.75×10^8
298	8.97×10^{11}	326	1.16×10^{12}
299	5.71×10^{11}	327	5.28×10^{11}
300	1.25×10^{12}	328	5.74×10^{11}
301	3.50×10^{12}	329	1.65×10^{11}
302	3.57×10^{12}	330	1.14×10^{11}
303	1.77×10^{12}	331	9.34×10^{10}
304	2.92×10^{12}	332	4.92×10^{10}
305	1.54×10^{12}	333	3.24×10^{10}
306	7.17×10^{11}	334	1.54×10^{10}
307	5.23×10^{11}	335	9.28×10^9
308	1.11×10^{11}	336	5.37×10^9
309	3.02×10^{11}	337	3.37×10^9
310	1.01×10^{12}	338	2.25×10^9
311	8.56×10^{11}	525	1.64×10^{11}

CHAPTER 5

RESULTS AND CONCLUSIONS

5.1 RESULTS

The results of the film-dosimeter readings at the various locations are presented in Appendix A. All dose readings are reported in roentgens.

5.2 CONCLUSIONS

The broad initial objectives of the project were met. Necessary radiation measuring devices were provided from a central pool for use by the various CETG projects.

The neutron effects on film dosimeters were studied. The results are not conclusive; they indicate that more work must be done before the extent of this effect can be determined. There is a need for additional laboratory studies and field tests.

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APPENDIX A

FILM-DOSIMETER READINGS

Table A.1 — SHOT WASP, PROJECT 39.6: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1	820	41071	500
		41072	490
2	907	41073	330
		41074	330
3	997	41075	220
		41076	220
4	1087	41077	140
		41078	140
5	1184	41079	85
		41080	85
6	1275	41081	55
		41082	55
7	1366	41083	40
		41084	40
8	1464	41085	25
		41086	25
9	1560	41087	17
		41088	16
10	1654	41089	11
		41090	12

Table A.2—SHOT WASP, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE ALUMINUM HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1b	310	41367	30,000
2b	400	41368	16,500
3b	475	41369	5,350
4b	530	41370	2,750
5b	645	41371	980
6b	810	41372	470
7b	950	41010	240
8b	1,065	41011	130
9b	1,115	41012	100
10b	1,160	41013	90
11b	1,205	41014	65
12b	1,260	41015	50
13b	1,305	41016	40
14b	1,360	41017	30
15b	1,405	41018	25
Lithium-coated dosimeters			
1b	310	41383	25,000
4b	530	41384	2,600
6b	810	41385	420
11b	1,205	41029	55
15b	1,405	41030	30

Table A.3—SHOT WASP, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE LEAD HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1a	310	41361	10,900
2a	390	41362	1,600
3a	440	41363	830
4a	495	41364	560
5a	640	41365	230
6a	760	41366	140
7a	875	41001	65
8a	985	41002	35
9a	1,015	41003	25
10a	1,070	41004	20
11a	1,100	41005	16
12a	1,150	41006	13
13a	1,190	41007	12
14a	1,225	41008	7.5
15a	1,270	41009	7.5

Table A.4—SHOT WASP, PROJECT 39.7: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1c	310	41373	29,000
		41374	30,000
2c	370	41375	15,000
		41376	15,000
3c	515	41377	3,000
		41378	3,200
4c	650	41379	1,150
		41380	1,100
5c	755	41381	570
		41382	570
6c	855	41019	400
		41020	400
7c	955	41021	250
		41022	250
8c	1,060	41023	140
		41024	140
9c	1,155	41025	100
		41026	90
10c	1,250	41027	60
		41028	60

Table A.5—SHOT WASP, PROJECTS 39.1 AND 39.7: FILM-DOSIMETER READINGS
AT VARIOUS LOCATIONS ABOVE AND BELOW GROUND

Station No.	Slant distance, yd	Dose with respect to ground level, r					
		+3 ft	+2 ft	+1 ft	0	-1 ft	-2 ft
1c	310					3,600	570
2c	370		28,000	28,000	28,000	8,200	650
3c	515	9,400	9,000	9,500	9,500	3,400	3,400
4c	650	6,000	6,000	7,500	7,500	300	60
5c	755	5,000	4,000	1,020	5,000	230	45
6c	855	380	380	370	380	100	19
7c	955	230	250	230	230	40	7
8c	1,060	150	150	150	135	30	5
9c	1,155	85	90	85	85	28	5
10c	1,250	55	55	55	55	18	4

Table A.6—SHOT MOTH, PROJECT 39.6: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1	413	44323	Not recovered
		44324	Not recovered
3	609	44325	Not recovered
		44326	Not recovered
4	706	41251	740
		41252	730
5	804	41253	440
		41254	440
6	906	41255	260
		41256	260
7	1005	41257	190
		41258	190
8	1104	41259	100
		41260	90
9	1203	41261	70
		41262	70
10	1303	41263	50
		41264	50
11	1402	41265	35
		41266	35
12	1500	41267	Not recovered
		41268	Not recovered
13	1600	41269	10
		41270	10

Table A.7—SHOT MOTH, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE ALUMINUM HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1b	280	41577	65,000
2b	345	41578	27,000
3b	420	41579	14,500
4b	500	41580	3,600
5b	560	41581	1,900
6b	685	41582	770
7b	805	41190	470
8b	645	41191	220
9b	995	41192	180
10b	1,050	41193	170
11b	1,110	41194	130
12b	1,180	41195	70
13b	1,240	41196	55
14b	1,300	41197	45
15b	1,370	41198	17
Lithium-coated dosimeters			
1b	280	41594	52,000
4b	500	41595	2,600
6b	685	41597	750
11b	1,110	41209	70
15b	1,370	41210	30

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Table A.8—SHOT MOTH, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE LEAD HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1a	255	41571	
2a	305	41572	5300
3a	375	41573	1390
4a	450	41574	770
5a	530	41575	380
6a	640	41576	190
7a	755	41181	90
8a	875	41182	45
9a	925	41183	30
10a	975	41184	20
11a	1020	41185	12
12a	1070	41186	8
13a	1120	41187	6
14a	1180	41188	4
15a	1245	41189	3.5

Table A.9—SHOT MOTH, PROJECTS 39.1 AND 39.7: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1c	255	41583	44,000
		41584	42,000
2c	365	41585	15,000
		41586	16,000
3c	480	41588	4,600
		41589	4,750
4c	600	41590	1,350
		41591	1,400
5c	715	41592	700
		41593	670
6c	835	41199	390
		41200	390
7c	955	41201	230
		41202	230
8c	1,070	41203	130
		41204	130
9c	1,190	41205	55
		41206	55
10c	1,310	41217	40
		41208	40

Table A.10—SHOT MOTH, PROJECTS 39.1 AND 39.7: FILM-DOSIMETER READINGS
AT VARIOUS LOCATIONS ABOVE AND BELOW GROUND

Station No.	Slant distance, yd	Dose with respect to ground level, r					
		+3 ft	+2 ft	+1 ft	0	-1 ft	-2 ft
1c	255						
2c	365	21,000	21,000	20,000	20,000	4,000	515
3c	480	4,650	4,400	5,000	46,000	660	130
4c	600	1,400	1,350	1,450	1,300	230	35
5c	715	625	630	650	640	140	25
6c	835	340	370	350	360	60	8.5
7c	855	220	210	210	45	8.5	2.5
8c	1,070	100	110	110	60	7.5	1.8
9c	1,190	65	70	65	65	7.5	1.7
10c	1,310						

Table A.11—SHOT TESLA, PROJECT 39.6: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1	600	41246	4750
		41241	4550
2	715	41298	2250
		41249	2150
3	830	41250	1000
		41271	1050
4	980	41272	500
		41273	500
5	1060	41274	330
		41275	330
6	1140	41276	230
		41277	200
7	1225	41278	160
		41279	170
8	1313	41280	95
		41281	90
9	1400	41282	70
		41283	70
10	1490	41284	50
		41285	50
11	1581	41286	35
		41287	35
12	1672	41288	25
		41289	25
13	1768	41290	14.5
		41291	14.5
14	1850	41292	9.8
		41293	9.8
15	1140	41294	6.7
		41295	6.7

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Table A.12—SHOT HORNET, PROJECT 39.6: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1	510	44380	8400
		44381	7600
2	609	44382	2750
		44383	2500
3	706	41464	1075
		41465	1075
4	804	41466	710
		41467	710
5	903	41468	450
		41469	450
6	1002	41470	275
		41471	275
7	1102	41472	255
		41473	255
8	1200	41474	110
		41475	110
9	1300	41476	75
		41477	75
10	1400	41478	50
		41479	50
11	1500	41480	35
		41511	35
12	1600	41512	25
		41513	25
13	1700	41514	15
		41515	15

Table A.13—SHOT HORNET, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE ALUMINUM HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1b	1,370	41320	Too high to read
2b	1,300	41319	75
3b	1,240	41318	110
4b	1,180	41317	120
5b	1,110	41316	210
6b	1,050	41315	230
7b	995	41314	260
8b	945	41313	420
9b	805	41312	800
10b	685	41311	1,200
11b	560	44350	11,000
12b	500	44349	13,000
13b	420	44348	28,000
14b	345	44347	13,000
15b	280	44346	65

Table A.14—SHOT HORNET, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE LEAD HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1a	1,245	41310	5.5
2a	1,180	41309	6
3a	1,120	41308	12
4a	1,070	41307	20
5a	1,020	41306	30
6a	975	41305	45
7a	925	41304	70
8a	875	41303	90
9a	755	41302	170
10a	640	41301	300
11a	530	44345	800
12a	450	44344	1,450
13a	375	44343	370
14a	305	44342	12,000
15a	255	44341	36,000

Table A.15—SHOT HORNET, PROJECT 39.7: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1x	270	41330	
		41329	
2x	365	41328	
		41327	
3x	480	41326	
		41325	14,000
4x	600	41324	3,100
		41323	3,150
5x	715	41322	1,200
		41321	1,200
6x	835	44360	1,150
		44359	1,150
7x	955	44358	600
		44357	600
8x	1,090	44356	370
		44355	370
9x	1,210	44354	210
		44353	220
10x	1,330	44352	120
		44351	120

Table A.16—SHOT HORNET, PROJECTS 39.1 AND 39.7: FILM-DOSIMETER READINGS
AT VARIOUS LOCATIONS ABOVE AND BELOW GROUND

Station No.	Slant distance, yd	Dose with respect to ground level, r					
		+3 ft	+2 ft	+1 ft	0	-1 ft	-2 ft
1x	270		190,000	180,000	110,000	24,000	
2x	365	52,000	50,000	50,000	36,000	2,300	380
3x	480	24,000	17,000	17,000	12,000	550	110
4x	600	5,100	5,200	4,050	3,000	460	85
5x	715	1,300	1,500	1,450	1,380	210	30
6x	835	640	640	640	670	130	20
7x	955	340	360	340	340	70	6.5
8x	1,090	190	190	190	180	15	3
9x	1,210	95	95	95	95	8	1.7
10x	1,330	60	60	60	60	60	7

Table A.17—SHOT BEE, PROJECT 39.6: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1	1013	45406	640
		45407	640
2	1113	45408	400
		45409	400
3	1210	42062	250
		42063	250
4	1310	42064	170
		42065	170
5	1410	42066	90
		42067	85
6	1509	42068	65
		42069	65
7	1609	42070	45
		42071	45
8	1708	42072	30
		42073	30
9	1808	42074	25
		42075	25
10	1908	42076	12
		42077	12
11	2008	42078	8.3
		42079	8.3
12	2100	42080	6.1
		42081	6.1
14	2300	42082	3.3
		42083	3.3
16	2500	42084	4.1
		42085	1.6
21	3000	42086	0.58
		42087	0.58

Table A.18—SHOT BEE, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE ALUMINUM HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1b	1,810	42043	20
2b	1,730	42042	30
3b	1,660	42041	40
4b	1,390	42040	50
5b	1,310	42039	60
6b	1,430	42038	100
7b	1,360	42037	140
8b	1,310	42036	180
9b	1,150	42035	330
10b	1,015	42034	360
11b	895	45390	1,130
12b	795	45389	1,650
13b	710	45388	3,800
14b	625	45387	10,500
15b	550	45386	20,000

Table A.19—SHOT BEE, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE LEAD HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1a	1550	42033	3
2a	1490	42032	3.6
3a	1430	42031	4.5
4a	1380	42030	14
5a	1330	42029	18
6a	1270	42028	35
7a	1220	42027	45
8a	1160	42026	65
9a	1040	42025	120
10a	925	42024	220
11a	805	45385	490
12a	730	45384	720
13a	645	45383	1080
14a	570	45382	1800
15a	490	45381	3600

Table A.20—SHOT BEE, PROJECT 39.7: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1c	1550	42044	65
		42045	55
2c	1430	42046	85
		42047	90
3c	1310	42048	170
		42049	170
4c	1190	42050	270
		42051	270
5c	1070	42052	470
		42053	440
6c	955	45391	850
		45392	870
7c	835	45393	1550
		45394	1700
8c	920	45395	3250
		45396	3050
9c	605	45397	
		45398	
10c	490	45399	
		45400	

Table A.21—SHOT BEE, PROJECTS 39.1 AND 39.7: FILM-DOSIMETER READINGS
AT VARIOUS LOCATIONS ABOVE AND BELOW GROUND

Station No.	Slant distance, yd	Dose with respect to ground level, r					
		+3 ft	+2 ft	+1 ft	0	-1 ft	-2 ft
10c	1,550		34,000	30,000	32,000	14,000	1,070
9c	1,430	15,000	15,000	15,000	16,000	2,900	500
8c	1,310	8,800	8,000	4,000	3,800	700	120
7c	1,190	1,700	1,650	1,700	1,100	230	10
6c	1,070	830	830	840	750	170	10
5c	955	430	440	440	410	100	7.5
4c	835	240	240	240	200	9	3.3
3c	720	160	170	160	160	8.8	3.0
2c	605	85	80	85	85	6.6	1.5
1c	490	10	11	10	11	4.7	1.4

Table A.22—SHOT APPLE I, PROGRAM 32: FILM-DOSIMETER READINGS

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
Station A at 1100 Ft		41161	180
41558	28,000	41159	95
41559	26,000	41162	230
41560	5,000	41164	120
41561	33,000	41165	210
41562	60,000	41163	270
41563	24,000	Station C at 5280 Ft	
41564	40,000	41177	70
41565	33,000	41178	50
41566	35,000	41179	70
Station B at 3600 Ft		41180	35
41567	90	41171	50
41154	65	41172	25
41568	110	41173	15
41155	90	41174	60
41569	130	41175	30
41156	110	41176	30
41160	190	41167	35
41570	140	41169	50
41151	120	41170	50
41158	130	41168	55

Table A.23—SHOT APPLE I, PROJECT 34.1: FILM-DOSIMETER READINGS

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
In Shelter b-1		41110	60
41557	5,300	41109	60
41556	5,750	41108	45
41555	17,900	41107	95
41554	27,500	41106	95
41553	15,000	41105	130
41552	26,500	41545	450
41120	20	41544	350
41119	20	41543	440
41118	20	41542	500
41117	25	In Shelter b-3	
41116	25	41541	7,750
41115	30	41420	6,500
41114	50	41104	60
41113	60	41103	70
41551	130	41102	70
41550	160	41101	85
41549	230	41100	95
41548	240	41099	120
In Shelter b-2		41098	150
41547	6,900	41097	220
41546	6,550	41419	310
41112	50	41418	390
41111	50	41417	560
		41416	580

Table A.24—SHOT APPLE I, PROJECT 34.3: FILM-DOSIMETER READINGS

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
In Shelter a-1		41409	3470
41415	7800	41408	290
41414	8500	41407	330
41413	1000	41406	330
41412	1230	41096	5
41153	30	41095	4.5
41152	30	41094	5.5
41151	5	41093	50
41150	5	41092	35
41149	4.1	41136	6
41148	4.4	41135	6.5
41147	0.4	41134	7.5
41146	0.4	41133	7.5
41145	0.26	41132	55
41144	0.26	41131	35
41143	0.54	41130	35
41142	0.32	41129	320
41141	0.34	41128	350
41140	0.34	41127	340
41139	0.45	41126	100
41138	0.45	41125	100
41137	0.62	41124	140
In Shelter b-1		41123	25
41411	5850	41122	30
41410	1700	41121	25

Table A.25—SHOT APPLE I, PROJECTS 39.1 AND 39.6: FILM-DOSIMETER READINGS AT VARIOUS LOCATIONS ABOVE GROUND

Station No.	Slant distance, yd	Dose with respect to ground level, r			
		+3 ft	+2 ft	+1 ft	0
1	1013	800	720	770	800
3	1210	350	340	350	350
5	1404	180	170	170	180
7	1600	65	65	65	70
8	1700	50	45	50	50
10	1900	19.8	19.5	19.8	25
11	2000	15.3	14.1	14.9	15.4
15	2400	10.9	10.3	10.8	12.3
17	2600	1.5	1.5	1.5	1.5
19	2800	1.2	1.2	1.2	1.2
20	2900		0.85	1.2	0.85
21	3000	0.70	0.68	0.74	0.70

Table A.26—SHOT WASP PRIME, PROJECT 39.6: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
3	740	42441	1200
		42442	1250
4	836	42443	800
		42444	780
5	933	42445	560
		42446	560
6	1032	42447	380
		42448	340
7	1127	42449	240
		42450	240
8	1225	42451	140
		42452	140
9	1313	42453	90
		42454	90
10	1409	42455	65
		42456	65
11	1500	42457	40
		42458	40
12	1600	42459	20
		42460	20

Table A.27—SHOT WASP PRIME, PROJECTS 39.1 AND 39.6: FILM-DOSIMETER READINGS
AT VARIOUS LOCATIONS ABOVE GROUND

Station No.	Slant distance, yd	Dose with respect to ground level, r			
		+3 ft	+2 ft	+1 ft	0
3	740	1250	1250	1300	1300
4	836	800	850	850	850
5	933	380	560	560	775
6	1032	140	240	240	340
7	1127	65	65	90	90
8	1225	15	40	40	65
9	1313	110	110	120	
10	1409	70	70	70	70
12	1600	30	30	30	35

Table A.28—SHOT WASP PRIME, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE ALUMINUM HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1b	280	45714	
2b	380	45722	38,000
3b	460	45724	5,100
4b	520	45740	3,300
5b	600	45715	1,850
6b	710	45700	1,330
7b	835	45687	730
8b	945	45696	520
9b	995	45683	400
10b	1,045	45684	340
11b	1,100	45706	230
12b	1,160	45698	240
13b	1,225	45691	200
14b	1,280	45710	75
15b	1,335	45701	120

Table A.29—SHOT WASP PRIME, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE LEAD HEMISPHERES

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1a	280	45718	18,000
2a	375	45725	2,450
3a	430	45719	1,650
4a	485	45716	900
5a	550	45711	650
6a	650	45729	360
7a	760	45728	200
8a	865	45721	120
9a	910	45727	95
10a	960	45713	55
11a	995	45712	40
12a	1,060	45726	30
13a	1,110	45720	25
14a	1,155	45723	20
15a	1,205	45717	20

Table A.30—SHOT WASP PRIME, PROJECT 39.7: FILM-DOSIMETER READINGS
INSIDE LEAD HEMISPHERES WITH LITHIUM-COATED DOSIMETERS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1b	280	45705	8300
2b	380	45688	2900
3b	460	45695	1750
4b	520	45693	890
5b	600	45681	650
6b	710	45689	390
7b	835	45690	230
8b	945	45703	120
9b	995	45697	110
10b	1045	45692	70
11b	1100	45704	45
12b	1160	45707	30
13b	1225	45694	35

Table A.31—SHOT WASP PRIME, PROJECT 39.7: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1c	280	45138	
		45730	
2c	350	45139	
		45731	
3c	445	45140	
		45732	
4c	535	41691	9000
		45733	3150
5c	640	41692	2850
		45734	1750
6c	740	41693	1500
		45735	1000
7c	845	41694	990
		45736	610
8c	965	41695	590
		45737	390
9c	1075	41696	370
		45738	290
10c	1185	41697	250
		45739	200

Table A.32—SHOT WASP PRIME, PROJECTS 39.1 AND 39.7: FILM-DOSIMETER READINGS
AT VARIOUS LOCATIONS ABOVE AND BELOW GROUND

Station No.	Slant distance, yd	Dose with respect to ground level, r					
		+3 ft	+2 ft	+1 ft	0	-1 ft	-2 ft
1c	280	40,000	40,000	40,000	40,000	11,000	940
2c	350	25,000	25,000	25,000	25,000	20,000	2,900
3c	445	16,000	16,000	16,000	14,000	8,500	700
4c	535	85,000	8,000	9,000	9,000	1,600	280
5c	640	9,200	8,800	5,900	5,100	1,150	180
6c	740	3,500	3,150	3,050	2,850	990	150
7c	845	1,400	1,500	1,500	1,200	350	60
8c	965	900	900	900	580	100	8.5
9c	1,075	560	560	560	510	110	9.5
10c	1,185	340	340	340	340	85	6.5

Table A.33—SHOT POST, PROJECT 39.6: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1	696	42501	680
		42502	690
2	756	42503	530
		42504	510
3	844	42505	320
		42506	310
4	962	42507	180
		42508	180
5	1031	42509	110
		42510	110
6	1105	42511	55
		42512	55
7	1180	42513	50
		42514	50
8	1260	42515	40
		42516	40
9	1345	42517	30
		42518	30
10	1430	42519	20
		42520	20
11	1525	42521	10.7
		42522	9.5
12	1610	42523	6.8
		42524	6.8
13	1700	42525	4.8
		42526	4.8
14	1790	42527	3.4
		42528	3.3
15	1890	42529	2.6
		42530	2.6

Table A.34—SHOT MET, PROJECT 39.6: FILM-DOSIMETER READINGS
OUTSIDE STATIONS

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
1	721	42327	
		42531	
2	818	42328	
		42331	
3	916	42332	
		42334	
4	1013	42337	2100
		42336	2500
5	1113	42340	1480
		42338	1580
6	1210	42345	
		42342	880
7	1310	42346	660
		42347	660
8	1405	42348	450
		42349	440
9	1502	42532	320
		42533	310
10	1600	42534	220
		42535	220
11	1700	42536	170
		42537	170
12	1800	42538	95
		42539	95
13	1900	42540	60
		42541	60
14	2000	42542	34
		42543	34
15	2100	42544	26
		42545	26
16	2200	42546	19
		42547	19
17	2300	42548	12
		42549	12

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Table A.35—SHOT APPLE II, PROJECT 31.1: FILM-DOSIMETER
READINGS INSIDE TWO-STORY MASONRY HOUSE AT 4700 FT

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Outside	41908		Second-floor	44097	
	41861		front bedroom	44100	
First-floor	43475	120		44092	
living room	43464			44099	
	43468		Basement	43593	
	43467			43592	
	43407	25		43591	
	43477			42605	13
	43465			42604	35
	43486			42603	6.5
First-floor	43481			42618	
bathroom	43471			42619	19
				42620	10
First-floor	43478			42615	
hallway	43490			42610	35
				42611	
First-floor	43462			42606	40
dining room	43473			42607	
	43487			42608	
	43463			41673	55
	43484			41674	15
	43469			41675	9.4
	43466			41667	45
	43482			41668	25
	43474			41669	15
First-floor	43480			41672	45
kitchen	44093			41671	35
	43472			41670	15
	43483			42599	40
	43488			42598	30
	43461	60		42597	25
Second-floor	44112			42616	25
bedroom	44111			42617	15
				42612	
Second-floor	44120			42613	
back bedroom	44119			42614	
	44095			42609	35
	44118			42177	6.1
	44103	90		42172	10
				42173	7.9
Second-floor	43479			41664	15
large bedroom	44091			41665	15
	43489			41666	8
	44096			41676	35
	44098			41677	40
	44101			41678	14
	44102			41688	35
Second-floor	44109			41689	20
hallway	44105			41690	15
	44094			41682	30
Second-floor	44111			41683	35
bathroom	44106	50		41684	25
				41679	40

Table A.35—(Continued)

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Basement	41680		Basement	41865	35
(Continued)	41681		(Continued)	41866	30
	41685	35		41867	25
	41686	30		41868	30
	41687	20		41869	30
	42179	20		41870	25
	42178	7.5		41901	25
	42184	10		41902	6.6
	42185	7.7		41903	5.6
	41841	36		41904	20
	41842	70		41905	15
	41843	20		41906	8.8
	41856	40		41907	40
	41857	35		41908	
	41858	20		41853	40
	41844	30		41854	20
	41845	30		41855	15
	41846			41859	50
	41847	20		41860	
	41848	10		41861	
	41849	6		41915	20
	41850	30		41916	40
	41851	15		41917	30
	41852	10		41918	25
	42602	35		41919	40
	42601	30		41920	30
	42600	23		41921	25
	42594	30		41922	35
	42595	30		41923	8.1
	42596	25		41924	6.1
	42177	6.1		41925	40
	42189	35		41926	20
	42190	10		41927	10
	42191	8.3		41628	45
	42192	30		41629	20
	42193	20		41630	15
	42194	10		41928	40
	42197	20		41929	20
	42196	20		41930	20
	42195	15		41601	40
	42198	35		41602	30
	42199	30		41603	15
	42200	40		41604	40
	42174	30		41799	
	42175	30		41625	40
	42176	20		41626	20
	41661	25		41627	10
	41662	30		41781	
	41663	25		41782	50
	42180	20		41783	35
	42181	7.5		41784	25
	42182	6.3		41785	35
	42183	25		41786	30
	41862	50		41789	20
	41863	30		41790	15
	41864	20		41791	15

Table A.35 — (Continued)

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Basement	41794	25	Basement	41610	25
(Continued)	41796	25	(Continued)	41611	20
	41798	15		41612	10
	41909			41613	40
	41910	40		41614	25
	41911	25		41615	15
	41912	30		41616	40
	41913	20		41617	25
	41914	30		41618	15
	41605	30		41619	15
	41606	25		41620	20
	41607	40		41621	20
	41608	35		41622	35
	41609	35		41623	25
	41792	35		41624	20
	41802	30		41800	

Table A.36—SHOT APPLE II, PROJECT 31.1: FILM-DOSIMETER READINGS
INSIDE FRAME RAMBLER HOUSE AT 4700 FT

Location	Dosimeter No.	Dose, r
Living room	45102	
	45091	
	45065	
	45069	110
	45081	150
	45104	
Small front bedroom	45060	
	45073	
	45058	
	45059	
	45074	
	45071	
Large front bedroom	45057	140
	45056	
	45080	
	45053	150
	45054	130
	45107	
Hallway	45072	
	45067	
	45068	
Dining room	45064	
	45110	
Kitchen	45094	
	45092	
	43378	
	45070	
	45088	
	45099	
Utility room	45175	
	45061	65
	45066	
	45077	

Table A.37—SHOT APPLE II, PROJECT 31.1: FILM-DOSIMETER READINGS
INSIDE ONE-STORY REINFORCED-MASONRY-BLOCK HOUSE AT 4700 FT

Location	Dosimeter No.	Dose, r
Living room	45085	80
	45103	
	45101	80
	45095	70
	45098	45
Kitchen	45037	30
	45106	20
	45093	25
	45108	25
Front bedroom	45097	85
	45083	40
	45089	40
	45109	160
	45086	75
	45105	60
Back bedroom	45084	25
	43390	50
	43399	45
	45096	20
	43375	50
	43391	35
	45082	25

Table A.38—SHOT APPLE II, PROJECT 31.1: FILM-DOSIMETER READINGS
INSIDE ONE-STORY PRECAST CONCRETE HOUSE AT 4700 FT

Location	Dosimeter No.	Dose, r
Garage	43371	90
	43372	40
	43385	55
	43377	30
	43381	45
	43397	80
Living room	44210	50
	43380	55
	43374	40
	43396	70
	43542	100
	43522	110
Kitchen	43531*	72
	43382	40
	43379	
	43393	30
Front bedroom	43384	
	43535	65
	43536	60
	43388	110
	43531*	72
Hallway	43526	
	43392	40
	43383	45
Back bedroom	43376	25
	43389	25
	43386	
	43400	25
	43394	20
	43395	25
	43387	25

*Duplicate listing of numbers.

Table A.39—SHOT APPLE II, PROJECT 31.1: FILM-DOSIMETER
READINGS INSIDE TWO-STORY FRAME HOUSE AT 5500 FT

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
First-floor living room	43254	50	Basement	43665	25
	43252	50		43666	2.2
	43262	40		43667	1.5
	43264			43662	25
	43372			43663	5.0
	43253	30		43664	3.2
	43251	30		43659	30
	43265	25		43660	8.6
	43260	30		43661	4.9
	43269	30		43656	25
First-floor hallway	43025	45		43657	15
	43030	60		43658	6.3
	43029			43653	20
First-floor bathroom	43276	30		43654	15
	43278	30		43655	7
First-floor kitchen	43016	40		43650	20
	43037	50		43651	20
	43018	35		43652	8.4
	43023	35		43647	4.8
	43031	50		43648	4.9
First-floor dining room	43032	65		43644	25
	43035	70		43645	7.2
	43014	40		43646	4.8
	43026	45		43641	25
	43011			43642	10
	43038	60		43643	5.9
	43024	20		43698	25
Second-floor back bedroom	43258			43699	15
	43279	45		43700	6.2
	43261	30		43695	25
	43257			43696	20
	43270			43697	9.3
	43277	40		43692	25
	43266			43693	20
Second-floor bathroom	43028	35		43694	10
	43040	55		43675	
Second-floor hallway	43034	55		43671	35
	43012	40		43672	6.3
	43015	40		43689	30
Second-floor front bedroom	43033	65		43690	7.6
	43019			43691	3.8
	43039	70		43686	25
	43017	50		43687	10
	43027	60		43688	5.6
	43020	45		43683	25
				43684	15
Second-floor large bedroom	43273	40		43685	7.6
	43021	45		43680	25
	43036	75		43681	20
	43271	45		43682	3.1
	43275			43557	25
	43255	35		43558	20
				43559	15
				43551	25
				43552	20

Table A.39—(Continued)

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Basement (Continued)	43553	15	Basement (Continued)	43801	
	43563	35		43802	
	43564	4.5		43797	25
	43565	2.4		43798	15
	43560	30		43799	7
	43561	6.5		43404	20
	43562	4.6		43405	70
	43428	40		43406	70
	43429	9.8		43401	30
	43430	6.5		43402	10
	43425	30		43403	7.4
	43426	15		43734	25
	43427	10		43735	3.3
	43422	30		43736	2.4
	43423	20		43728	30
	43424	10		43729	6.2
	43419	25		43730	3.4
	43420	20		43725	25
	43421	10		43726	8.2
	43554	15		43727	6.4
	43555	4.6		43722	30
	43556	2.7		43723	12
	43787	0.15		43724	5.9
	43788	0.13		43719	30
	43789	0.14		43720	20
	43416	20		43721	8.6
	43417	15		43794	25
	43418	9.0		43795	15
	43413	20		43796	10
	43414	20		43791	20
	43415	10		43792	20
	43595			43793	10
	43596			43710	30
	43597			43711	10
	43572	20		43712	4.6
	43573	5.2		43707	30
	43574	5.1		43708	15
	43668	25		43709	6.6
	43669	9		43704	30
	43670	4.9		43705	15
	43410	25		43706	8.4
	43411	9.0		43716	25
	43412	5.7		43717	20
	43407	25		43718	10
	43408	10		43713	25
	43409	7.2		43714	20
	43569	15		43715	10
	43570	4.5		43674	
	43571	2.7		43675	
	43566	30		43755	30
	43567	7.0		43756	8.1
	43568	4.2		43757	4.1
	43803	30		43752	30
	43804	8.4		43753	10
	43805	3.9		43754	5.9
	43800			43749	30

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Table A.39—(Continued)

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Basement	43750	15	Basement	43677	
(Continued)	43751	7.7	(Continued)	43678	
	43701	25		43746	20
	43702	15		43747	15
	43703	9.6		43748	8.2
	43758	25		43743	20
	43759	20		43744	15
	43760	10		43745	8.6

Table A.40—SHOT APPLE II, PROJECT 31.1: FILM-DOSIMETER
READINGS INSIDE TWO-STORY FRAME HOUSE AT 7800 FT

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Outside front	43524	15	Second-floor	43230	4.1
Outside front	42814	4.6	back bedroom	43297	4.7
Outside eastside	44187		(Continued)		
Outside southside behind chimney	43532	0.18	Second-floor	43226	5.7
First-floor	43285	5.5	front bedroom	43232	5.5
living room	43247	4.9		43238	4.3
	43284	4.9		43248	4.2
	43291	4.5		43231	5.4
	43286	3.8		43245	4.3
	43306	4.0	Basement	41808	1.4
	43295	3.4		41801	0.52
	43287	3.2		41810	0.17
	43282	4.8		41783	2.0
First-floor	43283	3.8		41786	0.32
hallway	43303	2.7		41788	0.15
	43293	3.7		41793	2.4
First-floor	43299	3.0		41795	0.18
bathroom	43294	3.1		41797	0.4
First-floor	43281	5.8		41804	2.4
dining room	43310	5.4		41805	0.78
	43309	4.3		41806	
	43288	4.2		42003	1.8
	43289	5.3		42004	0.9
	43308	5.7		42005	0.45
	43290	4.2		41809	1.7
	43301	4.8		41807	1.5
First-floor	43305	5.4		42000	3.1
kitchen	43302	3.0		42001	0.45
	43296	3.5		42002	0.26
	43304	3.5		42006	3.0
	43290	4.2		42007	0.95
	43298	3.8		42008	0.40
Second-floor	43233	5.4		42009	1.9
large bedroom	43239	5.3		42010	0.9
	43241	4.3		42011	0.5
	43246	4.1		41991	1.8
	43236	4.5		41992	1.1
	43225	3.0		41993	0.6
	43244	4.6		41998	2.5
Second-floor	43242	4.8		41999	2.5
hallway	43307	5.7		41994	3.1
	43300	4.8		41995	0.5
Second-floor	43223	3.2		41996	0.27
bathroom	43221	3.0		42012	3.2
Second-floor	43243	4.9		42013	0.85
back bedroom	43237	4.3		42014	0.50
	43234	4.0		42015	2.5
	43222	4.3		42016	1.6
	43227	3.5		42017	0.6
				42018	2.8
				42019	1.5
				42020	0.8
				41961	2.9
				41962	1.8

Table A.40—(Continued)

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Basement	41963	0.9	Basement	42408	1.1
(Continued)	41964	2.4	(Continued)	42409	0.4
	41965	1.7		42410	0.25
	41966	1.2		43161	0.95
	41967	1.6		43162	0.37
	41968	0.23		43163	0.28
	41969	0.18		43164	1.7
	41970	2.4		43165	0.76
	41971	0.45		43166	0.55
	41972	0.45		43167	1.5
	41973	2.8		43168	0.28
	41974	0.95		43169	0.23
	41975	0.34		43170	3.4
	41976	2.8		43171	0.43
	41977	1.2		43172	0.28
	41978	0.78		43180	2.2
	41979	2.8		43181	0.6
	41980	1.5		43182	0.35
	41981	0.7		43173	3.7
	41982	2.6		43174	1.1
	41983	1.4		43175	0.5
	41984	0.7		43183	3.7
	41985	1.8		43184	0.58
	41986	1.4		43185	1.2
	41987	0.85		43186	4.8
	41988	0.20		43187	1.4
	41989	0.50		43188	0.64
	41990	0.15		43189	2.5
	41997	1.0		43190	2.3
	42373	0.38		43179	1.0
	42381	0.25		43176	1.6
	42383	1.0		43177	0.34
	42382	1.8		43178	0.28
	42384	0.75		43191	3.3
	42385	0.38		43192	0.5
	42386	1.6		43193	0.23
	42387	0.78		43194	3.4
	42388	0.50		43195	0.56
	42389	1.6		43196	0.29
	42390	1.1		43197	3.7
	42391	0.18		43198	1.1
	42392	0.5		43199	0.5
	42393	0.22		43200	3.8
	42394	0.20		43201	1.4
	42395	1.3		43202	0.65
	42396	0.4		43203	2.6
	42397	0.3		43204	1.4
	42398	1.5		43205	0.76
	42399	0.45		43206	2.5
	42400	0.32		43207	0.8
	42402	1.8		43208	0.8
	42403	0.8		43085	
	42404	0.5		43086	
	42405	0.4		43209	4.0
	42406	0.23		43210	1.1
	42407	0.18		43211	0.84

Table A,40—(Continued)

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Basement	43212	3.1	Basement	43071	1.7
(Continued)	43213	1.5	(Continued)	43072	0.76
	43214	0.76		43073	0.40
	43215	3.5		43077	3.9
	43216	3.3		43078	1.0
	43217	0.85		43079	0.55
	43218	2.6		43074	1.7
	43219	1.8		43075	1.3
	43220	0.8		43076	0.75
	43083			43080	2.7
	43084			43081	1.1
				43082	0.68

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Table A.41—SHOT APPLE II, PROJECT 31.1: FILM-DOSIMETER
READINGS INSIDE TWO-STORY MASONRY HOUSE AT 10,500 FT

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
First-floor	43817	0.18	Second-floor	42827	0.20
kitchen	43814	0.20	large bedroom	42812	0.24
	43811	0.18	(Continued)		
	42826	0.18	Basement	44490	0.20
	43820	0.25		44491	0.13
First-floor	43679	0.27		44492	0.13
dining room	42188	0.27		44481	0.15
	42815	0.37		44482	0.13
	43816			44483	0.13
	43815	0.27		44484	0.20
	42818	0.24		44485	0.14
	42803	0.28		44486	0.14
	42821	0.24		43087	
First-floor	42186	0.25		44187	0.18
bathroom	43808	0.18		44488	0.14
				44489	0.13
First-floor	42816	0.37		44493	0.15
hallway	43812	0.25		44494	0.15
	43813	0.22		44495	0.14
First-floor	43318	0.20		44496	0.15
living room	43819	0.22		44497	0.15
	43807	0.20		44498	0.13
	43398	0.54		44499	0.20
	43649	0.20		44500	0.13
	43809	0.27		44501	0.13
	43676	0.30		44502	0.13
	43806	0.22		44503	0.20
	43810	0.20		44504	0.13
				44505	0.14
Second-floor	42825	0.24		44506	0.22
back bedroom	42828	0.21		44507	0.13
	42801	0.28		44508	0.20
	43373	0.22		44509	0.24
	42808	0.35		44510	0.13
	42829			44511	0.20
	42820	0.20		44512	0.15
				44513	0.14
Second-floor	42810	0.24		44514	0.35
front bedroom	42804	0.23		44515	0.15
	42807	0.24		44516	0.39
	42824	0.20		44517	1.5
	42817	0.28		44518	0.39
	42819	0.28		44519	0.27
Second-floor	42822	0.20		44520	0.25
bathroom	42806	0.24		44521	0.18
				44522	0.13
Second-floor	43813	0.22		44523	0.20
hallway	42811	0.24		44524	0.14
	42187	0.29		44525	0.13
Second-floor	42830	0.24		44526	0.18
large bedroom	42809	0.24		44527	0.14
	42805	0.24		44528	0.14
	42802	0.25		44529	0.18
	42823	0.20		44530	0.15

Table A.41 — (Continued)

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Basement	44531	0.13	Basement	43048	0.15
(Continued)	44532	0.13	(Continued)	43049	<0.1
	44533	0.15		43103	0.15
	44534	0.13		43104	0.28
	44535	0.18		43105	<0.1
	44536	0.13		43106	<0.1
	44537	0.13		43107	0.25
	44538	0.25		43108	0.22
	44539	0.15		43109	0.15
	44540	0.13		43110	0.28
	43761	0.13		43111	0.19
	43762	0.25		43112	0.19
	43763	0.20		43113	0.23
	43766	0.20		43114	0.19
	43765	0.14		43115	0.15
	43764	0.13		43116	0.20
	43769	0.20		43117	0.20
	43768	0.15		43118	<0.1
	43767	0.15		43119	0.20
	43775	0.20		43120	0.19
	43774	0.15		43121	0.15
	43773	0.15		43099	
	43772	0.20		43100	
	43771	0.15		43122	0.19
	43770	0.14		43123	0.28
	43781	0.14		43124	0.15
	43780	0.13		43125	0.23
	43779	0.13		43126	0.19
	43784	0.15		43127	0.15
	43783	0.13		43128	0.23
	43782	0.13		43129	0.15
	43778	0.18		43130	0.15
	43777	0.14		43811	0.22
	43776	0.14		43822	0.20
	43787	0.15		43823	0.14
	43786	0.14		43824	0.25
	43785	0.14		43825	0.18
	43790	0.15		43826	0.15
	43789	0.14		43097	
	43788	0.13		43098	
	43088	0.15		43839	0.18
	43089	0.15		43840	0.14
	43090	0.15		43841	0.14
	43091	0.22		43836	0.22
	43092	0.15		43837	0.14
	43093	<0.1		43838	<0.1
	43094	0.20		43833	0.18
	43095	0.21		43834	0.14
	43096	0.15		43835	0.13
	43041	0.22		43830	0.27
	43042	0.15		43831	0.30
	43043	<0.1		43832	0.20
	43044	0.20		43827	0.22
	43045	0.15		43828	0.15
	43046	<0.1		43829	0.15
	43047	0.20		43740	0.14

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Table A.41 — (Continued)

Location	Dosimeter No.	Dose, r	Location	Dosimeter No.	Dose, r
Basement	43741	0.14	Basement	43055	<0.1
(Continued)	43742	0.15	(Continued)	43056	0.15
	43737	0.14		43057	0.15
	43738	<0.1		43058	<0.1
	43739	0.13		43059	0.17
	43848	0.13		43060	0.15
	43849	0.13		43061	0.20
	43850	0.13		43062	0.15
	43845	0.15		43063	0.15
	43896	0.14		43064	<0.1
	43847	0.13		43065	0.15
	43842	0.15		43066	<0.1
	43843	0.15		43067	<0.1
	43844	0.13		43068	0.15
	43050	0.20		43069	<0.1
	43051	0.15		43070	0.15
	43052	0.15		43101	0.20
	43053	0.15		43102	0.19
	43054	<0.1			

Table A.42—SHOT APPLE II, PROJECT 31.1:
FILM-DOSIMETER READINGS INSIDE ONE-STORY
PRECAST CONCRETE HOUSE AT 10,500 FT

Location	Dosimeter No.	Dose, r
Garage	45537	0.27
	43549	0.18
	43528	0.22
	43529	0.27
Living room	43550	0.22
	43542	100*
	43543	0.15
	43544	0.20
Kitchen	43548	0.18
	44191	
	44197	0.15
Front bedroom	43539	0.27
	43525	0.35
	43538	0.30
	44198	0.18
Hallway	43540	0.5
Back room	43521	0.20
	43523	0.18
	43547	0.20
	43530	0.15

* Probable misplacement of dosimeter.

Table A.43—SHOT APPLE II, PROJECT 31.1:
FILM-DOSIMETER READINGS INSIDE FRAME
RAMBLER HOUSE AT 10,500 FT

Location	Dosimeter No.	Dose, r
Living room	43263	40*
	43259	
	43256	0.45
	43267	0.47
Small front bedroom	44183	0.25
	44203	0.39
	44205	0.35
	44194	0.54
Large front bedroom	43274	0.54
	43268	0.39
	43013	0.33
	44196	0.35
Dining room	44192	0.27
	44209	
Kitchen	44201	0.35
	44208	0.25
	44184	
	44206	0.22
Back bedroom	44185	0.27
	43240	0.35
	44186	0.15

* Possible misplacement of dosimeter.

Table A.44—SHOT APPLE II, PROJECT 31.1:
FILM-DOSIMETER READINGS INSIDE ONE-STORY
REINFORCED-MASONRY-BLOCK HOUSE AT 10,500 FT

Location	Dosimeter No.	Dose, r
Living room	44189	0.25
	44204	0.20
	43235	0.25
	44181	0.18
Kitchen	43249	
	44202	0.18
	44200	0.15
	44199	0.20
Front bedroom	43527	0.35
	43229	0.20
	43546	0.20
	43250	2.8
Back bedroom	43224	0.19
	43534	0.20
	43533	0.18
	44207	0.14
	44193	0.15

Table A.45—SHOT APPLE II, PROJECT 31.2:
FILM-DOSIMETER READINGS INSIDE
BUILDING 31.2 e-1 AT 5500 FT

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
42711	80	42727	70
42712	80	42728	70
42713	85	42730	70
42714	85	42731	50
42715	85	42732	70
42716	50	42733	70
42717	60	42734	70
42718	65	42735	60
42719	70	42736	100
42720	70	42737	40
42721	70	42738	80
42722	65	42739	110
42723	60	42740	30
42724	70	45076	45
42725	60	43476	
42726	65	45052	40

Table A.46—SHOT APPLE II, PROJECT 31.2:
FILM-DOSIMETER READINGS INSIDE BUILDINGS
31.2 a-1, 31.2 b-1, AND 31.2 d-1 AT 6800 FT

Location	Dosimeter No.	Dose, r
31.2 a-1	42741	25
	42742	30
	42743	25
	42744	25
	42745	25
	42746	
31.2 b-1	42751	25
	42752	25
	42753	25
	42754	25
	42755	20
	42756	20
31.2 d-1	42761	25
	42762	20
	42763	
	42764	20
	42765	11
	42766	20
	42768	20
	42769	15
	42770	18

Table A.47—SHOT APPLE II, PROGRAM 32: FILM-DOSIMETER READINGS

Location	Dosimeter No.	Dose, r
Underground shelter, 1050 ft	45820	1.3
Buried 4 in., 1270 ft	45806	47,000
	45807	62,000
	45808	46,000
	45809	50,000
	45810	70,000
Buried 4 in., 1270 ft		
Inside potato bag	45804	56,000
	45819	75,000
18 in. inside refrigerator box	45815	18,000
9 in. inside refrigerator box	45816	11,000
9 in. inside refrigerator box	45817	17,000
4 in. inside box of chemicals	45803	60,000
Block house, 2250 ft	45812	12,000
Buried 4 in., 2750 ft	45818	710
Buried 4 in., 2750 ft		
Inside potato bag	45805	45,000
Buried 18 in. inside refrigerator box	45814	140
Block house, 3750 ft	45813	230
Block house, 4700 ft		
Inside apple bag	42633	90
	42667	60
On shelves in basement	42668	25
	42632	60
Concrete house, 4700 ft		
On shelves in kitchen	42631	20
On floor	42659	25
In deep freeze in kitchen	42623	15
Inside refrigerator box	42622	50
	42662	45
	42661	45
Adjacent to concrete house in unprotected cases, 4700 ft	45802	110
	42663	90
	42664	60
	42678	110
	42665	45
	42679	220
	42680	100
	42666	250
	42676	60
	42677	60
Frame house, 5500 ft		
On shelves in kitchen	42635	40
Inside apple bag	42658	40
On shelves in basement	42669	30
	42634	10
	42638	20
On shelves in basement, inside apple bag	42670	10
On ground unprotected cases	42644	40
	42674	30
	42637	45
	42640	30
	42641	45
	42645	30
Adjacent to frame house in unprotected cases, 5500 ft	45811	25

Table A.47—(Continued)

Location	Dosimeter No.	Dose, r
Behlen building, 6800 ft, on shelves	42630	15
	42647	10
	42648	10
Frame house, 7800 ft		
On shelves in kitchen	42627	4.7
Inside apple bag	42671	2.1
On shelves in kitchen	42675	2.3
On basement shelves	42626	0.15
	42650	0.15
Ground surface	42636	5
	42642	2.5
	42643	4.9
	42646	2.5
	42649	4.9
	42673	2.0
Concrete house, 10,500 ft, on shelves in kitchen	42629	0.15
	42639	0.20
Frame rambler house, 10,500 ft	42628	0.35
Masonry house, 10,500 ft		
Inside apple bag	42672	0.20
Inside refrigerator box	42621	0.18
On shelves in kitchen	42625	0.27
On shelves in basement	42624	0.15

Table A.48—SHOT APPLE II, PROJECT 34.1: FILM-DOSIMETER READINGS

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
Inside Structure 31.1 a-1 Basement Corner-room Shelter		Inside Structure 31.1 b-1 Basement Reinforced-concrete Shelter	
43997	12	43943	1.0
43998	12	43944	0.95
43999	12	43945	0.95
44000	15	43946	0.95
44061	25	43947	0.95
44062	30	43948	1.1
44063	30	43949	1.1
44064	30	43950	1.5
44065	40	43951	1.5
44066	40	43952	1.6
44067	45	43953	2.0
44068	50	43955	7.6
44069	40	43956	11.8
44070	13		
Inside Structure 31.1 a-1 Basement Lean-to Shelter		Inside Structure 31.1 b-2 Basement Corner-room Shelter	
43992	6.5	43885	0.8
43993	6.7	43886	0.6
43994	6.7	43887	0.6
43995	6.7	43888	0.7
43996	6.7	43889	0.24
Inside Structure 31.1 a-2 Basement Corner-room Shelter		43890	1.2
44076	0.1	43891	1.3
44077	0.1	43892	1.6
44078	0.15	43893	1.6
44079	0.1	43894	2.0
44080	0.15	43895	2.2
44081	0.15	43896	2.5
44082	0.1	43897	1.6
44083	0.15	43898	0.2
44084	0.1	Inside Structure 31.1 b-1 Basement Lean-to Shelter	
44085	0.15	43957	2.2
44086	0.1	43958	3.2
44087	0.18	43959	2.4
44088	0.18	43960	2.4
44089	0.15	43961	2.2
Inside Structure 31.1 a-2 Basement Lean-to Shelter		Inside Structure 31.1 b-1 Basement Corner-room Shelter	
44071	<0.1	43962	8.3
44072	<0.1	43963	6.3
44073	<0.1	43964	3.3
44074	<0.1	43965	3.3
44075	<0.1	43966	5.6
		43967	6.2

Table A.48—(Continued)

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
43968	20.0	43989	0.20
43969	14.0	43990	
43970	18.0	43991	0.14
43971	18.0		
43972	25.0	Inside Structure 34.1 c-1	
43973	25.0	46131	52,000
43974	9.8	46132	55,000
43975	4.4	45831	70,000
		45832	56,000
Inside Structure 31.1 b-2		45833	
Basement Reinforced-concrete Shelter		45834	
43899	0.18	42903	160
43901	0.1	42904	160
43902	0.1	42905	170
43903	0.18	42906	190
43904	0.23	42907	220
43905	0.27	42908	210
43906	0.18	42909	230
43907	0.15	42910	290
43908	0.15	45835	370
43909	0.20	45836	650
43910	0.27	45837	640
43941	0.27	45838	1,330
43942	0.27		
		Inside Structure 34.1 c-2	
Inside Structure 31.1 b-2		45849	56,000
Basement Lean-to Shelter		45850	
43010	0.18	42919	310
43881	0.22	42920	370
43882	0.22	42921	370
43883	0.22	42922	460
43884	2.5	42923	500
		42924	430
Inside Structure 31.1 c-1		42925	
Reinforced-concrete Bathroom Shelter		42926	720
43976		45851	730
43977	170	45852	950
43978	30	45853	1,150
43979	30	45854	
43980	25		
43981	35	Inside Structure 34.1 d-1	
43982	50	45839	24,000
43983	13.6	45840	32,000
		45841	
Inside Structure 31.1 c-2		45842	
Reinforced-concrete Bathroom Shelter		45843	
43984	0.5	45844	150,000
43985		42911	75
43986	0.21	42912	75
43987	0.21	42913	75
43988	0.17	42914	90
		42915	100

Table A.48—(Continued)

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
42916	130	42958	6,500
42917	260	42959	
42918	200	42960	
45845	290	42961	
45846	380	42962	
45847	600		
45848	560		
Inside Structure 34.1 d-2		Inside Structure 34.1 h	
45855	35,000	42974	1,800
45856	32,000	42975	1,000
42928	270	42976	1,650
42929	250	42977	890
42930	190	42978	1,100
42931	220	42979	1,250
42932	220	42980	1,250
42933	290	42981	1,250
42934	270	42982	1,200
42935	460		
45857	2,130	Inside Structure 34.1 i	
45858	2,500	42965	2,200
45859	930	42966	1,050
45860	980	42967	1,250
		42968	830
		42969	1,080
Inside Structure 34.1 e		42970	1,150
42936		42971	1,120
42937		42972	1,120
42938		42973	1,000
42939			
42940	3,300	Inside Structure 34.1 j	
42941		42651	4,800
42942		42652	
42943	2,450	42653	1,450
42944	2,200	42654	1,000
		42655	1,350
Inside Structure 34.1 f		42656	1,350
42945	5,000	42657	1,430
42946	2,300	42963	850
42947	2,450	42964	820
42948	1,850		
42949	1,900	Inside Structure 34.1 k	
42950	2,650	42983	420
42951	2,650	42984	270
42952	2,650	42985	310
42953	2,650	42986	200
		42987	260
Inside Structure 34.1 g		42988	280
42954		42989	300
42955		42990	300
42956	8,000	42991	300
42957			

Table A.48—(Continued)

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
Inside Structure 34.1 l		Inside Structure 34.1 m	
42992	430	43001	490
42993	220	43002	290
42994	320	43003	240
42995	200	43004	210
42996	280	43005	210
42997	280	43006	210
42998	320	43007	220
42999	290	43008	220
43000	290	43009	210

Table A.49—SHOT APPLE II, PROJECT 34.3:
FILM-DOSIMETER READINGS
INSIDE STRUCTURE 34.3 a-2

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
45821	24,000	42478	1.0
45822	27,000	42479	1.2
45823	1,100	42480	1.1
45824	760	42481	1.8
45825	130	42482	1.7
45826	150	42483	1.7
42471	20	42484	1.7
42472	25	42485	1.5
42473	30	42486	3.7
42474	30	42487	3.8
42475	1.3	42488	7.5
42476	2.0	42489	7.2
42477	2.3		

Table A.50—SHOT APPLE II, PROJECT 34.3: FILM-DOSIMETER
READINGS INSIDE STRUCTURE 34.3 b-1

Dosimeter No.	Dose, r	Dosimeter No.	Dose, r
45827		42891	480
45828		42892	320
45829	50,000	42893	240
45830	650	42894	930
42490	940	42895	
42831	730	42896	1,030
42832	30	42897	1,200
42833	45	42898	390
42834	60	42899	300
42835	40	42900	190
42836	30	42901	190
42837	50	42902	190
42838	70	43900	90
42839	70	43927	
42840			

Table A.51—SHOT APPLE II, PROJECT 35.5:
FILM-DOSIMETER READINGS INSIDE SAFES

Location from Ground Zero, ft	Dosimeter No.	Dose, r
1840	44412	
2250	44397	3350
3750	44415	560
3750	44396	
4700	44411	110
4700 (basement A-1)	44410	18
4700 (basement A-1)	44398	14
4700 (basement A-1)	44419	15
4700 (basement A-1)	44413	10
5500 (basement B-1)	43879	17
5500 (basement B-1)	44404	13

Table A.52—SHOT APPLE II, PROJECT 39.6: FILM-DOSIMETER
READINGS OUTSIDE ON 90-DEG BEARING

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
8	815	46145	3550
		46160	2500
9	914	46151	2600
		46152	2050
10	1013	46153	1650
		46154	1700
11	1113	46155	1150
		46157	980
12	1210	46156	740
		46158	740
13	1309	44031	550
		44032	550
14	1408	44033	400
		44034	400
15	1508	44035	280
		44036	280
16	1605	44037	200
		44038	170
16.5	1653	44039	100
		44040	170
17	1702	44041	120
		44042	120
17.5	1750	44043	90
		44044	90
18	1800	44045	75
		44046	75
18.5	1850	44047	70
		44048	70
19	1900	44049	40
		44050	45
19.5	1950	44051	45
		44052	45
20	2000	44053	45
		44054	45
20.5	2050	44055	30
		44056	30
21	2100	44057	25
		44058	25
21.5	2150	44059	25
		44060	25
22	2200	44002	18
		44003	12
23	2300	44004	13.6
		44005	9.2
24	2400	44006	10

Table A.53—SHOT APPLE II, PROJECT 39.6: FILM-DOSIMETER
READINGS OUTSIDE ON 290-DEG BEARING

Station No.	Slant distance, yd	Dosimeter No.	Dose, r
8	815	46142	4,000
		41159	12,500
9	914	46143	12,000
		46144	11,000
10	1,013	46146	2,600
		46147	2,650
11	1,113	46148	1,425
		46149	1,425
12	1,290	46132	55,000
		46135	980
13	1,309	44007	715
		44008	715
14	1,408	44009	500
		44010	515
15	1,508	44011	355
		44012	355
16	1,605	44013	250
		44014	250
17	1,702	44015	185
		44016	185
18	1,800	44017	50
		44018	50
19	1,900	44019	80
		44020	80
20	2,000	44021	55
		44022	55

APPENDIX B

FILM-BADGE RADIATION MEASUREMENT

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B.1 INTRODUCTION

During Operation Teapot it was desired to determine the amount of gamma radiation at varying distances from Ground Zero (GZ). EG&G was required to make these measurements by means of film badges. This appendix discusses the controls required to ensure uniformity of measurements and the sensitometric problems encountered during the program.

B.2 FILM HANDLING

An individual film badge consists of several components: the film in a lighttight package, a plastic box that serves as an electron diffuser, a special lead-tin box that acts as a filter, a polyethylene bag to protect against the weather, and a means of identification. These are shown in Figs. B.1 and B.2. On Operation Teapot the film usually consisted of one packet containing three different types of emulsion (502, 510, and 606) made by Du Pont and one packet containing a single emulsion (SO-1112) made by Eastman Kodak. The envelope containing the films supplied by Du Pont displayed an embossed number as did the films themselves. This embossed number was always easily distinguishable on the envelope and on the first film in the packet. The number was more difficult to read on the other two films. Figure B.1 illustrates the manner in which the films were packaged by the manufacturer. The embossed number can be seen on the film packet. The Eastman film did not contain a number, but for identification it was always associated with the Du Pont packet. The packets were in themselves lighttight and could therefore be handled in the light.

The films were placed in the plastic case, and a lid of the same plastic was inserted to seal the open end. Note in Fig. B.2 that a tab bearing the same number as the film was attached to the plastic lid. The plastic case was then inserted into a metal box made of a lamination of tin on the inside and lead outside. The lid for this box was held in position by means of a piece of adhesive tape wrapped around the box. The identification tab was allowed to protrude so that it always remained visible. The assembled metal box was next inserted into a sealed clear plastic bag for purposes of weather protection.

In order to maintain efficiency in handling so many pieces of film with the attendant problem of keeping track of the identity of each film, it was necessary to set up an assembly line (see Fig. B.3). As the film badges were received from the field, the outside plastic envelopes

Fig. B.1 —Film packet as supplied by manufacturer.

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Fig. B.2—Film badge and protective containers.

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Fig. B.3—Assembly line for handling film badges.

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Fig. B.4—EG&G edge-taping machine.

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Fig. B.5—Operator reading and recording film-badge densities.

and the metal cases were removed. The plastic cases containing the film and identification tab were then sorted out and placed in numerical order in groups of 10. Next a data sheet was made out listing the embossed film number and the number of films in each badge. The film packets were then removed from the plastic cases and inserted into a special dispenser in the numerical order listed on the data sheets. The dispenser, loaded with the films, was taken to the dark-room, each film packet was opened in the dark, and the individual films were fastened together by means of the special edge-taping machine developed for this purpose. This machine has been described in EG&G Report 1184, Film Badge Radiation Dosimeter, and can be seen in Fig. B.4.

It was found that approximately 200 complete badges or 800 pieces of film could be thus assembled onto a single reel and processed together. This number was a convenient size to handle; larger rolls could have been used but they were somewhat awkward.

After processing in the motion-picture machine, the films were removed to a densitometer room, and densities of each individual film were measured. In order to conserve on man power, the person reading the densities transcribed the density values directly onto a magnetic tape. Figure B.5 shows the arrangement used for this step. The density values thus recorded were next played back, and the equivalent roentgen exposures were determined from a tabulated chart. These evaluated dosages were then tabulated according to the proper film-badge number.

B.3 SENSITOMETRIC BACKGROUND

The use of photographic films for the determination of gamma radiation is fundamentally a sensitometric procedure on a quantitative plane. The same precautions found necessary in visible-light sensitometry must also be observed with short wavelength or gamma-radiation sensitometry. Whether the exposing medium be visible light or gamma radiation, the relation between exposure and developed density can be presented in the form of a D-log E characteristic curve. The relation between density and exposure will vary as a function of the degree of development. As development is increased, a given exposure will produce increasing values of density, until a point is reached at which no further increase in development will alter the density. This point is termed "complete development." Ideally, for supreme accuracy in sensitometric work, development should be carried to this extent. However, several limitations are then encountered which offset most advantages thereby gained. Probably the most severe limitation would be noticed in the high-density range. Densitometer measurements at high values are likely to be considerably in error because of several factors, one of which is the effect of extraneous light hitting the photocell. Small areas that might not receive complete development as a result of air bubbles, locally exhausted developer, or other factors will materially change density measurements at high values. Nonuniformity of the emulsion coating will also greatly affect the density at high levels.

B.3.1 Effect of Development Time on Image Density

If development is not carried to completion, more control will be required in the actual developing phase, but several advantages will be noticed. First, the range of exposures over which the film is responsive will be considerably extended. Figure B.6 presents a family of D-log E characteristic curves for different times of development of a typical medium-speed emulsion. It will be noted that the exposure range covers eight decades. The curve designated infinity represents development to completion; whereas the other curves are designated by developing time in minutes. From these curves it can be deduced that the maximum density to which this film can be developed is approximately 2.80. Since this is a saturated level, a further increase in either exposure or development time will produce no additional density. It will be noted that, as the development time is reduced, the maximum developed density is somewhat below 2.80. A further increase in exposure does not increase the density to the saturation point, but rather produces a definite reduction of density, or a reversal exposure response. This effect becomes more pronounced as the development time is decreased, until a point is reached at which the reversal is minimized.

Fig. B.6—Effect of development time on the shape of the characteristic curve of a typical medium-speed film. (C. E. K. Mees, "Theory of the Photographic Process," p. 261, The Macmillan Co., New York, 1942.)

A closer examination of this family of curves also reveals the fact that the positive exposure response extends nearly two orders of magnitude beyond that exhibited by the completely developed film. It will be noted further that the curves appear to have two distinct slopes and that, as the development time is reduced, both slopes tend to become more nearly equal. The slope of the curve in the first slope region is very nearly a straight line and is the one commonly referred to as the "gamma" of the D-log E curve. This value, gamma, increases very rapidly with an increase in developing time up to a point where its increase slows down and finally levels off with no further change. This leveling point is termed "gamma infinity," or complete development. The second slope region is less well defined because it is seldom found to be a straightforward logarithmic response. Its average slope, however, exhibits considerably less change for different developing times than does the value of gamma.

B.3.2 Problems of Processing Control

It is difficult to achieve consistent results when developing film for times considerably less than the time for complete development. The process of development is dependent upon fresh developer entering the emulsion by diffusion. Once in the emulsion the developer reacts with the exposed silver halides and forms complexes which must diffuse out of the emulsion before a new developer can enter. The complexes thus formed contain a mild acid that retards development. These complexes tenaciously cling to the surface of the emulsion, preventing new developer from entering. A violent action is necessary to remove them from the surface. Once away from the surface these complexes diffuse throughout the developer and become neutralized or they are rendered inactive by components of the solution placed there to serve as such a buffer.

If a film is placed in the developer and it remains idle, the complexes retarding development will gradually be reduced by the buffer. Hence development to completion will ultimately occur. When the film is being processed for a time shorter than that required for complete development, however, it is necessary to physically aid the removal of the complexes from the emulsion surface. This aid is generally in the form of some sort of violent agitation. The tenacity of the complexes is such that a streamline flow of fresh developer will scarcely budge them. A violent turbulent flow or a reduction of surface tension will remove them. This type of agitation is difficult to obtain with individual pieces of film, but it is relatively simple to obtain with a continuous strip. Such a strip can be moved periodically past brushes, or chamois, or other materials, so that the surface of the film is physically wiped. This is perhaps the most violent type of agitation possible, and it will definitely remove the development by-products; however, there is a considerable chance of damaging the emulsion from such agitation.

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Fig. B.7—Density range resulting from processing variations.

Fig. B.8—Exposure uncertainty for various density variations.

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Fig. B.9—Comparison of white-light and gamma-radiation exposure densities. SO-1112 emulsion: —, Co⁶⁰ exposure; ----, 400 μ sec white-light exposure.

Fig. B.10—Du Pont film packet 553 exposed to Co^{60} . ----, developed to completion; —, EG&G controlled.

Fig. B.11 — All Operation Teapot film badges assembled in rolls.

A method of agitation that is nearly as effective, but gives considerably less chance of damage to the film, is one in which a turbulent flow is set up near the emulsion surface. This flow is caused by the film moving past a series of knifelike edges such as soft rubber windshield-wiper blades. These blades are held in near contact with the emulsion surface, and they set up a turbulent-flow pattern of developer as the film and a layer of developer move past them.

B.3.3 Results Obtained from SO-1112 Emulsion

Such a system as described previously has been incorporated in the EG&G processing machine and has been found to be quite effective in producing consistent densities. The method employed in studying the development characteristics is the EG&G standard sensitometric procedure. A graduated series of known white-light exposures on the order of 400 μ sec is applied to several strips of film. These strips are run through the processing machine at intervals to assure a constant value of gamma. The densities of the various strips are measured and plotted as D-log E characteristic curves. Figure B.7 is the envelope of a composite of several such curves collected over a period of five weeks. The variations in the density at given exposure levels depict the gross processing errors. These include developer replenishment, machine-speed and temperature variations, and densitometer errors. The particular emulsion chosen for this illustration (Eastman Kodak SO-1112) is an extremely difficult one to control for development to a gamma of 1. The recommended gamma for this emulsion is four times higher. The density variations shown in Fig. B.7 would cause an over-all uncertainty in exposure evaluation of approximately ± 15 per cent. If the development on this same type of emulsion is increased to produce a gamma approximately 30 per cent higher, then the density excursions are reduced by a factor of 2, and the exposure evaluation error drops by approximately the same value. An examination of the curves of Fig. B.7 reveals the double slope previously pointed out in Fig. B.6. It can be seen that the density variations are much greater in this second slope region. Because the first slope is always steeper than the second, the error of exposure evaluation will be less in the first region.

The relation between exposure error and image gradient is shown in Fig. B.8 for several different values of density excursion. With reference to Fig. B.7 the error in determining the exposure between points A and B would be ascertained by noting the gradient in this section, which in this case is 0.95, and the average density variation, which is ± 0.02 . Then the error could be found by noting the intersection of curve 0.02 in Fig. B.8 and the image contrast value of 0.95. In this case it is found to be approximately ± 5 per cent. The exposure error between points B and C would be determined in a similar manner. In this case, since the density excursion is ± 0.04 for this region, the curve 0.04 would be used. The gradient between points B and C is 0.60, and the error is given as ± 16 per cent. It must be recognized that these data refer only to white-light exposures with an exposure time of approximately 400 μ sec on special film, emulsion No. SO-1112, made by Eastman Kodak. Such white-light sensitometric exposures were used on Operation Teapot for development control purposes when processing film exposed to gamma radiation.

B.4 RESULTS OF CONTROLLED PROCESSING OF RADIATION FILM BADGES

Several of the SO-1112 films not receiving gamma-radiation exposures were given the sensitometric series of white-light exposures and assembled in the roll with the calibrated gamma-radiation series. A striking similarity will be noticed in Fig. B.9 between the gamma-radiation series D-log E curve and the 400 μ sec white-light D-log E curve for SO-1112 for this type of development. The curves presented in Fig. B.9 give the exposure values in arbitrary units. More experimental work must be done before any conclusions can be made regarding the use of white-light sensitometric exposures for the purpose of a quantitative calibration substitution for Co^{60} . However, the similarity of D-log E curves for this particular emulsion is at present satisfactory evidence that white-light exposures can be used for process control of gamma-radiation exposures. If, for some reason, the development contrast becomes either

too high or too low or if the process causes the sensitivity to shift, it appears to be a safe assumption that the white-light curve can be used to determine a density correction for the gamma-radiation exposures.

It will be observed from Fig. B.9 that the development was carried out to a higher contrast than that shown in Fig. B.7. This was done in an effort to reduce the exposure evaluation errors described previously. With the contrast as shown in Fig. B.9, the evaluation errors drop to ± 3 per cent in the lower region and to ± 7 per cent in the upper slope region. The resulting D-log E curves show a considerable range in gamma-radiation exposure, especially in comparison with the accepted useful range produced as a result of development to completion. The dashed lines shown in Fig. B.10 are gamma-radiation response curves as given by Du Pont in a booklet entitled "Dosimeter Films." The solid lines represent the same type of emulsion processed on the EG&G machine to a considerably lower contrast and in a different type of developer. The two curves of emulsion 502 deserve comment. The curve from the series receiving complete development shows a saturation of density at approximately 20 r, with no change beyond this exposure level. The D-log E curve produced by the EG&G controlled low-contrast processing shows a saturation level at approximately 100 r, with a diminution of density beyond this exposure point. This is an excellent example of solarization and reversal with gamma-radiation exposures. Such a reversal exposure response is not revealed with development to completion.

B.5 CONCLUSIONS

The major portion of the film-badge dosimetry program for Operation Teapot was concentrated on Apple II shot. Approximately 2000 film badges were placed in the field. Of this number, 1720 were recovered, processed, and evaluated for gamma dosage. The majority of the dosimeters contained four pieces of film, and a few contained five. The total number of individual films handled on this shot was 6952. Figure B.11 shows the complete collection of films read for Project 39.1.

The first stage of stripping the containers and assembling the films into proper numerical order in the dispensers required approximately 100 man-hours of labor. Assembly of the films onto a continuous strip required 40 man-hours, and processing of the films consumed 10 man-hours. Measurement of density and evaluation of the effective gamma dosage required 30 man-hours. The total effort on the program converts to approximately one film badge every 12 min per man.

APPENDIX C

NATIONAL BUREAU OF STANDARDS CALIBRATION OF FILM DOSIMETERS USED IN THE 1955 ATOMIC TEST SERIES

Calibration data were obtained on the following film types contained in a National Bureau of Standards (NBS) type dosimeter:

Du Pont film types 502, 510, and 606, emulsion No. 553-302

Eastman film type 1112, emulsion No. 111204011482

Eastman film type 548-0, double coated, emulsion No. 42710203463

All film dosimeters were exposed at the NBS Radiation Physics Laboratory and shipped to Las Vegas for processing by EG&G. Whenever feasible, duplicate exposures were made for processing at NBS. The study included a calibration of all film types with Co^{60} gamma radiation, a calibration of all but the most insensitive film type with x radiation from a 10-Mev betatron, and a calibration of the three Du Pont film types with x radiation of effective energies between about 40 and 200 kev.

The Co^{60} dose rates were measured with a cavity ionization chamber with equilibrium wall thickness, calibrated against radium. The Victoreen 25-r thimble chamber used for the determination of the dose rates from the 10-Mev betatron had been calibrated against Co^{60} and was equipped with a Lucite equilibrium shell of about 2-cm thickness. Earlier work indicated that the response of a Victoreen thimble chamber to Co^{60} radiation was within 5 per cent of the response to the radiation from a 10-Mev betatron, provided the readings were corrected for absorption of the radiation in the thick walls of the chamber. Such a correction (amounting to about 4 per cent) was applied in the present work. The dose rates for the work at low x-ray energies were determined by means of a Victoreen thimble chamber calibrated against a standard free-air ionization chamber.

Table C.1 was prepared by determining the film sensitivity (reciprocal of the dose needed

Table C.1—ENERGY DEPENDENCE OF FILM DOSIMETER

Effective energy, kev	Relative sensitivity of indicated film				
	D-502	D-510	D-606	E-1112	E-548-0 (double coated)
40	0.02	0.04	0.03		
120	0.69	1.38	1.0		
210	0.79	1.38	1.0		
1250	1.0	1.0	1.0	1.0	1.0*
10-Mev betatron	0.90	1.0	1.04	1.23†	1.13*

* Data were obtained on a different emulsion number.

† Sample was extrapolated.

for unit density) for the EG&G processing conditions. A similar energy-dependence study carried out on the Du Pont films processed at NBS in Kodak liquid x-ray developer showed essentially the same results. The sensitivity data shown in the table are all relative to the sensitivity obtained with Co^{60} gamma radiation (1250 kev), which was arbitrarily set equal to unity. The data shown for Eastman film type 548-0, double coated, were obtained with film of a different emulsion number from that used for the Co^{60} calibration curve and for the field-test exposures; also, they were obtained on film processed with Kodak liquid x-ray developer since work on film processing in the much slower developer used by EG&G would have necessitated prohibitively long betatron exposure times. However, it is thought that the data shown in Table C.1 for the 548-0 film are representative for the behavior of the presently used emulsion number and for the EG&G type of processing as well.

It may be worth while to mention that the fading characteristics of all but the Eastman 548-0, double coated, have been found to be such that a variation of the interval between exposure and processing from about three to eight days would not introduce an error in dose interpretation of more than about 5 per cent. This is not the case for the Eastman 548-0, double coated, in which fading would produce an increase of nearly 20 per cent in dose interpretation if the films were developed eight days, rather than three days, after exposure (M. Ehrlich, National Bureau of Standards Handbook 57, p. 25, Aug. 20, 1954).