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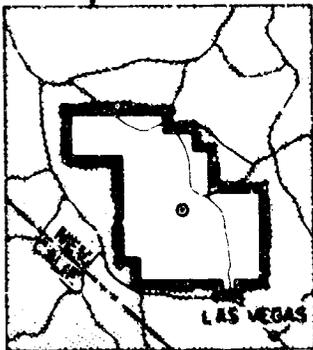
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Military Categories: 26, 28, 32, and 42

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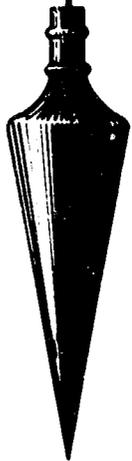
THE INTERNAL ENVIRONMENT OF UNDERGROUND
STRUCTURES SUBJECTED TO NUCLEAR BLAST.
II. EFFECTS ON MICE LOCATED IN HEAVY
CONCRETE SHELTERS

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Report to the Test Director

**THE INTERNAL ENVIRONMENT
OF UNDERGROUND STRUCTURES
SUBJECTED TO NUCLEAR BLAST.
II. EFFECTS ON MICE LOCATED
IN HEAVY CONCRETE SHELTERS**

By

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**Lovlace Foundation for Medical Education and Research
Albuquerque, New Mexico
September 1960**

ABSTRACT

A cage containing 20 mice was placed in each of 12 underground shelters tested on shot Smoky in an attempt to assess biologically the inside environment of the shelters. Two samples of 20 mice each acted as controls. The structures, of French and German design, were located at ranges between 840 ft and 4320 ft from Ground Zero. Shot Smoky, a nuclear device, was exploded atop a 700-ft tower and had a yield of 43 kt.

All but one group of mice were recovered on D+2 days. Aside from two samples placed in unrealistic locations, all animals were alive at recovery. With one exception, the peak pressures in the chambers that contained mice were insignificant, ranging from a fraction of 1 psi to 1.6 psi. The one high pressure of 14.4 psi did not kill any of the mice. According to the film-badge dosimeters, one group of mice received 190 r of gamma radiation. The others were exposed to 54 r of gamma or less.

The mice were observed for a 60-day postshot period. The deaths that occurred were attributed to a *Salmonella* infection in the animal colony and not to radiation.

Although the gamma radiation doses that most of the animal groups received were low, the levels that existed in the main chambers near the entry doors of the German shelters were over 100 r, a biologically significant dose. In contrast, the environment within two of the French shelters appeared to be quite acceptable.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to the many individuals whose cooperation and support made the project possible:

R. L. Corsbie, Director, Civil Effects Test Group

L. J. Deal, AEC Assistant to Director, Civil Effects Test Group

E. R. Saunders, FCDA Assistant to Director, Civil Effects Test Group

Edward Bryant, Ballistics Research Laboratories

Anton Bottenhofer, Assistant Project Officer, Civil Effects Test Group, Project 30.7,
Amman and Whitney

Appreciation is also expressed to the following Lovelace Foundation personnel: Mrs. Isabella D. Benton, for secretarial and editorial aid; Robert A. Smith, Albert W. Dennis, and Robert A. MacMahon, for preparation of the illustrative material.

The investigations included in this project were jointly financed by the Atomic Energy Commission and Federal Civil Defense Administration.

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CHAPTER 3 RESULTS

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Chapter 1

INTRODUCTION

At the request of the Federal Civil Defense Administration, this project placed biological specimens in a number of heavy concrete underground shelters of foreign design which were to be subjected to a nuclear detonation. The shot, code named "Smoky," was exploded on top of a 700-ft tower and had a yield of 43 kt.

The objectives were (1) to place the specimens in the main personnel chambers of the structures and to note any mortality over a 60-day postshot period and (2), if possible, to relate the cause of any deaths to a specific environmental factor.

Chapter 2

PROCEDURE

2.1 STRUCTURES

The general layout of the structures in relation to Ground Zero (GZ) is shown in Fig. 2.1. Ground Zero was to the north of the structures; the blast line ran approximately north and south. Those structures to the west of the blast line were of French design,* and those to the east were of German design.†

The French structures II-3, II-4, and II-5 were primarily for entryway tests and tests of blast-closing ventilation ducts; they did not contain a large personnel chamber. The main room of Shelter II-1 was rectangular in shape, the thickness of the walls was 1 ft 11½ in., and it was 3 ft 11¼ in. beneath the surface. Shelter II-2 had a main room that was circular in cross section with walls that were 10 in. thick. It had 4 ft 9 in. of earth cover.

There were three types of German shelters. The CA design had main personnel rooms that were circular in cross section with walls of 1 ft 3¼ in. thickness; they were 5 ft 3 in. below ground. The shelters of the RA type were 4 ft underground, rectangular, and had walls whose thickness was 1 ft 11½ in. The RC type were less massive than the RA type, having walls of 11¾ in. thickness and only 3 ft of earth cover.

2.2 ANIMALS

The experimental animals used in this study were female mice of the RAP strain‡ whose body weights were between 20 and 25 g at the time of testing. Their ages were approximately 5 weeks. A sample of 20 mice in a wire-mesh cage (approximately 9 by 15 by 9 in.) was placed in each of twelve of the fourteen structures. Those shelters in Fig. 2.1 marked 33.6 contained animal specimens. In addition, two cages of 20 mice each were kept as controls. The cages contained copious amounts of food (Purina Laboratory Chow) and two water bottles (Fig. 2.2). In the event the blast jarred the water bottles from the cage, each cage also contained sliced raw potatoes to act as a source of moisture. Control tests showed that mice under these circumstances could survive a four-day period unattended.

Following the test all the mice from a given shelter were maintained as a group in one cage, the same type in which they had been exposed (Fig. 2.2). The animal cages were inspected daily, and the date of any deaths was recorded. Dead mice were preserved in formalin.

* See Project 30.6, T-1453.

† See Project 30.7, T-1454.

‡ Purchased from Lockland Farms, New York.

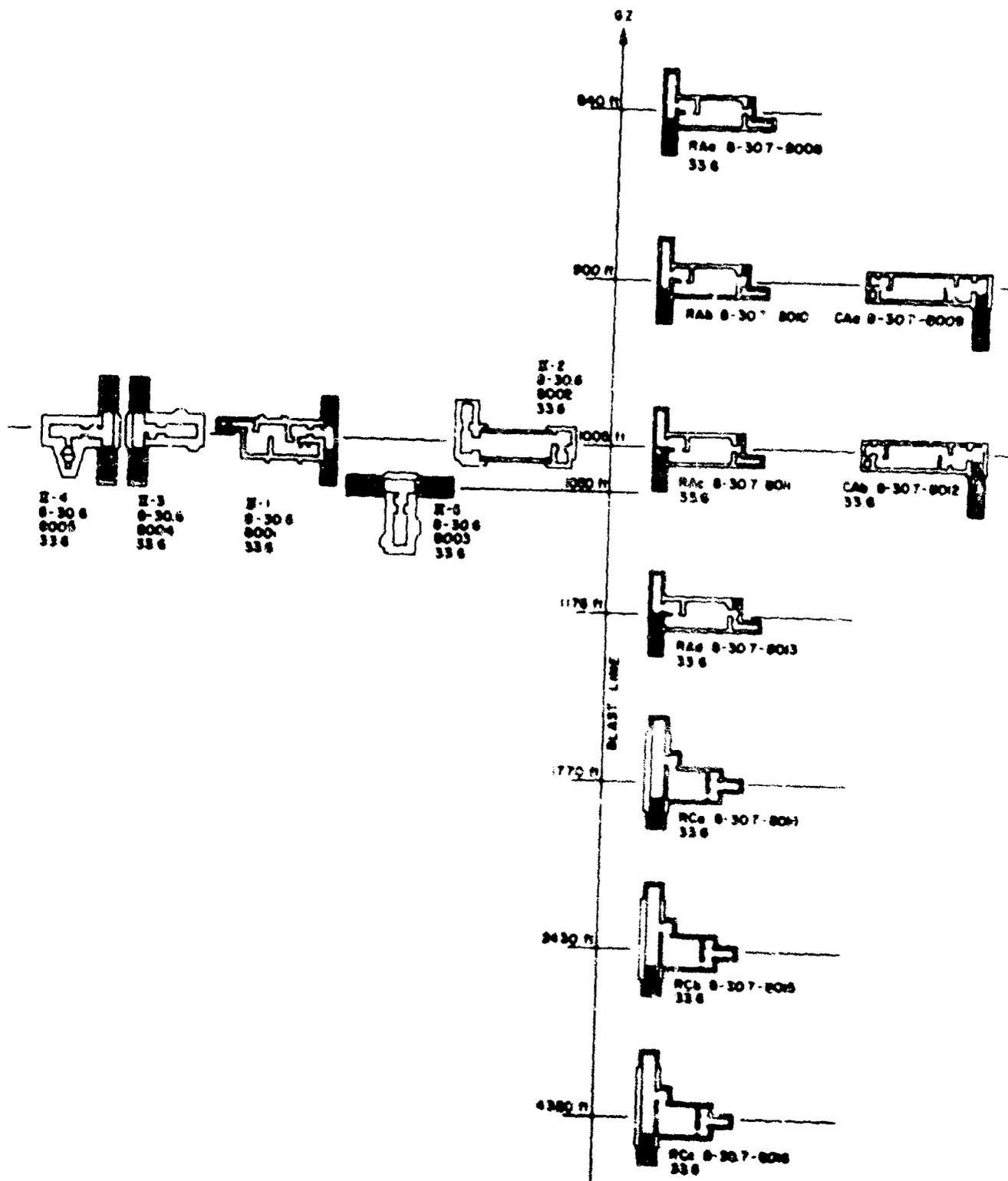


Fig. 2.1—Layout drawing of heavy concrete shelters in relation to GZ.

2.2.1 Location of Animal Cages in Shelters

(a) *French Structures (II-1 to II-5)*. Each of the five French structures contained a cage of 20 mice. In Shelters II-2 (Station 8004), II-4 (Station 8005), and II-5 (Station 8003), the cages were secured on a spring-suspended platform with several heavy elastic bands. The platforms were 3 ft above the floor in the approximate center of the room. In Shelter II-1 (Station 8001), the cage was located on the floor of the main personnel chamber 3 ft to the west of the partial partition and 1½ ft from the south wall. Because gasoline-driven generators were to be run in Structure II-2 (Station 8002), the cage was placed on the top landing of the main stairway and not in the main personnel chamber. The exact locations of the cages in these structures are shown in Figs. 2.3 through 2.7.

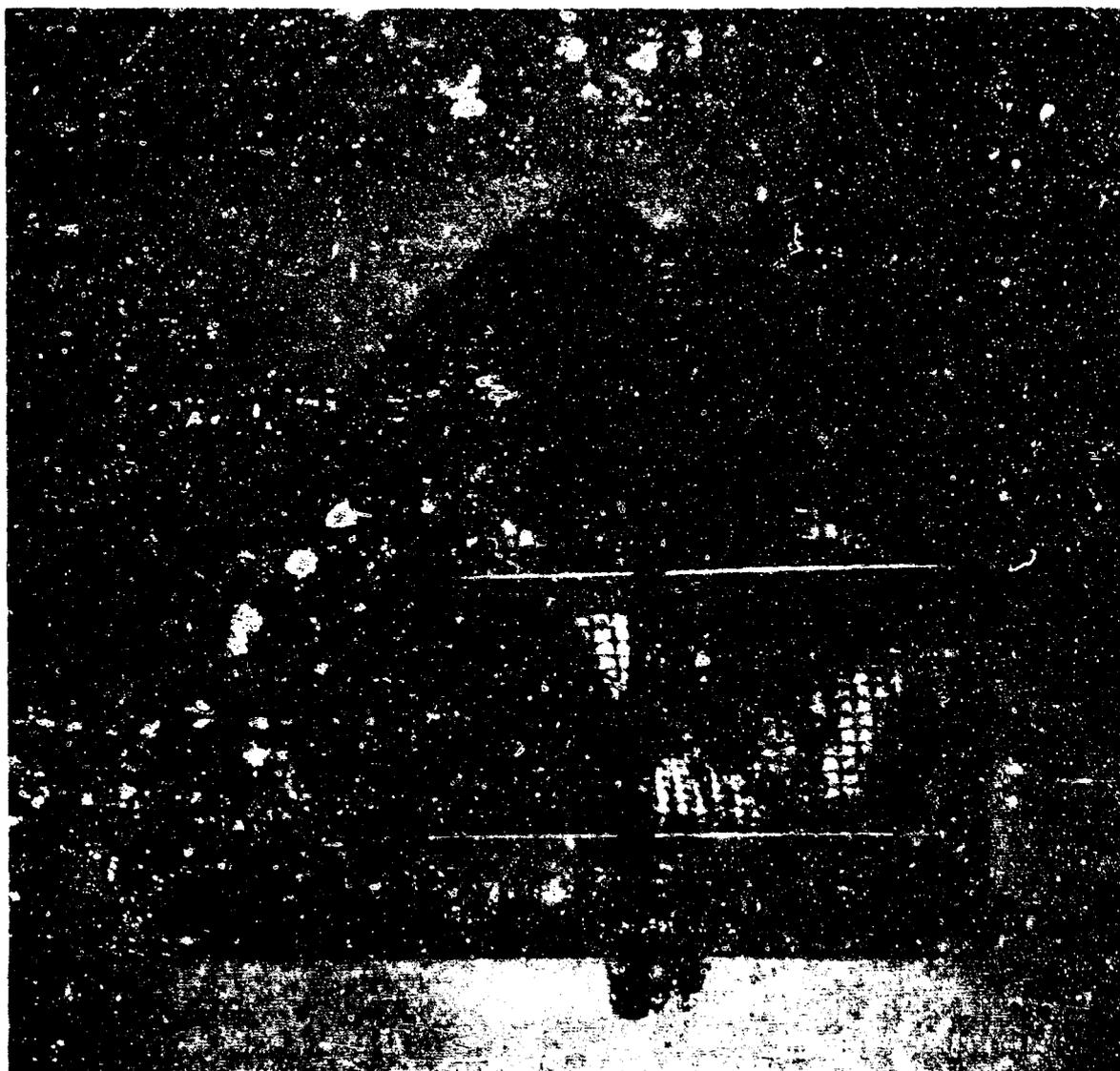


Fig. 2.2 - Mouse-cage installation.

(b) *German Shelters*. A cage of 20 mice was placed in each of seven of the nine German shelters. In all but one case the cage was placed on the floor of the main chamber 1½ ft from the north wall and 3 ft east of the inner-door baffle partition. The exception was in Shelter CAb (Station 8012), where the cage was placed on the floor of the main personnel chamber in the approximate center of the room. There were no mice in Structures RAa (Station 8010) and CAa (Station 8009). A more exact location of the animal cages can be seen in the plan drawings of

the shelters in Figs. 2.8 through 2.14. This information is provided in tabular form in Table 2.1. Cages were secured to the floor by a heavy cord stretched across the top of the cage and anchored to the floor by studs (Fig. 2.2).

2.3.2 Time of Placement

Animals were placed in the structures between D-4 and D-3 days. Each day thereafter the food and water supply was replenished up to, and including, D-1 day.

2.3 INSTRUMENTATION

2.3.1 Ionizing Radiation

(a) *Gamma Radiation.* Edgerton, Germeshausen & Grier film badges were used as gamma-radiation dosimeters. They were placed in considerable numbers in the entryway ramp, escape hatch, and inner rooms of each structure by Project 39.1a (WT-1466).

(b) *Neutron Radiation.* Germanium neutron detectors, along with sulfur and gold neutron detectors, were used to measure neutrons of different energies. Germanium detectors were in all the structures except RCb and RCc. Each of four structures at the 1005-ft range from GZ, II-1, II-3, RAc and CA6, contained two sulfur and gold dosimeters.

2.3.2 Pressure-Time Measurements

Ballistic Research Laboratory self-recording mechanical gauges were used to measure and record pressure-time. Gauges were installed in the different compartments of the shelters as well as in the entryway ramps and outside along the main blast line by Project 30.5b (WT-1535).

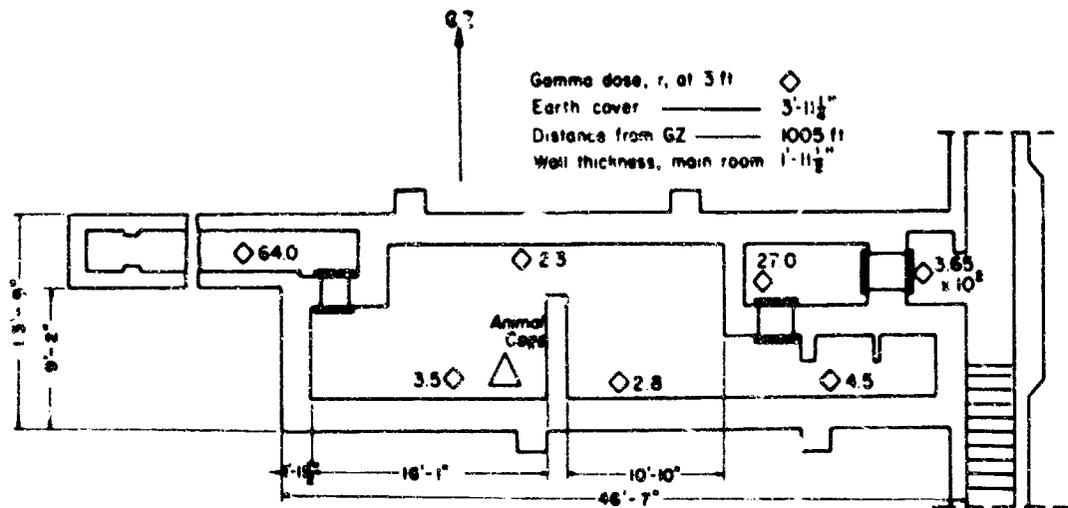


Fig. 2.3—Location of mouse cage in Shelter II-1 (8-30.6-8001).

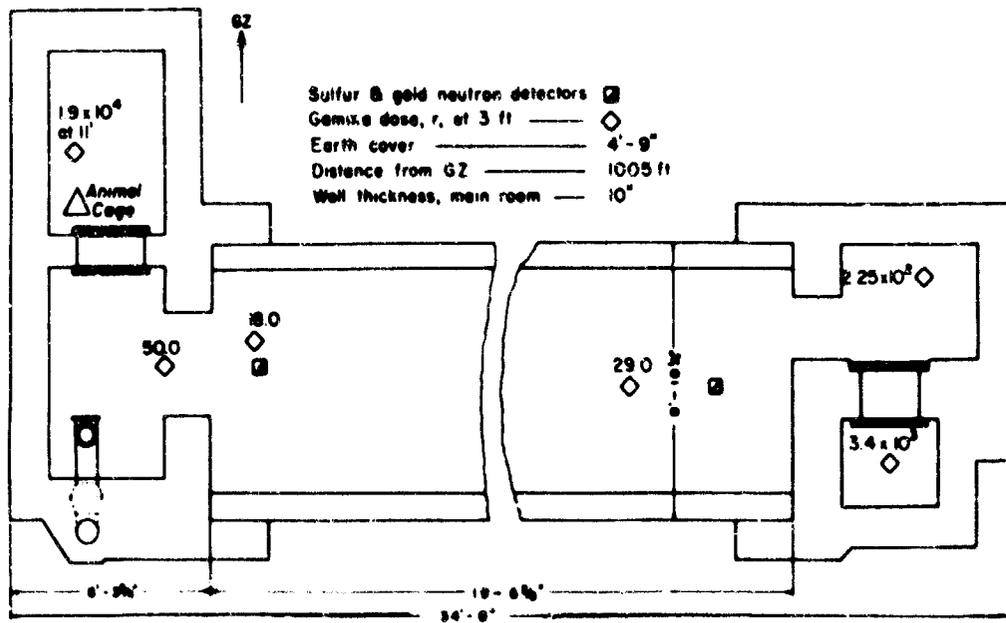


Fig. 2.4—Location of mouse cage in Shelter II-2 (8-30.6-8002).

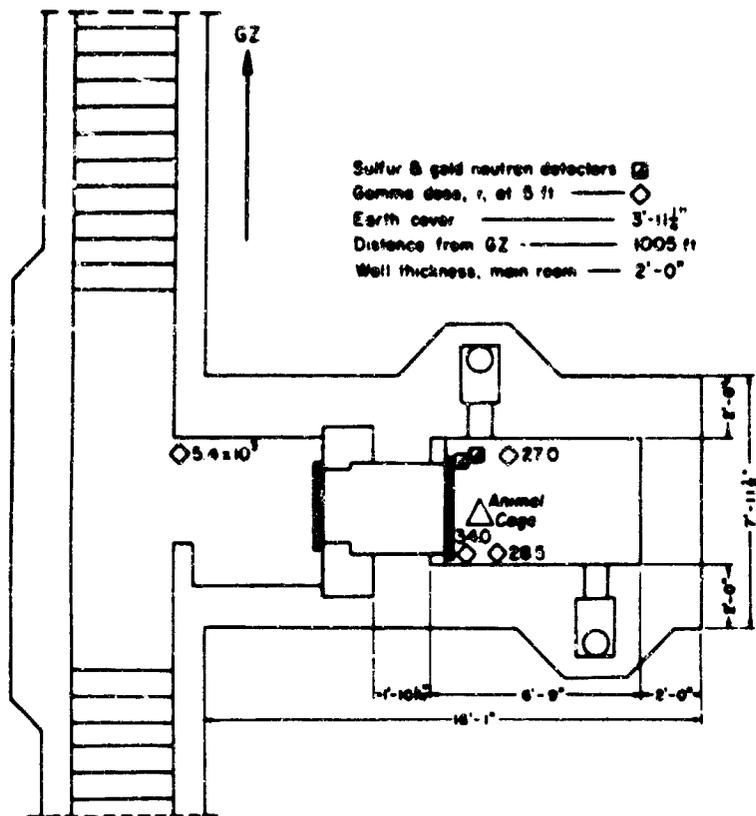


Fig. 2.5—Location of mouse cage in Shelter II-3 (S-30.6-8004).

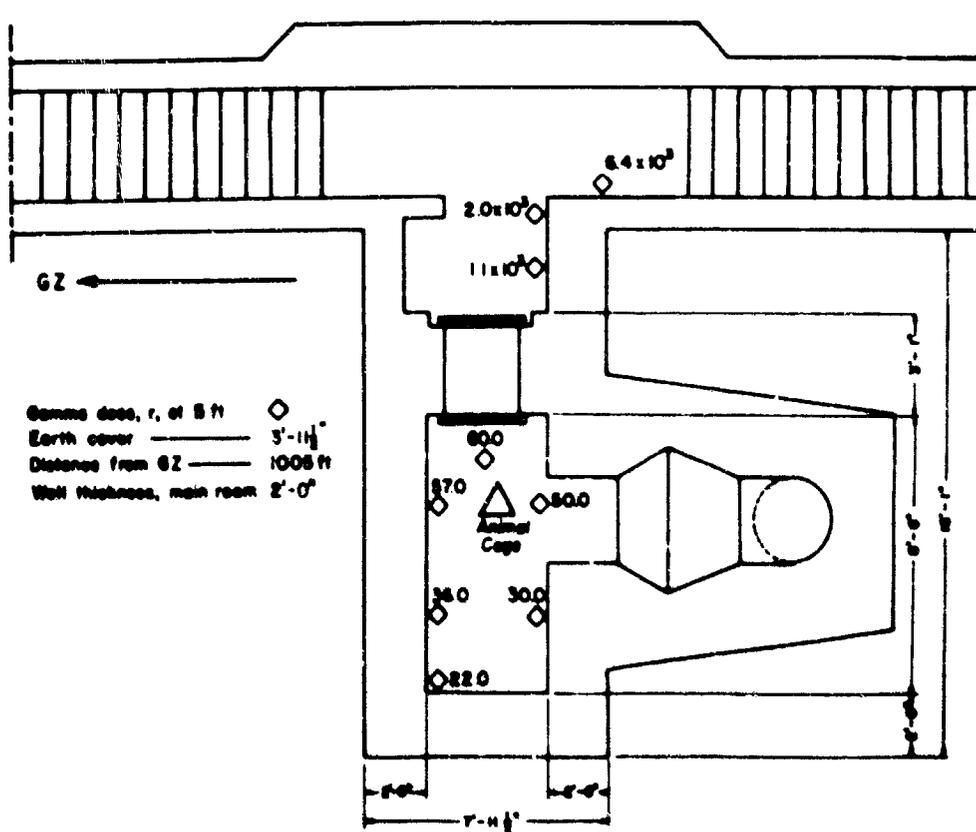


Fig. 2.6—Location of mouse cage in Shelter II-4 (S-30.6-8005).

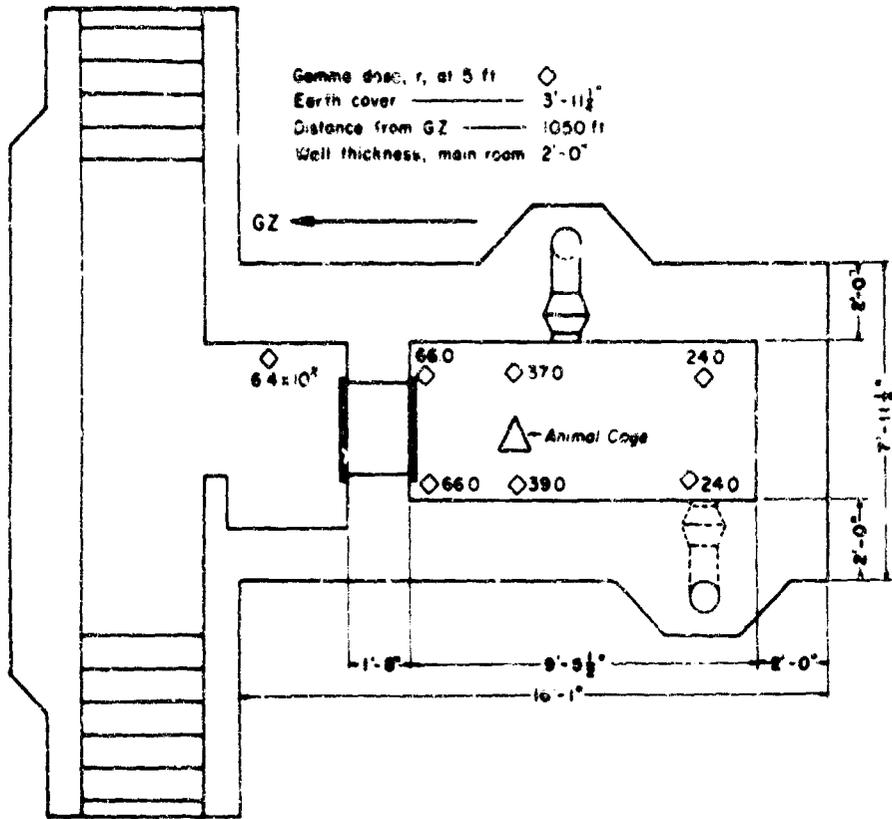


Fig. 2.7—Location of mouse cage in Shelter II-5 (8-30.6-8003).

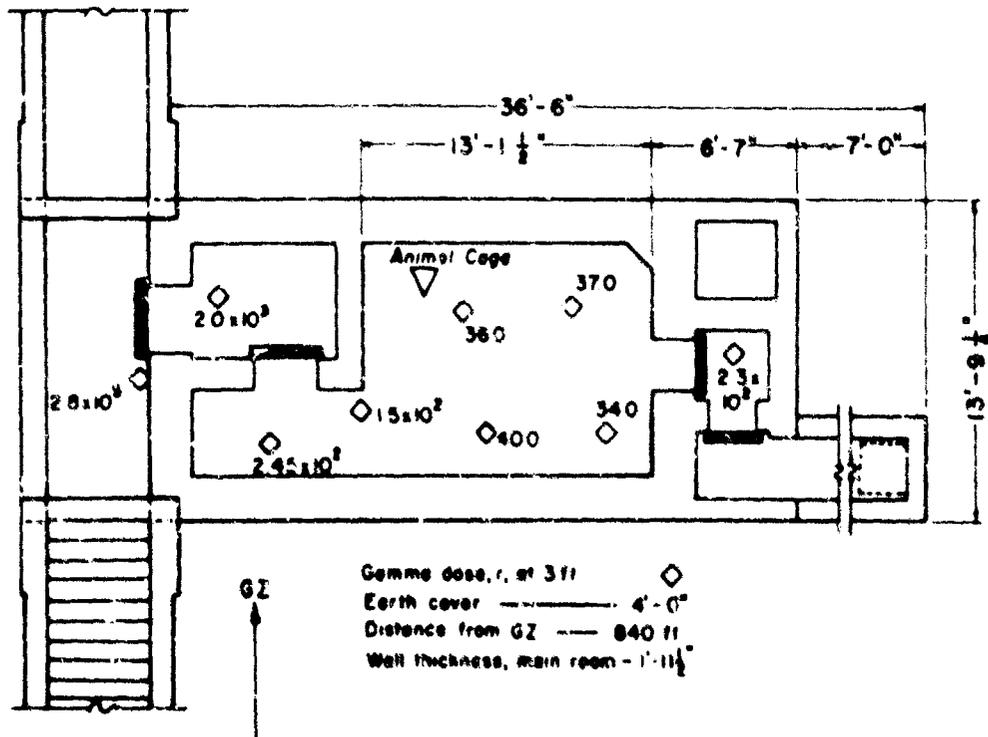


Fig. 2.8—Location of mouse cage in Shelter RAa (8-30.7-8000).

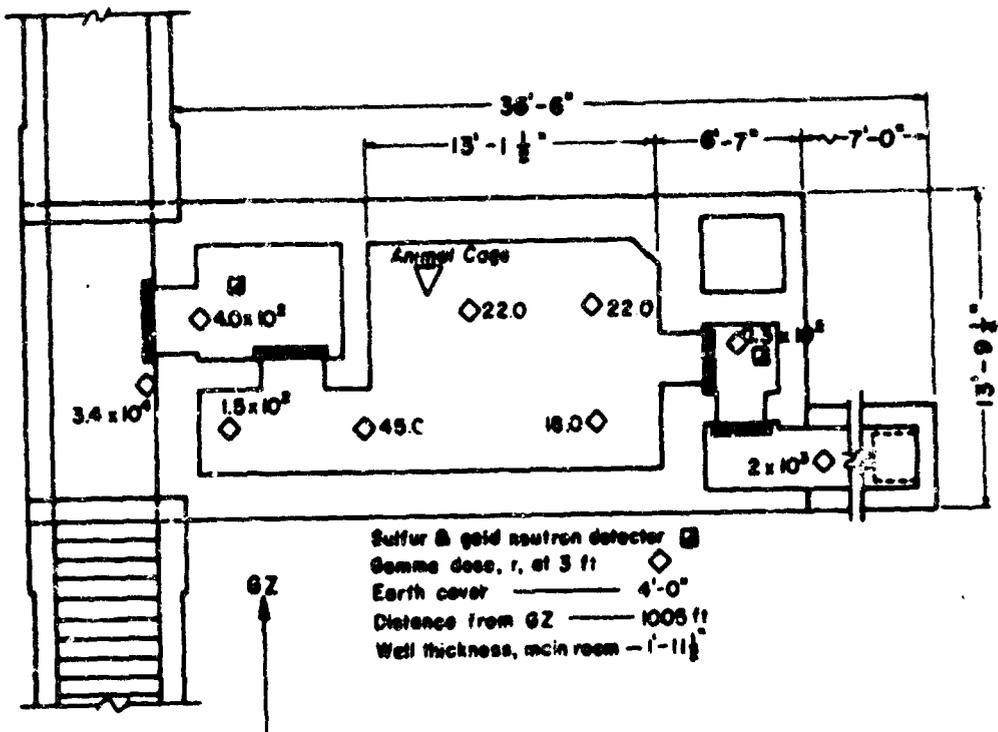


Fig. 2.9—Location of mouse cage in Shelter RAc (8-30.7-8011).

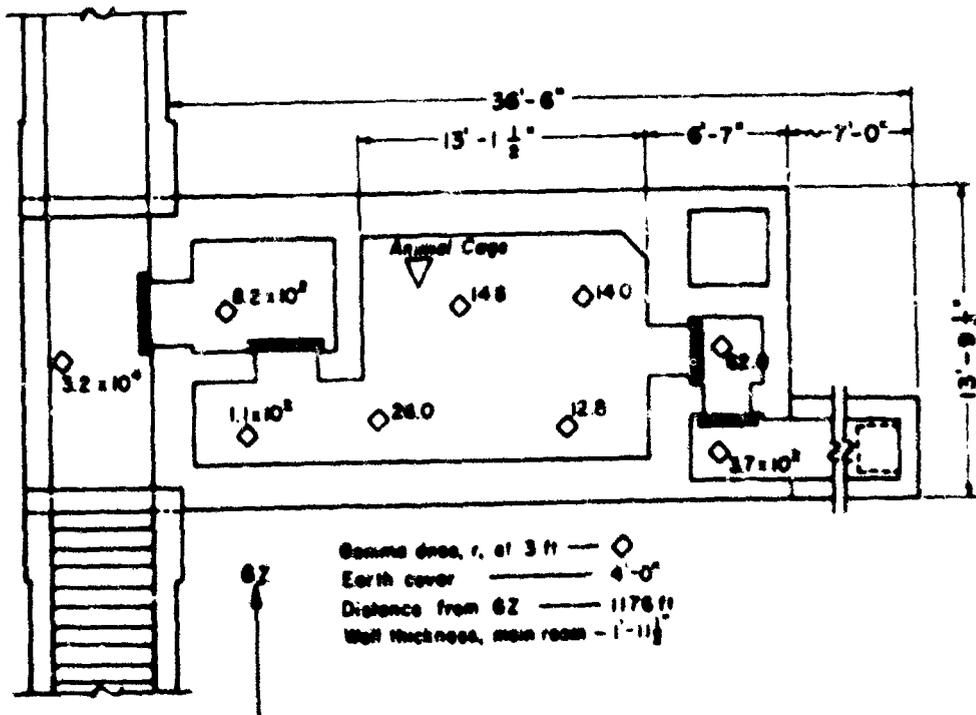


Fig. 2.10—Location of mouse cage in Shelter RAd (8-30.7-8013).

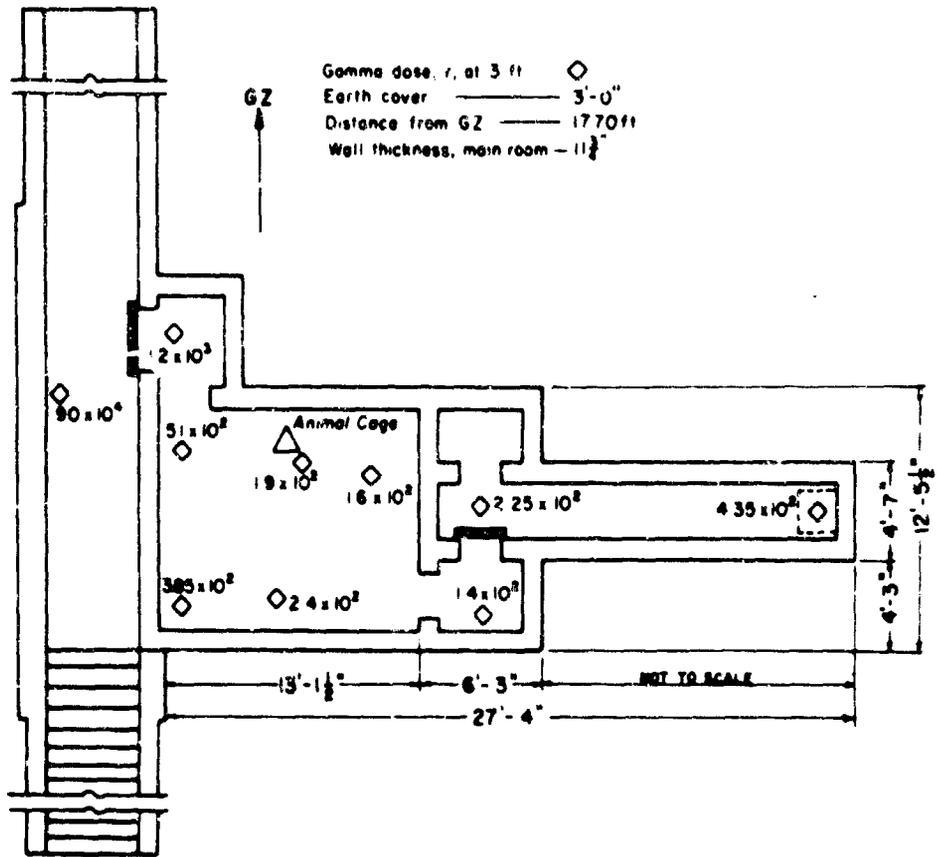


Fig. 2.11—Location of Mouse cage in Shelter RCa (8-30.7-8014).

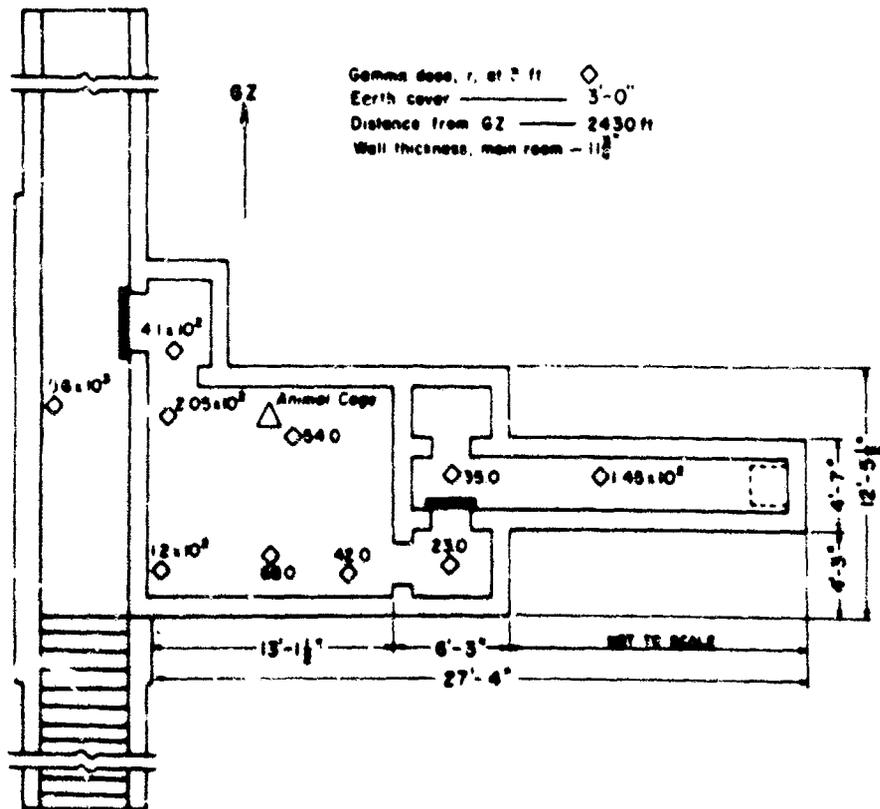


Fig. 2.12—Location of mouse cage in Shelter RCb (8-30.7-8015).

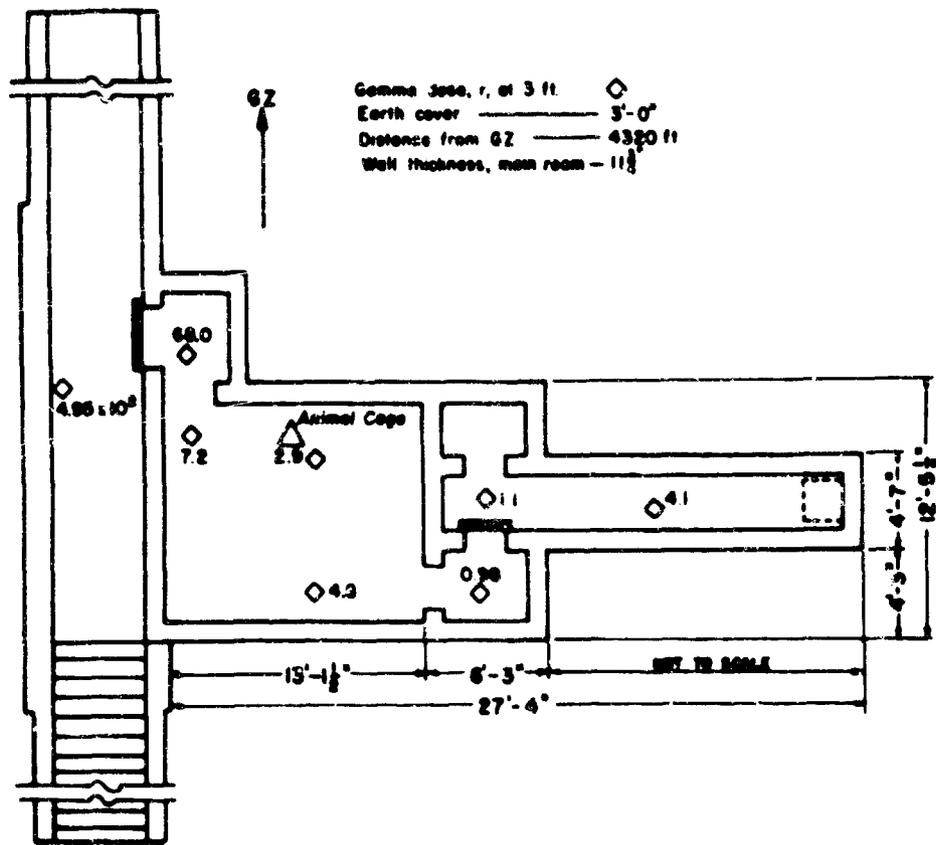


Fig. 2.13—Location of mouse cage in Shelter RCc (8-90.7-0010)

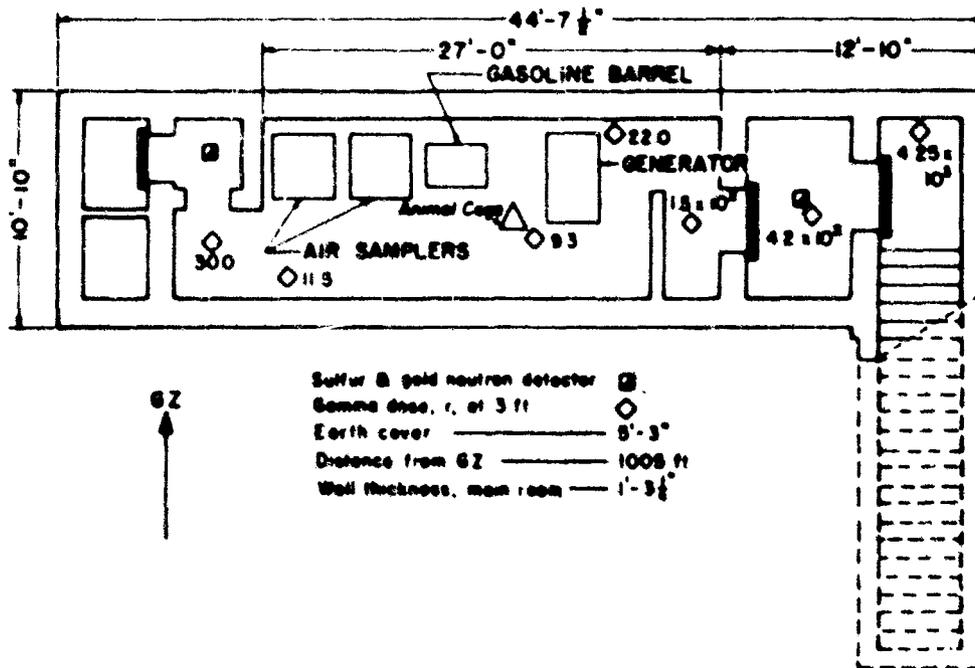


Fig. 2.14—Location of mouse cage in Shelter CAb (8-90.7-0012).

TABLE 2.1—STRUCTURES IN WHICH ANIMAL CAGES WERE LOCATED

Structure No.	Distance from GZ. ft	Wall thickness*	Depth of structure	Location of animal cages
French Shelters				
II-1(S-30.6-8001)	1006	1 ft 11½ in.	3 ft 11¼ in.	Floor of main chamber 1½ ft from south wall and 13 ft from west wall
II-2(S-30.6-8002)	1006	"	"	On first landing in main stairway
II-3(S-30.6-8004)	1006	2 ft 0 in.	3 ft 11¼ in.	On table in main chamber 3 ft high
II-4(S-30.6-8006)	1006	2 ft 0 in.	3 ft 11¼ in.	On table in main chamber 3 ft high
II-5(S-30.6-8003)	1060	2 ft 0 in.	3 ft 11¼ in.	On table in main chamber 3 ft high
German Shelters				
RAa(S-30.7-8008)	840	1 ft 11¼ in.	4 ft 0 in.	On floor of main chamber 1½ ft from north wall and 3 ft from partition door
RAc(S-30.7-8011)	1006	1 ft 11¼ in.	4 ft 0 in.	On floor of main chamber 1½ ft from north wall and 3 ft from partition door
RAd(S-30.7-8013)	1176	1 ft 11¼ in.	4 ft 0 in.	On floor of main chamber 1½ ft from north wall and 3 ft from partition door
RCa(S-30.7-8014)	1770	11¾ in.	3 ft 0 in.	On floor of main chamber 1½ ft from north wall and 3 ft from partition door
RCb(S-30.7-8015)	2430	11¾ in.	3 ft 0 in.	On floor of main chamber 1½ ft from north wall and 3 ft from partition door
RCc(S-30.7-8016)	4320	11¾ in.	3 ft 0 in.	On floor of main chamber 1½ ft from north wall and 3 ft from partition door
CAB(S-30.7-8012)	1066	1 ft 3¼ in.	3 ft 3 in.	On floor in the approximate center of the main chamber

* Not in main chamber.

Chapter 3

RESULTS

3.1 TIME OF RECOVERY

Because of high radiation levels following the shot, it was D+2 days before the animals were recovered from the shelters. Those in the stairway of Structure II-2 (Station 8002) were not recovered until D+3 days.

3.2 IMMEDIATE MORTALITY

There were no immediate deaths as a result of the nuclear detonation among any of the mice that were located in the main chamber of the structures. All 20 mice from Shelter CAB (Station 8012) were dead upon recovery; however, the cause of death, as determined by a pathologist, was carbon monoxide poisoning. The source of the carbon monoxide was a gasoline-driven generator. Even though the exhaust of the gasoline engine was piped to the outside, carbon monoxide gas evidently leaked passed the cylinders down through the oil pan and into the room. The only other animals dead at recovery were 10 of the 20 mice located in the stairway of Structure II-2 (station 8002) shown in Fig. 2.4, a position that provided little radiation shielding.

3.3 RADIATION AND OVERPRESSURE MEASUREMENTS

3.3.1 Radiation Measurements

(a) *Gamma Radiation.* Since the gamma-radiation levels varied considerably within the same shelter, some of the values obtained at different locations have been added to the plan drawings (Figs. 2.3 through 2.14). As one would expect, the radiation levels in the entryway ramps were high. Within the structures the highest readings were just inside the outer main door and in the escape hatch. Within the main personnel chamber the gamma radiation was highest near the wall that separated the room from the entryway ramp, the values decreasing toward the center of the room. This pattern was particularly true in the German shelters of the RA and RC design (Figs. 2.8 through 2.12).

Table 3.1 lists the gamma dose (in roentgens) as measured by the film badge that was closest to the animals' cage or, in Structures II-3, II-4, and II-5, the average of a reading taken on either side of the room opposite the cage. The highest gamma dose to which mice were exposed (190 r) was recorded adjacent to the cage in Shelter RCa. This shelter was not the closest to GZ but was at the 1770-ft range. The lower levels that animals received were 2.0 r in II-1 and 2.9 r in RCc at the 1008- and 4320-ft ranges, respectively. As seen in Table 3.1, the other doses ranged between 14.8 r and 54.0 r.

TABLE 3.1—MORTALITY FOR MICE EXPOSED IN UNDERGROUND SHELTERS

Structure designation	Distance from GZ, ft	Peak pressure inside shelter, psi	Gamma radiation inside shelter, r	Number of deaths by days*			
				15	30	45	60
II-1	1008	0.3	3.0	0	0	0	0
II-3	1008	1.6	27.7†	1	2	9	11
II-4	1008	14.4	83.5†	1	2	7	13
II-5	1080	1.5	38.9†	4	5	5	5
RAa	840	‡	36.0	1	2	2	2
RAc	1008	0.2	22.0	0	1	1	1
RAd	1176	‡	14.8	0	1	1	2
RCa	1770	0.8	190.0	0	1	1	1
RCb	2430	0.3	84.0	0	0	0	0
RCc	4320	‡	2.9	0	3	12	12
Control 1				0	0	0	0
Control 2				0	0	2	2

* A group of 20 mice in each shelter.

† Average of two film-badge dosimeters that were located on either side of the chamber. The other values were from a single badge dosimeter close to the animal cage and 3 ft above the floor. No neutron measurements were taken adjacent to an animal cage.

‡ No results available.

TABLE 3.2—NEUTRON MEASUREMENTS INSIDE STRUCTURES

Shelter designation	Location of detectors inside structures*	Fast neutron		Slow neutron	
		Neutrons/sq cm	Calculated dose, rad	Neutrons/sq cm	Calculated dose, rad
II-2	Personnel chamber (east end)	2.318×10^7	0.83	1.568×10^{10}	0.79
	Personnel chamber	†			
II-3	Main chamber	†			
	Main chamber	†			
RAc	Between outer and inner blast doors	2.362×10^9	84	2.217×10^{12}	116.9
	Inner compartments of escape hatch	1.103×10^8	2.8	7.421×10^{10}	3.7
CAb	Between outer and inner blast doors	2.296×10^8	8.7	7.147×10^{11}	28.7
	Inner compartment of escape hatch	†			

* For the location of each dosimeter see also Figs. 2.4, 2.8, and 2.14.

† No results available.

(b) *Neutron Measurements.* There are only a few neutron measurements available.* No reliable results were obtained from the germanium detectors, and only four of the eight sulfur and gold dosimeters were recovered. The results of four sulfur and gold detectors are given in Table 3.2. Although none of these measurements were made in the main room with an animal cage, they do provide some indication of how much neutron radiation may have entered these rooms.

In the main personnel chamber of Shelter II-2, the fast- and slow-neutron doses were calculated† from the measured flux intensities to be 0.83 and 0.79 rad, respectively (see Table 3.2). Between the outer and inner blast doors of Shelter RAc, the fast- and slow-neutron fluxes were equivalent to 84 rad and 115.9 rad. In the escape hatch at the opposite end of the same structure, values of 2.8 rad and 3.7 rad were measured for fast and slow neutrons. Inside the outer door of Structure CAb, which was oriented differently than RAc, only 5.7 rad and 35.7 rad were recorded for fast and slow neutrons.

3.3.2 Pressure-Time Measurements

Although numerous pressure-time measurements were made both inside and outside the shelters, only the peak pressures recorded in the room that contained animals are given in Table 3.1. The only pressure within the shelters of any consequence (14.4 psi) resulted when the blast-closing valve in the ventilation duct of Structure II-4 failed to close. For detailed results the reader is referred to the reports of Projects 30.5b and 30.5c, WT-1535 and WT-1538.

3.4 DELAYED MORTALITY

The number of mice dead by 15, 30, 45, and 60 days postshot are tabulated in Table 3.1, along with the gamma dose and peak pressure. A graph showing the number of mice surviving vs. time is presented in Fig. 3.1. There were no deaths among the II-1 or RCb groups and only a single fatality in the RCa and RAc groups. Two of the control mice expired in the 60-day postshot period.

According to the data in Table 3.1, the number of deaths in each group had no relation to the magnitude of the gamma radiation which the animals received. For example, only one mouse died from the RCa group, which was subjected to the highest dose (190 r); whereas 12 mice died in the sample from RCc, which was exposed to only 2.9 r.

The most fatalities (13) occurred in the sample from II-4 in which an overpressure of 14.4 psi was recorded. However, the deaths were not attributed to blast since there were no immediate deaths in that group.

3.5 PATHOLOGICAL FINDINGS

A chronic infection of *Salmonella* (mouse typhoid) in the animal colony undoubtedly was the cause of the delayed deaths. At autopsy, splenomegaly and enlarged spotted livers were invariably found. This, along with diarrhea and congested livers (observed histologically), plus the actual identification of the organism from cultures taken from contents of the gastro-intestinal tract, left little doubt regarding this conclusion.

* See the report of Project 30.1b, WT-1471.

† The authors are indebted to Mr. J. Bayeg, Health Division of the Los Alamos Scientific Laboratory, for these calculations.

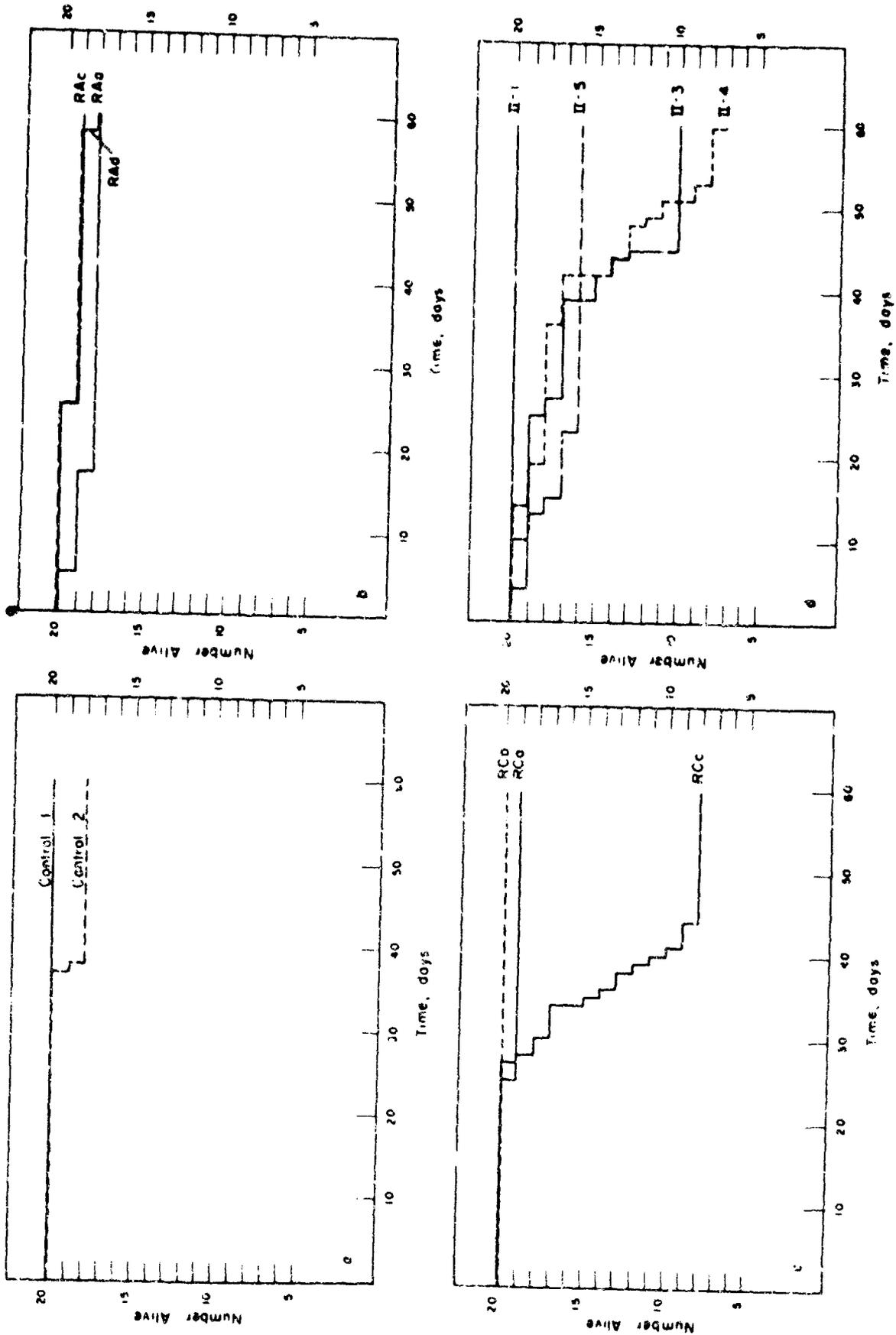


Fig. 3.1—Mouse survival over a 60-day postshot period.

Chapter 4

DISCUSSION

Of the immediate effects from a nuclear detonation (thermal radiation, ionizing radiation, and blast), it appears that ionizing radiation was the only one to reach biologically significant levels, most notably in the German structures of the RC and RA design. The gamma-radiation levels of over 100 r recorded in the west end of the main personnel rooms are undesirably high and would be acceptable for man only in the gravest emergencies (see Figs. 2.8 through 2.12). Moreover, if the neutron radiation followed the same general pattern as did the gamma, the radiation levels may well have been still higher because 200 rad of neutron radiation was measured inside the main door of Shelter RAc.

Unfortunately, the mice were placed in that portion of the main rooms where radiation levels happened to be minimal. The various groups were therefore exposed to sublethal levels of radiation.

That all 20 animals survived in the French Shelter II-1 draws one's attention to the encouraging fact that the environment inside the shelter, only 1005 ft away from a 43-kt nuclear explosion, no doubt would have allowed survival of human occupants.