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February — May 1955

Project 32.4

THE EFFECT OF NUCLEAR EXPLOSIONS ON SEMIPERISHABLE FOODS AND FOOD PACKAGING

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Report to the Test Director

THE EFFECT OF NUCLEAR EXPLOSIONS ON SEMIPERISHABLE FOODS AND FOOD PACKAGING

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ABSTRACT

Semiperishable foods were exposed to two atomic shots of Operation Teapot, identified for purposes of this report as Shot I and Shot II. The yield of Shot I was approximately nominal (a nominal atomic bomb has an energy release equivalent to 20 kt of TNT). The yield of Shot II was approximately 50 per cent greater than nominal. Ten types of semiperishable products (apples, oranges, potatoes, onions, raisins, dry beans, dry milk, cereals, flour, and candy) were exposed at distances of ½ mile to 2 miles from the blast. Foods were placed in trenches at approximately 1270 and 2750 ft and were covered with 1 to 2 in. of soil. At these locations foods were subjected to high initial radiation and blast overpressures. Foods also were placed on shelves in kitchens and basements of houses constructed at the test site at distances ranging from 4700 to 10,500 ft.

At the close-in buried positions many types of food packages were partially crushed; some were broken, and their contents were contaminated with radioactive dirt. A high percentage of the apples, potatoes, onions, and oranges were severely crushed and bruised at the 1270-ft location, greatly reducing their possible food value in an emergency. As a result of the mechanical damage to the produce, decay during subsequent storage was much higher than in nonexposed produce.

Many of the semiperishable foods recovered from the 1270- and 2750-ft trench positions were radioactive from the initial neutron bombardment. This was mostly induced radioactivity, rather than the surface type of contamination from fall-out. Most of this induced radioactivity decayed within 3 to 4 days, and food in intact packages could then be used, if needed, in an emergency. Dry milk, dry beans, raisins, and ready-mixed cake and biscuit flours were types of semiperishable staples which were found to have high levels of induced radioactivity. Potatoes showed higher levels of induced activity than onions, apples, or oranges. The initial radiation caused no visible effect on the foods or packages other than to cause a slight darkening of glass containers. However, potatoes exposed at 1270 and 2750 ft from the explosion failed to develop normal sprouts during subsequent storage. The high initial radiation from neutrons or gamma rays is assumed to have inhibited sprouting.

The type of package, whether glass, tin, chipboard, or plastic film, appeared to have no protective effect on the extent of induced radioactivity of the contents. For example, rolled oats in a tin can or in a chipboard carton showed a similar amount of radioactivity, and raisins in aluminum-foil packages or in transparent film packages showed similar radioactivity.

Food products in houses as close as 4700 ft were substantially free of induced radioactivity. No induced radioactivity was present in foods exposed in the houses at 5500, 7800, or 10,500 ft.

Damage to foods in kitchens of houses at 4700, 5500, and 7800 ft was due principally to gross dislodgment from cupboards by the blast or from secondary missiles such as glass or wood splinters. The amount of bruising from the blast to perishable fruits and vegetables in these houses was negligible.

There was no bursting of food packages at any exposure location. As expected, houses provided considerable protection from the blast for packaged foods. Most types of consumer

packages withstood the physical shock of falling from cupboards to the floor. Chipboard cartons with film windows and cellophane bags were two types of containers that broke most frequently on falling.

Generally, foods fared much better when stored on basement shelves than on kitchen shelves as far as blast damage from dislodgment was concerned. Foods did not fall from basement shelves even in houses where the above-ground portion of the house was destroyed. A basement food storage cabinet should be a relatively safe place for a family's emergency food supply.

The flavor of a few products was damaged when exposed in the forward trench positions. The nonfat dry milk samples from the 1270-ft position had a very strong stale flavor and odor when reconstituted. This off-flavor was less intense in dry milk samples exposed at 2750 ft, but it was still objectionable. In general, the palatability of foods exposed to the atomic detonation in houses at 4700 ft and beyond was unaffected.

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CHAPTER 1

INTRODUCTION

This report covers one phase (Project 32.4) of the food testing program conducted during the spring of 1955 at the Nevada Test Site (NTS) of the Atomic Energy Commission. Other phases of the food test concerning staples, canned foods, meat and meat products, and frozen foods are described in separate reports.

About 90 food products were subjected to atomic explosions at distances ranging from $\frac{1}{4}$ mile to 15 miles. Of this number, results with 10 commodities in different types of packages are included in this report. The commodities were apples, oranges, potatoes, onions, raisins, dry beans, dry milk, flour, cereals, and candy. Readers particularly interested in staples will also want to examine the report for Project 32.1, WT-1163.

CHAPTER 2

OBJECTIVES

The major question to be answered involved the fitness for human consumption of semiperishable foods found in undamaged containers following an atomic disaster. Another objective was to determine what types of damage to food may occur at various distances from the center of a nuclear detonation. Such information is of value to the Federal Civil Defense Administration to aid in preparedness.

The objectives in testing semiperishable foods, some of which were composed of living plant tissue, were to determine the extent of physical damage to the product and to various types of containers and also to note any organoleptic changes, surface contamination, or induced radioactivity. If packaged foods become radioactive, what limitations, if any, must be placed on the handling of the containers and the consumption of the contents? A number of different kinds of wholesale- and retail-size packages were included in the study in an effort to establish guide lines for the best preservation of foods from radioactive fall-out contamination and from blast damage.

Criteria of possible exposure effects on the semiperishable foods (besides physical damage from blast, heat, secondary missiles, or from induced radioactivity) were changes in color, odor, flavor, or texture, rate of softening, and extent of decay and sprouting (with onions and potatoes).

CHAPTER 3

BACKGROUND

Little information is available on the effect of a nuclear detonation on food and food packaging. Peterson et al.[1] made calculations, based on cyclotron studies, of induced radioactivity in foods anticipated following a nominal bomb burst. They reported that of the elements in most foods only sodium, phosphorus, and potassium are in high enough concentration to yield radioactive products of practical importance. They calculated that the radioactivity induced in foods at a distance of 1700 ft would be so low that the ingestion of reasonable amounts would give a radiation dose that is insignificant compared to presently accepted tolerance doses. Aside from induced radioactivity, an additional problem with food after the detonation of a nuclear device may be surface contamination, when radioactive materials fall on food or food packages. This type of contamination may be fairly easy to wash or brush off, making the product safe to use. This is in contrast to the induced type of radioactivity, where the activity is all through the product and cannot be washed off.

If radioactivity is induced in some of the exposed foods, it will be caused by the initial neutron flux associated with the detonation rather than from gamma radiation. Meinke[2] in laboratory studies has shown that gamma rays from a Co^{60} source induced no radioactivity in food elements. He irradiated 24 elemental food constituents, such as calcium, iron, phosphorus, potassium, sodium, and sulfur, with a high dosage of gamma rays and found no induced radioactivity when these elements were checked with the usual radiation monitors.

Most of the work on radiation sterilization has been done with gamma irradiation using 500,000 to 1,000,000 r. Gamma radiation in these Nevada food tests was not expected to be nearly this high, except perhaps at close-in areas of complete destruction. Gamma radiation 2,000 ft from a nominal 20-kt nuclear device might be approximately 10,000 r. Sparrow and Christensen[3] and Brownell et al.[4] have reported that gamma dosages of 10,000 to 20,000 r are effective in inhibiting potato sprouting and prolonging storage life. This use of gamma radiation is now being adapted for possible commercial application in potato storage.

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CHAPTER 4

EXPERIMENTAL PROCEDURES

Semiperishables were exposed to two shots of Operation Teapot, identified for purposes of this report as Shot I and Shot II. The yield of Shot I was approximately nominal (a nominal atomic bomb has an energy release equivalent to 20 kt of TNT). The yield of Shot II was approximately 50 per cent greater than nominal.

Participation on Shot II (during which Operation Cue of the Federal Civil Defense Administration was conducted) was on a much larger scale than for Shot I. Food products were both buried in trenches and exposed on the ground surface. In addition, several houses of varying construction were erected at different distances from Ground Zero (GZ) on Yucca Flat for Shot II, and food products were placed in them to simulate actual home storage.

4.1 TEST STATIONS OR LOCATIONS

Semiperishable foods packaged in different types of wholesale- and retail-size containers were exposed at several distances from GZ. Two stations in each shot were selected as close enough to receive heavy exposures to nuclear and thermal radiation and high blast overpressures. For Shot I, exposure was in trenches at 1100 ft (Station A) and 3600 ft (Station B) and on the ground surface at 1 mile (Station C) west of GZ (Table 4.1). In addition, three fall-out food test stations were set up on the ground surface; two were $4^3/_4$ and 7 miles north of GZ, and one was 15 miles east of GZ. The two nearer fall-out stations were enclosed in a poultry wire cage to keep out predators but were shielded in no way from fall-out (Fig. 15). At the 1100-ft location samples were buried at three depths: (1) flush with no soil cover, (2) with 1 in. of soil cover, and (3) with 12 in. of soil cover. This was intended to give varying amounts of protection from nuclear and thermal radiation. At the 3600-ft location all samples were buried with 1 in. of protective soil cover. The light soil cover was used to prevent flash burn, but the main purpose of burying the test foods was to prevent physical displacement and possible total loss of experimental materials. Figure 2 shows the arrangement of food packages at different depths in the trench at 1100 ft, and Fig. 3 shows the ground surface food station 1 mile from GZ.

Locations of exposure for Shot II, which was the main test, were more numerous and are described in detail in Table 4.2 (see Fig. 1). Two locations were in trenches at 1270 and 2750 ft (Fig. 5). Six food test locations were in two-story houses. These were in the kitchen and basement of a brick house at 4700 ft (Fig. 26), in the kitchen and basement of a frame house at 5500 ft, and in the kitchens of houses at 7800 and 10,500 ft. Kitchen cabinets with doors were available in the four kitchens, and food packages were spread out on shelves (Figs. 28 and 32). All the kitchens were in the back of the test houses away from the blast. In the basement, open shelves along the rear walls away from the blast were used for food storage (Figs. 30 and 34).

Three food stations in Shot II were on the ground surface in a quadrant calculated to be in the fall-out zone and beyond the range of the initial effects. These were located about 15 miles northeast of GZ. It was hoped that the test packages in at least one of these distant stations would be showered by fall-out from the radioactive cloud and become contaminated.

Table 4.1 — LOCATION OF EXPOSURE OF SEMIPERISHABLE FOODS IN DIFFERENT TYPES OF CONTAINERS FOR SHOT I

Exposure station and distance from GZ	Products tested	Size and type of container
Station A, trench, 1100 ft, buried flush, no soil cover	Apples	1-bu wooden box
	Potatoes	30-lb kraft bag
	Onions	25-lb mesh bag
	Semiperishable staples (14 items)	30-lb wooden tomato lug with paperboard liners
Station A, trench, 1100 ft, buried, 1-in. soil cover	Apples	1-bu wooden box
	Potatoes	30-lb kraft bag
	Onions	25-lb mesh bag
	Semiperishable staples (14 items)	30-lb wooden tomato lug with paperboard liners
Station A, trench, 1100 ft, buried, 12-in. soil cover	Apples	1-bu wooden box
	Potatoes	30-lb kraft bag
	Onions	25-lb mesh bag
	Semiperishable staples (14 items)	30-lb wooden tomato lug with paperboard liners
Station B, trench, 3600 ft, buried, 1-in. soil cover	Apples	1-bu wooden box
	Potatoes	30-lb kraft bag
	Onions	25-lb mesh bag
	Semiperishable staples (14 items)	30-lb wooden tomato lug with paperboard liners
Station C, ground surface at 1 mile	Apples	1-bu wooden box
	Potatoes	30-lb kraft bag
	Onions	25-lb mesh bag
	Semiperishable staples (14 items)	30-lb wooden tomato lug with paperboard liners
Fall-out Station A, ground surface at $4\frac{3}{4}$ miles	Apples	1-bu wooden box
	Onions	25-lb mesh bag
	Potatoes	30-lb kraft bag
	Semiperishable staples (14 items)	30-lb wooden tomato lug with cover removed
Fall-out Station B, ground surface at 7 miles	Apples	1-bu wooden box
	Potatoes	30-lb kraft bag
	Onions	25-lb mesh bag
	Semiperishable staples (14 items)	30-lb wooden tomato lug with cover removed

4.2 SEMIPERISHABLES TESTED

Products tested in Shot I included three kinds of fresh produce, Delicious apples, Yellow Globe onions, and Russet Burbank potatoes; and five kinds of semiperishable staples, seedless raisins, dry baby lima beans, nonfat dry milk solids, bleached flour, and various cereals (rice, rolled oats, Grape Nuts, and sugar-coated corn pops). The disposition of these foods at the various test stations is described in Table 4.1. Potatoes, onions, and apples were selected because they have a relatively long shelf life under nonrefrigerated conditions. It was necessary to complete placement of samples for exposure at approximately D−2 day and recovery was completed at D+2 day. This minimum period of 4 days, plus the time required to prepare the samples at Fresno, Calif., or Las Vegas, Nev., and transport them by truck to NTS, in addition to postponements due to adverse weather, precluded the testing of some of the more perishable kinds of fresh produce. Postponements after the scheduled date amounted to several weeks for Shot I and 9 days for Shot II.

Table 4.2 — EXPOSURE LOCATIONS OF SEMIPERISHABLE FOODS FOR SHOT II

Location code	Description of location
1	Station A, trench, 1270 ft south (azimuth 150°) of GZ
2	Station B, trench, 2750 ft south (azimuth 150°) of GZ
3 and 4	Kitchen and basement of two-story brick house 4700 ft south (azimuth 150°) of GZ
5 and 6	Kitchen and basement of two-story frame house 5500 ft south (azimuth 150°) of GZ
7 and 8	Kitchen of two-story frame house at 7800 ft and kitchen of two-story brick house 10,500 ft east (azimuth 110°) of GZ
9	Ground surface, beside two-story brick house 10,500 ft east of GZ; food samples, each packaged in a different kind of container, were placed on sheet of masonite in exposed position where contamination from fall-out was probable
10, 11, 12	Ground surface, approximately 15 miles northeast of GZ in Papoose Valley at three locations (azimuth 45, 60, and 70°); food samples arranged to receive fall-out the same as at location No. 9
13	Check, nonexposed samples at NTS; samples held in quonset hut at Camp Mercury under temperature conditions fairly similar to those at test site

Semiperishables tested in Shot II included four kinds of fresh produce: Washington State Winesap apples (size 138), Arizona Valencia oranges (size 220), Utah Russet Burbank potatoes (old crop, 4- to 10-oz size), and Texas White Crystal Wax onions (new crop, $1\frac{1}{2}$- to 3-in. size). In addition, six types of semiperishable staples were tested: seedless raisins, dry baby lima beans, nonfat dry milk solids, and various kinds of flour, cereals, and candy.

Check packages of the produce items and of the staples, not exposed to the detonation, were brought to the NTS so that they would undergo approximately the same temperature and transportation conditions as the exposed packages. Outdoor temperatures during the test period varied from 40 to 70°F.

Cultures of five common fruit and vegetable decay-producing fungi in 8-in. glass test tubes also were exposed at three locations in Shot I. The fungi included were *Penicillium* sp., *Aspergillus* sp., *Botrytis* sp., *Cladosporium* sp., and *Stemphylium* sp.

4.3 CONTAINERS TESTED

All the products exposed were packaged in two or more ways. Usually at least one common wholesale type container was included as well as several types of retail-size packages (see

Figs. 6 to 14). The appendix lists the 62 different combinations of products and containers included in the tests and gives the size and description of each. Containers made of fiberboard, chipboard, tin, glass, kraft paper, waxed paper, aluminum foil, paper mesh, cellophane, polyethylene, Pliofilm, Mylar, and laminations and combinations of these materials were represented (Table 4.3). Some of the products and types of containers were not included at all the exposure locations. In most instances only a single package of each type was placed at any one of the locations.

Exposure of the retail-size packages of the semiperishable staples in the buried positions was in master containers of wood to facilitate placement and recovery. For this purpose a standard 30-lb tomato lug was used for Shot I (Fig. 4), and a standard $^4/_5$-bushel pear box was used for Shot II (Fig. 5). Masking tape over all cracks between slats helped to exclude the dirt placed over the boxes.

All the foods other than the fresh produce items and all the packaging materials were donated through the generous cooperation of manufacturers or their representatives.

4.4 PRODUCT EVALUATION

Following the nuclear detonation the extent of physical damage, such as breakage, crushing, and bruising, to the products was recorded either at the scene or after recovery and transport to Camp Mercury. Recovery of the foods in the test houses at 4700 ft or at greater distances from GZ began 7 or 8 hr after the explosion and after documentary photographs were taken. Recovery of the food buried in trenches was delayed until the following day to allow some of the ground radioactivity in the area to decay. After the initial examination some of the products were taken to the Horticultural Laboratory of the U. S. Department of Agriculture at Fresno, Calif., for holding tests and further examination. Some products were sent to other research laboratories, mentioned later, for evaluation and analyses.

For the grading analyses of exposed and nonexposed samples of dry milk solids, the methods outlined in Bulletin 911 (revised 1954) of the American Dry Milk Institute were followed. The methods for the determination of protein and ash were standard methods found in the Association of Official Agricultural Chemists (A.O.A.C.), "Methods of Analysis," 1950. Methods used for the other dry milk determinations were as follows: (1) Lactose: Munson and Walker, A.O.A.C., "Methods of Analysis," 1950; (2) color: Method of Choi et al., J. Dairy Sci., 32: 580 (1949); (3) protein reducing value: Method of Choi et al., J. Milk and Food Technol., 16(5) (1953); (4) whey protein nitrogen: Harland and Ashworth, Food Research, 12: 237 (1947); and (5) dispersibility: unpublished method of Stone et al., Quartermaster Food and Container Institute, Chicago, Ill.

All the food samples from the trench locations and those in the nearer houses were examined for radioactivity. Monitoring for beta-gamma activity in counts per minute was done with a Tracerlab instrument, model SU-14 (Alpha Beta Gamma Survey Meter). Measurements were made with the probe-shield open and held with the guard in contact with the package being monitored. A sample of the product from each package was monitored in a tin dish, $3^1/_3$ in. in diameter and $^1/_4$ in. deep, filled to level capacity. When fresh produce was monitored for radioactivity, the probe shield was placed against three specimens in a line on a table.

Dosage of neutrons received at various distances was recorded with gold-foil dosimeters for thermal neutrons and sulfur dosimeters for fast neutrons. The dosage of gamma radiation was measured with high-, intermediate-, and low-range film packs. These film dosimeters, in addition to being placed beside the food at each test station, were placed in the center of kraft bags of potatoes and in polyethylene bags of apples at several locations.

Table 4.3—SEMIPERISHABLE PRODUCTS AND TYPES OF CONTAINERS EXPOSED AT VARIOUS LOCATIONS, SHOT II

Product and type of package	Buried at 1270 and 2750 ft	Kitchens, 4700 and 5500 ft	Basements, 4700 and 5500 ft	Kitchens, 7800 and 10,500 ft
Apples				
1-bu wooden box	x		x*	
1-bu fiberboard carton	x		x*	
5-lb polyethylene bag	x	x	x	x
5-lb mesh bag		x	x	x
5-lb Pliofilm bag		x	x	
5-lb Mylar bag		x	x	
Oranges				
0.7-bu fiberboard carton	x		x*	
5-lb polyethylene bag	x	x	x	
Potatoes				
50-lb kraft bag	x		x*	
10-lb kraft bag		x	x	x
5-lb kraft bag		x	x	
10-lb mesh bag	x	x	x	x
10-lb polyethylene bag		x	x	
Onions				
30-lb kraft bag	x		x*	
3-lb window bag	x	x	x	x
5-lb mesh bag		x	x	
3-lb polyethylene bag		x	x	x
Raisins				
15-oz waxed carton		x	x	
15-oz foil carton	x	x	x	x
15-oz window carton		x	x	
1-lb 450 K202 bag	x	x	x	x
1-lb poly X300 bag		x	x	
2-lb Pliofilm bag		x	x	
2-lb kraft waxed bag		x	x	
2-lb kraft film bag		x	x	
Dry milk solids				
9.7-oz glass jar	x	x	x	x
1-lb round carton	x	x	x	x
2-lb 3-oz chipboard carton		x	x	
9.6-oz newsboard carton	x	x	x	x
24-lb fiberboard carton	x		x*	
Dry beans				
4-lb polyethylene bag	x	x	x	
1-lb window carton		x	x	x
1-lb cello 450 MST bag	x	x	x	x
2-lb cello duplex bag		x	x	
1-lb cello 600 MST bag		x	x	
2-lb cello 600 MST bag		x	x	
1-lb Mylar 50 bag		x	x	
Flour				
25-lb kraft bag	x		x*	
5-lb kraft bag	x	x	x	x
2-lb kraft bag		x	x	
2½-lb chipboard carton	x	x	x	x
17-oz chipboard carton	x	x	x	x
2-lb polyethylene bag		x	x	
Cereals				
20-oz carton rolled oats	x	x	x	x
20-oz can rolled oats	x	x	x	x
1-lb cello bag rice	x	x	x	x
1-lb carton rice		x	x	
18-oz carton wheat cereal	x	x	x	x
8-oz carton wheat flakes	x	x	x	
10.5-oz carton Grape Nuts	x	x	x	x
5-oz carton corn pops	x	x	x	x
8-oz carton Rice Krispies	x	x	x	
Candy				
1-lb poly bag hard candy	x	x	x	x
1-lb window carton peanuts	x	x	x	x
24-bar carton fudge	x	x	x	x
1-lb carton chocolate mixture	x	x	x	x

*In basement at 4700 ft only.

CHAPTER 5

RESULTS

5.1 DOSIMETRY

Tables 5.1 and 5.2 list the neutron and gamma dosimetry, respectively, recorded at the various food test stations in Shot II (Operation Cue). As expected, the neutron flux and gamma radiation were much higher at the forward trench position approximately $\frac{1}{4}$ mile from GZ, even though the dosimeters were buried, than they were in or around the houses about a mile away. High-range film dosimeters buried 4 in. deep beside the food at 1270 ft measured 75,000 r. These dosimeters were recovered the day following the shot (D + 1 day). A film dosimeter in the center of a 10-lb bag of potatoes buried in the same trench but covered with 1 in. of soil recorded 56,000 r. A film dosimeter in the center of a similar bag of potatoes buried at 2750 ft recorded 4300 r.

Dosimeters outside the food test house at 4700 ft measured 110 r. Inside the house readings were 60 r on the kitchen food shelves and 35 r on the basement food shelves. Dosimeters placed inside 5-lb polyethylene bags of apples on these same shelves read 60 r in the kitchen and 25 r in the basement. Other film dosimeters on kitchen shelves at greater distances recorded 40 r at 5500 ft, 5 r at 7800 ft, and 0.3 r at 10,500 ft.

5.2 PHYSICAL DAMAGE

Tables 5.3 and 5.4 show the damage sustained by the packaged foods at the nearest trench positions at 1100 ft from Shot I and 1270 ft from Shot II. Damage to containers was most extensive on those buried flush without any soil cover (see Figs. 16 and 17). Food containers that were buried with 1 in. of soil cover were protected from flash burn but not from blast damage. The blast removed the 1 in. of soil cover from some of the boxes, and two fiberboard boxes in the trench at 1270 ft (Shot II) were torn open. None of the boxes were blown out of the buried positions. However, the high overpressures at the forward food trench broke several of the sealed exposure boxes and crushed many of the chipboard consumer packages inside. Although many chipboard packages were severely misshapen, most of them were not broken open. Consumer packages with inner liners provided extra protection for the contents.

The fresh produce in all containers in the forward trench sustained serious bruising and crushing. In Shot I the greatest damage to potatoes, apples, and onions occurred in the buried containers with 1 ft of soil over the top. Somewhat less damage occurred in buried containers with only 1 in. of soil cover, as shown in Table 5.3. A considerable part of the fresh produce exposed in the trench at 1100 ft was unusable as a result of the severe mechanical damage.

The extent of severe bruising and crushing of the apples, oranges, potatoes, and onions at 1270 ft in Shot II is shown in Table 5.5 (see Figs. 21 and 22). Of a total of 68 potatoes in a multiwall kraft bag, 23 were severely crushed by the blast. Of a total of 159 onions in a multi-

Table 5.1 — NEUTRON DOSIMETRY AT VARIOUS FOOD TEST STATIONS FOR SHOT II

Type and location of dosimeter	Radiation dose, neutrons/cm^2*
Sulfur dosimeter	
Trench at 1270 ft, buried 4 in. deep	2.77×10^{10}
Trench at 1270 ft, center of buried bag of potatoes	2.99×10^{11}
Trench at 2750 ft, buried 4 in. deep	1.36×10^{10}
Trench at 2750 ft, center of buried bag of potatoes	7.72×10^{9}
Outside house at 4700 ft	8.26×10^{8}
Outside house at 5500 ft	1.90×10^{8}
Gold dosimeter	
Trench at 1270 ft, buried 4 in. deep	1.89×10^{13}
Trench at 1270 ft, center of buried bag of potatoes	1.24×10^{13}
Trench at 2750 ft, buried 4 in. deep	5.05×10^{11}
Trench at 2750 ft, center of buried bag of potatoes	7.03×10^{11}
Outside house at 4700 ft	1.09×10^{10}
Outside house at 5500 ft	2.75×10^{9}

*Sulfur dosimeters measure fast neutrons; gold dosimeters measure slow neutrons. Both are expressed as number per square centimeter.

Table 5.2 — GAMMA DOSIMETRY AT VARIOUS FOOD TEST STATIONS FOR SHOT II, MEASURED WITH HIGH- AND LOW-RANGE FILM DOSIMETERS

Location of dosimeter	Radiation dose, r
Trench 1270 ft, buried 4 in. deep	75,000
Trench 1270 ft, center of buried potato bag	56,000
Trench 2750 ft, buried 4 in. deep	710
Trench 2750 ft, center of buried potato bag	4,300
House 4700 ft, outside	110
House 4700 ft, on kitchen shelf	60
House 4700 ft, on kitchen shelf in apple bag	60
House 4700 ft, on basement shelf	35
House 4700 ft, on basement shelf in apple bag	25
House 5500 ft, on kitchen shelf	40
House 5500 ft, on kitchen shelf in apple bag	30
House 5500 ft, on basement shelf	10
House 5500 ft, on basement shelf in apple bag	10
House 7800 ft, on kitchen shelf	5
House 7800 ft, on kitchen shelf in apple bag	2
House 10,500 ft, on kitchen shelf	0.3
House 10,500 ft, on kitchen shelf in apple bag	0.2

Table 5.3 — PHYSICAL DAMAGE TO SEMIPERISHABLE FOODS IN TRENCH AT STATION A (1100 FT), SHOT I

		Buried flush, no soil cover		Buried, 1 in. of soil cover		Buried, 12 in. of soil cover	
Product	Container	Product	Container	Product	Container	Product	Container
Staples in consumer packages	Wooden tomato lug		Most of lid blown off		1 slat broken		
Potatoes	10-lb polyethylene bag	10.5% moderately bruised	Melted and torn	Few slightly bruised	None	20% severely bruised	None
Dry beans	16-oz cellophane bag	None	Broken	None	Broken	None	None
Other staples	Miscellaneous containers	None	None	None	None	None	None
Cultures of five fungi	Pyrex test tubes		All tubes broken		3 tubes broken		
Apples	Standard wooden apple box	63% severely bruised	Lid scorched and broken	72% severely bruised	None	80% severely bruised	None
Potatoes	Multiwall baler bag with three 10-lb kraft bags	7% crushed and severely bruised	Baler bag scorched and torn	25% crushed and severely bruised	None	40% crushed and severely bruised	None
Onions	25-lb mesh bag	Most burned, crushed and cut	Bag burned and torn	55% severely crushed and bruised	None	63% severely crushed and bruised	None

wall kraft bag, 94 were bruised and crushed. The $^1/_8$- to $^1/_4$-in. sprouts on potatoes at this distance had black tips and appeared dead.

The potatoes and onions exposed under Shot II, on May 5, were taken to Fresno, Calif., where storage facilities for holding tests were available. The onions were discarded June 10 because those exposed at 1270 and 2750 ft were badly decayed following the physical injury from the blast. On the other hand, the unexposed lots and those exposed in the houses at 4700 ft or at greater distances from GZ were still in good condition when discarded and showed very little decay. There was no sprouting or root growth on any of the lots, and, since these were current (new) crop onions, none was expected in the near future.

Table 5.4—PHYSICAL DAMAGE TO SEMIPERISHABLE FOODS IN TRENCH AT STATION A (1270 FT), SHOT II

Product	Type of container	Damage
Raisins	15-oz foil carton	Slightly crushed, not broken
Dry milk	9.6-oz newsboard carton	Crushed, not broken
Dry milk	9.7-oz glass jar	Slight discoloration of glass
Dry beans	1-lb cello 450 MST bag	Bag broken
Flour	5-lb kraft bag	1 of 2 bags broken, contents lost
Flour (biscuit)	$2^1/_2$-lb chipboard carton	Crushed, not broken
Flour (cake)	17-oz chipboard carton	Crushed, not broken
Rice	1-lb cello bag	Bag broken, contents lost
Wheat cereal	18-oz chipboard carton	Crushed, not broken
Wheat flakes	8-oz newsboard carton	Severely crushed, broken
Rice Krispies	8-oz newsboard carton	Crushed, 2 of 8 cartons broken
Corn pops	5-oz newsboard carton	Crushed, not broken
Grape Nuts	$10^1/_2$-oz chipboard carton	Slightly crushed, not broken
Rolled oats	20-oz round carton	Crushed, 2 of 4 broken
Rolled oats	20-oz tin can	Severe top and bottom seam dents
Fudge	24-bar carton	Slightly crushed, wrappers intact
Chocolate mixture	1-lb cello carton	Slightly crushed, not broken
Hard candy	1-lb polyethylene bag	Bag punctured by candy
Candy peanuts	3-lb window carton	Film window broken, contents lost
Apples	1-bu fiberboard carton	Severely crushed, apples bruised
Apples	5-lb polyethylene bag	Bag broken, apples bruised
Oranges	1-bu fiberboard carton	Severely crushed, oranges bruised
Oranges	5-lb polyethylene bag	Dirt entered vent holes, oranges bruised
Potatoes	50-lb kraft bag	Bag torn, potatoes crushed
Potatoes	10-lb mesh bag	Dirt in bag, potatoes crushed
Onions	3-lb window bag	Bag split, some onions crushed

The potatoes were examined for extent of sprouting on July 1, nearly two months after exposure. As shown in Table 5.6, there was no sprout growth on the potatoes from the 1270-ft position, and sprouting was abnormal on the potatoes exposed at 2750 ft. Some of these latter potatoes had numerous fine hairlike sprouts which were just starting. At this time, most of the potatoes from the house at 4700 ft and the unexposed potatoes had normal sprouts at most eyes which were 4 to 6 in. long (Fig. 23). Apparently exposure to the neutron and gamma radiation completely inhibited sprouting at the nearest trench position. The potatoes in the 1270-ft trench received radiation of more than 50,000 r (see dosimetry Tables 5.1 and 5.2). The heat from the initial fireball may have been another contributing factor preventing sprouting. It has been well established previously from laboratory studies that gamma irradiation of potatoes will prevent sprouting.

Table 5.5—PHYSICAL DAMAGE TO APPLES, ORANGES, POTATOES, AND ONIONS AT VARIOUS DISTANCES FROM GZ, SHOT II

Location and product	Type of container	No. in container	No. bruised or crushed
Trench at 1270 ft			
Apples	1-bu wooden box	140	93
Apples	1-bu fiberboard box	140	125
Apples	5-lb poly bag	13	13
Oranges	0.7-bu fiberboard box	113	60
Oranges	5-lb poly bag	14	8
Potatoes*	30-lb kraft bag	68	23
Potatoes*	10-lb mesh bag	22	16
Onions	30-lb kraft bag	159	94
Onions	3-lb kraft bag	17	8
Trench at 2750 ft			
Apples	1-bu wooden box	138	31
Apples	1-bu fiberboard box	142	29
Apples	5-lb poly bag	14	2
Oranges	0.7-bu fiberboard box	108	18
Oranges	5-lb poly bag	14	4
Potatoes	30-lb kraft bag	75	3
Potatoes	10-lb mesh bag	28	0
Onions	30-lb kraft bag	160	25
Onions	3-lb kraft bag	18	0
Basement at 4700 ft			
Apples	1-bu wooden box	138	22
Apples	1-bu fiberboard box	140	13
Apples	5-lb poly bag	14	2
Oranges	0.7-bu fiberboard box	105	15
Oranges	5-lb poly bag	14	4
Potatoes	30-lb kraft bag	78	0
Potatoes	10-lb mesh bag	23	2
Onions	30-lb kraft bag	153	6
Onions	3-lb kraft bag	16	0
Unexposed at test site (control)			
Apples	1-bu wooden box	128	21
Apples	1-bu fiberboard box	130	31
Apples	5-lb poly bag	14	2
Oranges	0.7-bu fiberboard box	110	20
Oranges	5-lb poly bag	16	1
Potatoes	30-lb kraft bag	69	0
Potatoes	10-lb mesh bag	22	3
Onions	30-lb kraft bag	158	2
Onions	3-lb kraft bag	18	1

* Sprouts on potatoes at this position had black tips.

Table 5.6—EFFECT OF EXPOSURE TO A NUCLEAR EXPLOSION ON THE SUBSEQUENT SPROUTING OF RUSSET BURBANK POTATOES, SHOT II (Stored May 5, 1955, until July 1 at 45 to 50°F)

Location of potatoes	Percentage with normal sprouts at most eyes	Percentage with normal sprouts at a few eyes	Percentage with abnormal fine hairlike sprouts
Trench at 1270 ft	0	0	0
Trench at 2750 ft	0	36	60
Basement at 4700 ft	73	20	7
Unexposed controls	100	0	0

There was more decay in the potatoes from the 1270- and 2750-ft trench positions than in other lots examined on July 1 because of the physical damage. All the sound potatoes appeared normal internally. The sound potatoes in each lot also had a normal flavor.

The firmness of the Winesap apples in Shot II was measured with a fruit pressure tester before and after exposure. On April 30, the pressure test readings averaged 15.0 lb. Four days after exposure, on May 9, the pressure test readings averaged 13.3 lb on unexposed fruit, 13.3 lb on fruit exposed in the trench at 1270 ft, and 13.5 lb on fruit exposed in the 2750-ft trench. For this short holding period the blast had no effect on the rate of softening of apples. Because of extensive mechanical damage to the fruit at these close-in positions, it could not be stored to determine the long-time effect on softening and keeping quality (Figs. 18 and 19).

Many of the flexible packages made of kraft paper or transparent films were broken at the 1270-ft position and the contents were lost. Figures 20, 24, and 25 show the damage to some of the different types of packages. Mesh bags used for onions, apples, and potatoes were not broken; yet the produce in this type of bag, and in any type of bag that was broken, was surface contaminated by radioactive dirt forced into the packages. This contamination would necessitate very careful washing before using the food. The problem of induced radioactivity is covered in Sec. 5.4.

Rolled oats in 20-oz paperboard cartons and in 20-oz vacuum-packed tins was exposed in a wooden pear box in the trench at 1270 ft. The paperboard cartons were badly dented, and some were broken open. Vacuum-packed tins at this location were slightly dented, and some seams were sprung (Fig. 25). At greater distances, where blast damage also was extensive, the tins offered more physical protection to the product than the paperboard cartons, as would be expected.

Food packages buried at 3600 ft and on the ground surface at 1 mile in Shot I sustained only minor damage. However, there was some flash burn on the wooden boxes even at 1 mile from GZ. Fresh produce buried at 3600 ft was moderately bruised from the blast, but most of it would have been usable as food. Food buried at 2750 ft from GZ in Shot II showed little physical damage (Table 5.7). Most of the produce and the semiperishable staples appeared to be in good condition with little damage to the containers. In some window cartons the transparent film windows were broken.

Table 5.7 lists the damage which occurred to food in the kitchens and basements of houses at 4700, 5500, 7800, and 10,500 ft. Most of the damage to the food packages was the result of physical dislodgment from kitchen cupboards when the blast struck (Figs. 29 and 33). Some damage resulted from secondary missiles such as fragments of glass, wood, and miscellaneous household accessories. In the two-story brick house at 4700 ft, some of the test foods could not be recovered because the above-ground portion of the house had been destroyed (Fig. 27); yet it was amazing that so many intact packages of usable food were recovered from the wreckage.

Produce and semiperishable staples placed on open shelves in the basement of houses at 4700 and 5500 ft generally were not damaged. None of them were dislodged from the shelves, as shown in Figs. 31 and 35. Flying glass particles from basement windows punctured a few packages, making consumption of the contents of such broken packages hazardous. In a few instances even tin cans were penetrated by secondary missiles. Aside from a slight amount of damage from such missiles, it was apparent that basements were relatively safe places to store a reserve supply of food. Doors on basement food cabinets should give added protection against physical damage.

The two-story frame houses at 5500 and 7800 ft were severely damaged; the one at 5500 ft probably being damaged beyond repair. The paint was burned from the front of this house. The roof was blown off, the chimney was down, all doors and windows were broken, and many floor joists were shattered. A high percentage of the food packages placed in closed kitchen cupboards at 5500 and 7800 ft were thrown to the floor by the blast (Fig. 33). Some were broken by the impact, but most were recoverable in intact containers. Definite conclusions should not be drawn from the breakage data in Table 5.7 as to containers giving the most or least protection. Only single packages of a type were used in most instances, and they were at different heights on the shelves.

Table 5.7 — PHYSICAL DAMAGE TO SEMIPERISHABLE FOODS IN TRENCH AT STATION B (2750 FT) AND IN HOUSES AT 4700, 5500, 7800, AND 10,500 FT FROM SHOT II

Location and product	Type of container	Damage
Trench B, 2750 ft		
Produce	1-bu fiberboard carton	This carton used as a master container for consumer bags of apples, oranges, potatoes, and onions was broken open by the blast; radioactive dirt sifted into most of the consumer bags
Onions	3-lb window bag	Bag torn
Apples	1-bu fiberboard carton	Slightly crushed
Apples	1-bu wooden box	No damage
Semiperishable staples	Many types	No damage to any of the consumer packages exposed within the wooden box; radioactive dirt on most packages
Kitchen, brick house at 4700 ft		
General		House destroyed; many food packages removed from rubble completely undamaged
Dry beans	1-lb cello 600 MST bag	Torn bag
Dry beans	2-lb cell 300 MST duplex bag	Outer bag torn, contents intact
Dry beans	1-lb Mylar 50 bag	Torn bag
Flour (cake)	17-oz chipboard carton	Slightly crushed, not broken
Flour (biscuit)	$2\frac{1}{2}$-lb chipboard carton	Crushed, not broken
Flour	2-lb polyethylene-coated cello bag	Bag torn from flying glass
Chocolate mixture	1-lb cello carton	Cellophane wrapper torn
Hard candy	1-lb polyethylene bag	Bag torn
Candy peanuts	3-lb window carton	Film window broken, contents lost
Potatoes	10-lb polyethylene bag	Bag torn
Onions	3-lb polyethylene bag	Bag torn
Onions	3-lb window bag	Bag torn
Basement, brick house at 4700 ft		
Produce	All types	No damage to either wholesale- or consumer-size packages except that some film and paper bags were cut by flying glass or wood splinters
Staples and candy	All types	No damage; all products still on shelves
Kitchen, frame house at 5500 ft		
General		House severely damaged; many food packages thrown from kitchen cupboards to floor
Raisins	2-lb Pliofilm bag	Bag broken; contents lost
Dry beans	1-lb cello 450 MST bag	Bag broken
Dry beans	1-lb cello 600 MST bag	Bag broken
Dry beans	2-lb cello 600 MST bag	Bag broken
Dry beans	2-lb cello 300 MST duplex bag	Both layers of bag broken
Flour	2-lb polyethylene-coated cello bag	Bag torn by flying glass
Candy peanuts	3-lb window carton	Film window broken
Apples	5-lb polyethylene bag	Bag broken
Basement, frame house at 5500 ft		
Staples and produce	All types	All packages still on shelves and for the most part completely undamaged; some film and paper bags torn by flying glass
Kitchen, frame house at 7800 ft		
General	All types	House severely damaged; about 50% of food packages fell from cupboards to floor, most of which were undamaged
Kitchen, brick house at 10,500 ft		
General	All types	House severely damaged, windows and doors blasted out; no damage to any food package as all products remained on shelves

Three of the five test tubes containing fungi cultures on agar were badly shattered when exposed in the trench at 1100 ft with 1 in. of soil cover. The cultures in the shattered test tubes could not be recovered. The two cultures that were intact (*Aspergillus* sp. and *Botrytis* sp.) appeared to be dead at first, but mycelium survived down in the agar and within 10 days was again sporulating. Later transfers from these cultures (both spore and mycelium) were made, and the transfers grew normally and appeared on microscopic examination to be unchanged from the original inoculum. All five of the cultures exposed in a trench at 3600 ft apparently were unaffected by the blast or the radiation. They had the same appearance as the unexposed controls when recovered from the field, and live spores were recovered from the surface of the cultures within a few days of exposure. The original cultures and transfers are being maintained to determine possible mutations as a result of exposure.

5.3 CHEMICAL AND ORGANOLEPTIC EVALUATION

5.3.1 General Observations

No effects on flavor, color, or texture which could be attributed to radiation from the nuclear explosion were observed in the potatoes, onions, apples, oranges, raisins, dry cereals, or candy. The physical damage to fresh produce at 1270 ft was so extensive that no chemical evaluation was attempted. No detailed evaluation of most of the semiperishable staples for possible nutritive changes was conducted; but samples of dry milk, flour, and rolled oats were sent to research laboratories for examination.

5.3.2 Dry Milk

Following exposure to Shot II, samples of nonfat dry milk solids in four different types of packages were examined at the American Dry Milk Institute in Chicago, Ill. One type of consumer package was exposed in a fiberboard shipping container (24 per case) to represent a wholesale-size package. Samples of dry milk were analyzed for quality and composition factors from the following locations: (1) trench at 1270 ft, (2) trench at 2750 ft, (3) kitchen of brick house at 4700 ft, (4) basement of same house, and (5) control or unexposed samples at the NTS.

Table 5.8 shows the data obtained on the grading analysis of the samples of nonfat dry milk solids, and Table 5.9 gives the data of other analyses. Except on flavor, there was little or no difference between the exposed samples and the control in the various factors analyzed. Slight variations, such as in the moisture content, may be due to variations in the initial sample, package protection, or in the analytical methods used. The effect of exposure to the atomic blast on the flavor and palatability of the dry milk in the trench positions was very pronounced. The dry milk 1270 ft from the blast had a very strong stale flavor and odor when reconstituted (Table 5.8). This off-flavor was less intense in the samples exposed at 2750 ft but was still objectionable. With only one exception, no stale flavor was detected in the dry milk exposed in the brick house at 4700 ft. All the control or unexposed samples had a good flavor when reconstituted.

The stale flavor which developed in the exposed samples was very similar to that obtained when nonfat dry milk solids are stored under conditions of high temperature and high moisture content. At a moisture content of less than 4 per cent, normally no stale flavor will develop in nonfat dry milk solids for at least one year if the product is stored under a temperature not higher than about 85°F. Apparently, exposure to the atomic blast accelerated the reaction(s) responsible for stale-flavor development. It was interesting to note that no browning effect accompanied the development of stale flavor, as is generally true when dry milk is stored under high temperature and high humidity.

5.3.3 Flour

Three types of flour products were sent to the American Institute of Baking in Chicago, Ill., for baking tests of samples exposed to Shot II on May 5, 1955. These were enriched

Table 5.8—GRADING ANALYSIS OF NONFAT DRY MILK SOLIDS AFTER EXPOSURE AT VARIOUS DISTANCES FROM SHOT II

Location of sample	Brand No.	Type of container	Fat, %	Mois-ture, %	Titratable acidity, %	Solubility index, ml	Bacterial estimate per gram	Scorched particles*	Flavor†	Grade
1270 ft	1	1-lb cartons	0.53	3.8	0.125	0.5	<3000	A	Stale	
2750 ft	1	in fiberboard	0.61	3.7	0.125	0.5	<3000	A	S.S.	
4700 ft‡	1	shipping	0.55	3.6	0.13	0.5	<3000	A	Good	Extra
Unexposed	1	container	0.52	3.7	0.13	0.6	<3000	A	Good	Extra
1270 ft	2	9.7-oz glass	0.52	3.2	0.13	0.2	<3000	A	Stale	
2750 ft	2	jars for	0.52	3.2	0.13	0.3	<3000	A	S.S.	
4700 ft	2	all locations	0.59	3.2	0.13	0.2	<3000	A	Good	Extra
Unexposed	2		0.60	3.2	0.125	0.3	<3000	A	Good	Extra
1270 ft	3	1-lb cardboard	0.53	3.8	0.12	0.2	<3000	A	V.S.	
2750 ft	3	drums for	0.51	3.5	0.12	0.2	<3000	A	Good	Extra
4700 ft	3	all locations	0.52	3.0	0.12	0.2	<3000	A	Good	Extra
Unexposed	3		0.53	3.4	0.12	0.2	<3000	A	Good	Extra
1270 ft	4	9.6-oz chip-	0.70	3.9	0.12	0.1	<3000	A	V.S.	
2750 ft	4	board cartons	0.96	3.3	0.125	0.2	<3000	A	V.S.	
4700 ft	4	for all	0.88	3.5	0.125	0.1	<3000	A	S.S.	
Unexposed	4	locations	0.64	4.3	0.125	0.1	<3000	A	Good	Standard

*A = absent.
†S.S. = slightly stale; V.S. = very stale.
‡In basement of brick house; the other brands exposed at 4700 ft were on shelves in the kitchen.

Table 5.9—COMPOSITIONAL ANALYSIS OF NONFAT DRY MILK SOLIDS AFTER EXPOSURE AT VARIOUS DISTANCES FROM SHOT II

Location of sample	Brand No.	Type of container	Protein, %	Lactose, %	Ash, %	Color units	Protein reducing value, mg $K_4Fe(CN)_6$/g	Whey protein nitrogen, mg/g	Dispersibility, g/20 sec
1270 ft	1	1-lb cartons	34.6	50.7	8.31	0.64	2.14	5.0	46.1
2750 ft	1	in fiberboard				0.64	2.00	5.0	46.8
4700 ft*	1	shipping				0.64	2.00	5.0	46.6
Unexposed	1	container	35.2	50.9	8.31	0.56	2.26	4.8	46.1
1270 ft	2	9.7-oz glass	37.7	48.4	8.33	0.56	4.80	3.4	45.1
2750 ft	2	jars for				0.64	4.70	3.4	45.9
4700 ft	2	all locations				0.64	4.74	3.4	45.5
Unexposed	2		37.5	48.3	8.15	0.64	4.70	3.4	45.6
1270 ft	3	1-lb cardboard	36.0	50.4	8.32	0.56	1.74	5.6	35.0
2750 ft	3	drums for				0.48	1.74	5.8	36.9
4700 ft	3	all locations				0.48	1.54	5.6	37.2
Unexposed	3		35.9	50.3	8.33	0.56	1.74	5.8	37.6
1270 ft	4	9.6-oz chip-	37.5	48.7	8.33	0.64	2.14	3.1	41.9
2750 ft	4	board cartons				0.56	1.80	3.6	41.7
4700 ft	4	for all				0.56	1.94	3.0	41.7
Unexposed	4	locations	37.5	48.9	8.28	0.48	2.10	3.0	42.2

*In basement of brick house; the other brands exposed at 4700 ft were on shelves in the kitchen.

bread flour, prepared biscuit mix, and prepared white cake mix; each exposed in the trench at 1270 ft, the kitchen of a frame house at 7800 ft, and unexposed control samples. The baking tests were conducted on June 17, 1955.

Evaluation of bread made from exposed and unexposed flour showed no appreciable difference either in baking quality or bread produced (Table 5.10). It appeared that the blast did not change the baking quality of the flour even at the nearest exposure location (Fig. 36).

Similar results were obtained in a baking test of baking powder biscuits made from a prepared biscuit mix. There were no noticeable differences in biscuits made from flour exposed at different distances from the blast, as shown in Fig. 37.

The results of baking tests of samples of prepared white cake mix are given in Table 5.11. The grain, texture, and tenderness of cakes made from flour exposed in the trench at 1270 ft and in the house at 7800 ft were not quite so good as in the cakes made from unexposed flour. It appears that the atomic blast may have affected the baking quality of the prepared cake mix slightly (Fig. 38).

5.3.4 Rolled Oats

Following exposure to Shot II, samples of rolled oats were returned to the Quaker Oats Co., Chicago, Ill., for laboratory evaluation. The rolled oats were in two types of container, 20-oz paperboard cartons and 20-oz vacuum-packed tins. Results of a sensory examination by a panel of judges are shown in Table 5.12. The scoring on the check (unexposed) samples was normal for this product. Rolled oats exposed to the blast at 1270 and 4700 ft had both a poorer flavor and poorer aroma (burnt, metallic) than the unexposed samples. The exposed samples in paperboard cartons had more burnt flavor and aroma than those in tins and were judged by the panel as being unacceptable by normal standards. On the other hand, the rolled oats in tins were still quite acceptable even though a slight burnt flavor could be detected in the samples exposed 1270 ft from the blast.

There were no significant changes in the thiamine, riboflavin, or niacin content of either the exposed or unexposed packages of rolled oats (Table 5.13). All samples were stored at 100°F for 1 month after arrival at the laboratory, and no further changes occurred in that time.

5.4 INDUCED RADIOACTIVITY

In Shot I the semiperishable foods that were buried flush without soil cover at 1100 ft were recovered the day after shot day (D+1 day). At the initial monitoring (H+42 hr) some foods showed very high levels of induced radioactivity from neutron bombardment. Table 5.14 shows the readings made on each of the products in and out of its container. Of the staples, the dry beans and dry milk were highest in induced activity; the raisins were also relatively high. Cereals such as rice, rolled oats, and flour were relatively low. Potatoes showed much higher levels of induced activity than apples or onions, although all were low when compared with some of the staples.

There was no evidence that the type of container affected the level of induced activity in a product. The radioactivity of rolled oats in a paperboard carton was similar to that of rolled oats in a tin can at the trench positions. As another example, the radioactivity of dry milk packaged in glass jars was similar to that in chipboard cartons. However, glass containers themselves showed much higher levels of induced radioactivity than did containers of metal, paper, or film.

Induced radiation levels in products buried with 1 in. of soil cover at 1100 ft are shown in Table 5.14. The shallow soil cover apparently provided substantial protection from the radiation flux. Although the readings were not made at comparable intervals from exposure, the levels found in both containers and products were materially lower where 1 in. of soil covered the product than where the surface was exposed.

Table 5.14 also shows the amount of induced radioactivity found in products in and out of containers which had been buried at 1100 ft from GZ with 1 ft of soil cover during exposure.

Table 5.10 — EVALUATION OF BREAD BAKED FROM FLOUR EXPOSED AT VARIOUS DISTANCES FROM SHOT II*

Location of bread flour samples	Weight, oz	Volume, cc	Break and shred	Appearance	Crust color	Grain texture	Crumb color	Flavor	Score
Trench, 1270 ft	16	2475	G	G	G	G	G	G	G
Kitchen, 7800 ft	16	2600	G	G	G	G	G	G	G
Unexposed control	16	2575	G	G	G	G	G	G	G

* Baked 23 min at 450°F; rating of G = good.

Table 5.11 — EVALUATION OF CAKE BAKED FROM PREPARED WHITE CAKE MIX EXPOSED AT VARIOUS DISTANCES FROM SHOT II*

Location of cake flour samples	Volume	Symmetry	Crust color	Grain	Tenderness	Texture	Crumb color	Flavor	Score
Trench, 1270 ft	G	G	P(pale)	G–	G– (tough)	G–	G	G	G–
Kitchen, 7800 ft	G	G	P(pale)	G–	G– (tough)	G–	G	G	G–
Unexposed control	G	G	P(pale)	G	G	G	G	G	G

* Rating of G = good, P = poor.

Table 5.12 — EFFECT OF EXPOSURE AT VARIOUS LOCATIONS ON THE COLOR, CONSISTENCY, AROMA, AND FLAVOR OF ROLLED OATS

Type of container and location of samples	Judging panel score			
	Color	Consistency	Aroma	Flavor
Paperboard cartons				
Check (unexposed)	2.00	3.00	2.50	2.25*
Trench at 1270 ft	2.00	2.75	1.25	1.00†
Kitchen at 4700 ft	1.75	3.00	2.00	1.50‡
Export tin cans				
Check (unexposed)	1.50	2.75	3.50	3.75
Trench at 1270 ft	1.75	2.75	3.25	3.00§
Kitchen at 4700 ft	1.75	2.50	3.25	3.25
Total possible rating	2.00	3.00	4.00	4.00

* Judges described as stale, store taste.
† Scorched, burnt, metallic taste.
‡ Scorched, metallic taste.
§ Slightly burnt taste, bitter.

Table 5.13 — EFFECT OF EXPOSURE AT VARIOUS LOCATIONS ON THE VITAMIN CONTENT OF ROLLED OATS

Type of container and location of samples	Thiamine, mg/1 lb	Riboflavin, mg/1 lb	Niacin, mg/1 lb
Paperboard cartons			
Check (unexposed)	3.7	0.60	5.5
Trench at 1270 ft	3.7	0.64	6.6
Kitchen at 4700 ft	3.7	0.62	5.6
Export tin cans			
Check (unexposed)	3.5	0.63	5.7
Trench at 1270 ft	3.4	0.62	5.2
Kitchen at 4700 ft	3.2	0.58	4.9

Table 5.14—INDUCED RADIOACTIVITY (COUNTS/MIN) IN SEMIPERISHABLE FOODS EXPOSED IN TRENCH AT STATION A (1100 FT) AT VARIOUS DEPTHS, SHOT I*

Location and product	Container	Container and product H + 42 hr	Container and product H + 53 hr	Container and product H + 88 hr	Product alone H + 42 hr	Product alone H + 53 hr	Product alone H + 88 hr
Buried flush, no soil cover							
Dry beans	16-oz carton	22,000(10 cm)	46,000	12,000	50,000(5 cm)	48,000(2 cm)	15,000
Dry beans	16-oz cellophane bag		45,000				
Raisins	12-oz polyethylene bag	50,000(2 cm)	36,000				
Raisins	15-oz waxed carton	50,000(2 cm)	35,000				
Raisins	15-oz foil carton	50,000(2 cm)		7,000	41,000	30,000	5,000
Rice	16-oz cellophane bag	13,000			13,000		
Rolled oats	20-oz tin can	20,000		3,000	20,000		3,000
Rolled oats	20-oz chipboard drum	18,000		2,400	22,000		4,000
Enriched flour	32-oz kraft bag	11,000		1,500	11,000		1,500
Corn pops	5-oz foil-lined carton	52,000		3,200	45,000		2,200
Grape Nuts	10.5-oz waxed carton	70,000		11,000	50,000		8,000
Dry milk	9.6-oz carton	5,000(50 cm)	2,500(50 cm)	25,000			25,000
Dry milk	9.7-oz glass jar	32,000(50 cm)	20,000(50 cm)	14,000(50 cm)	35,000(8 cm)	38,000(4 cm)	25,000
Potatoes	10-lb polyethylene bag	36,000	27,000	4,000	36,000	27,000	4,000
Potatoes	Baler bag (3, 10-lb bags)			4,000			4,000
Apples	48-lb wooden box	6,000			6,000		600
Onions	25-lb mesh bag			1,500			1,500
Background	Tracerlab survey meter serial No. 263, shield open, 2000 counts/min = 1.0 mr	350	500	600	350	500	600

Location and product	Container	Container and product H + 63 hr	Container and product H + 75 hr	Container and product H + 99 hr	Product alone H + 63 hr	Product alone H + 75 hr	Product alone H + 99 hr
Buried with 1 in. of soil cover							
Dry beans	16-oz carton	27,000	15,000	6,000	30,000	16,000	6,500
Dry beans	16-oz cellophane bag	25,000	12,000		25,000	10,000	6,500
Raisins	12-oz polyethylene bag	21,000	6,000	3,200			
Raisins	15-oz waxed carton	15,000	7,000				
Raisins	15-oz foil carton	15,000	7,000		19,000	7,000	3,000
Rice	16-oz cellophane bag	4,800	3,000	1,200	4,800		1,200
Rolled oats	20-oz tin can	4,000		3,000	5,500		4,400
Rolled oats	20-oz chipboard drum	3,000		1,900	5,000		3,500
Enriched flour	32-oz kraft bag	2,000		1,500	1,800		1,200
Corn pops	5-oz foil-lined carton	20,000	8,000		15,000		
Grape Nuts	10.5-oz waxed carton	48,000	27,000	11,000	41,000	20,000	9,000
Dry milk	9.6-oz carton	16,000(10 cm)	30,000	16,000	49,000	28,000	18,000
Dry milk	9.7-oz glass jar	14,000(50 cm)	38,000(10 cm)	27,000(10 cm)	49,000	29,000	18,000
Potatoes	10-lb polyethylene bag	13,000			13,000	7,000	2,000
Potatoes	Baler bag (3, 10-lb bags)	11,000	4,000		11,000	3,800	
Apples	48-lb wooden box				2,300	1,500	500
Onions	25-lb mesh bag				3,000	1,500	
Fungus cultures	Pyrex test tubes	25,000	9,000				
Background	Tracerlab survey meter serial No. 263, shield open, 2000 counts/min = 1.0 mr	500	550	400	500	550	400

Location and product	Container	Container and product H + 64 hr	Container and product H + 76 hr	Container and product H + 88 hr	Product alone H + 64 hr	Product alone H + 76 hr	Product alone H + 88 hr
Buried with 1 ft of soil cover							
Dry beans†	16-oz carton	3,500	1,200		4,000	1,500	
Dry beans†	16-oz cellophane bag	3,500	1,200		3,500		
Raisins	12-oz polyethylene bag	3,000	1,100				
Raisins	15-oz waxed carton	3,000					
Raisins†	15-oz foil carton	3,000	1,100		3,400		
Rice	16-oz cellophane bag	500			500		
Rolled oats	20-oz tin can	800					
Rolled oats	20-oz chipboard drum	500			500		
Enriched flour	32-oz kraft bag	500			500		
Corn pops	5-oz foil-lined carton	500					
Grape Nuts	10.5-oz waxed carton	10,000	6,500	5,000	8,000	5,000	
Dry milk	9.6-oz carton	10,000	5,000	3,500	10,000	5,000	
Dry milk	9.7-oz glass jar	21,000(10 cm)	37,000	24,000	10,000	5,000	4,200
Potatoes	10-lb polyethylene bag	2,300	1,000		2,300	1,000	
Potatoes	Baler bag (3, 10-lb bags)	2,000	800		2,000	800	
Apples	48-lb wooden box	500			500		
Onions	25-lb mesh bag	500			500		
Background	Tracerlab survey meter serial No. 263, shield open, 2000 counts/min = 1.0 mr	500	550	600	500	550	600

*Readings were in counts per minute. Figures shown in parentheses after the reading indicate distance probe was held from product in cases where the level of radioactivity was above the capacity of the instrument at guard contact.

†Containers alone for these three items gave readings (counts/min) at H + 64 hr of 1,500 for (dry beans) 16-oz cartons, 2,000 for (dry beans) 16-oz cellophane bags, and 2,000 for (raisins) 15-oz foil cartons, with a background of 500 counts/min.

Levels of activity were much lower at this location than in the surface exposed samples or those buried with 1 in. of soil cover. The only products which showed significant induced radiation from this location at H + 64 hr were dry beans, raisins, Grape Nuts, dry milk, and potatoes.

Products buried with 1 in. of soil cover at position B (3600 ft) had relatively low rates of induced radioactivity at H + 39 hr. None of the products when removed from the containers showed more than about double the background reading, and, of the containers, only the glass ones showed substantial activity at this location.

No significant induced radioactivity was found in any of the products exposed on the surface at 1 mile, although a glass container at this position gave a reading about three times above background at H + 39 hr.

In Shot II, all the semiperishable foods were recovered not later than D + 1 day. Readings for radioactivity in products exposed at Station A (1270 ft) were begun at H + 40 hr, and three readings were made at intervals of approximately 24 hr. Products from Station B (2750 ft) and from the kitchen of the brick house at 4700 ft were initially read at H + 52 hr. All the products from these locations which showed appreciable radioactivity at the initial examination were read twice more at approximately 24-hr intervals.

As shown in Table 5.15, all the products exposed in the trench at 1270 ft showed significant induced radioactivity through the entire reading period, although levels of activity were dropping rapidly during this time. In general, radioactivity of the product itself at H + 86 hr was only about 10 to 20 per cent of the readings at H + 40 hr. Of the staples exposed at 1270 ft, those showing high levels of activity included nonfat dry milk solids, dry beans, raisins, ready-mixed biscuit and cake flours, processed breakfast cereals, and chocolate candies. Since cereals without additives, such as whole wheat, rolled oats, rice, and white flour, showed much lower levels of induced radioactivity, it was assumed that additives such as salt, baking powder, and shortening were responsible for the materially higher levels of activity found in the processed cereals and ready-mixed flours.

Fresh fruits and vegetables all showed some induced activity after exposure at 1270 ft in Shot II. However, the levels of activity were about the same as the cereals without additives and materially below most of the semiperishable staples. Potatoes showed higher levels of induced activity than any of the other fresh products. Apples and onions showed considerably lower levels than potatoes, and oranges were intermediate between apples and potatoes.

While readings of the product in the package were consistently higher than those made on the product alone, the differences were not as great as the data indicate because readings on the contents alone were made on a smaller quantity. In some cases the difference was due to higher levels of induced activity in the container, which showed a materially higher level than the contents. In some instances the overpressure at the exposure location apparently forced radioactive soil into the package material, which resulted in higher readings when the package and contents were read as a unit.

All the products exposed at Station B (2750 ft) showed some induced radioactivity at the first reading (H + 52 hr). However, as shown in Table 5.16, levels were relatively low, particularly as compared with those found at Station A. The most induced radioactivity in the food exposed 2750 ft from the blast was found in dry milk, dry beans, raisins, ready-mixed flours, and some of the processed cereals with additives, such as salt. With the exception of potatoes, the fresh produce items showed readings only slightly above background at H + 52 hr. At H + 100 hr all the fresh produce from the 2750-ft location was essentially free of radioactivity.

As an additional check on induced radioactivity in packaging materials, plastic film bags of various materials were exposed at Station A. Results of three readings on these materials are shown in Table 5.17. All the films except polyethylene showed some induced radioactivity at H + 62 hr. The highest initial readings occurred on cellophane and Pliofilm with polyethylene-coated cellophane and Mylar at somewhat lower levels. Radioactivity had decreased materially in all these materials by H + 100 hr but was decreasing more slowly in Mylar than in the other films tested.

Table 5.15 — INDUCED RADIOACTIVITY (COUNTS/MIN) IN SEMIPERISHABLE FOODS EXPOSED IN TRENCH AT STATION A (1270 FT), SHOT II

Type of product	Type of container	Container and product*			Product alone*		
		H + 40 hr	H + 62 hr	H + 86 hr	H + 40 hr	H + 62 hr	H + 86 hr
Raisins	15-oz foil carton	48,000	22,000	6,000	51,000	21,000	7,000
Raisins	1-lb 450 K202 bag	36,000(5 cm)	31,000	10,000	25,000(5 cm)	23,000	8,000
Dry milk	9.6-oz newsboard carton	46,000(10 cm)	30,000(5 cm)	28,000	29,000(10 cm)	25,000(5 cm)	31,000
Dry milk	1-lb round carton	38,000(10 cm)	27,000(5 cm)	22,000	27,000(10 cm)	27,000(5 cm)	30,000
Dry milk	9.7-oz glass jar	33,000(50 cm)	34,000(30 cm)	50,000(10 cm)	33,000(10 cm)	30,000(5 cm)	32,000
Dry beans	4-lb polyethylene bag	33,000(5 cm)	32,000	15,000	33,000(5 cm)	30,000	10,000
Dry beans	1-lb cellophane 450 MST bag	26,000(5 cm)	32,000	13,000	34,000(5 cm)	27,000	10,000
Flour	5-lb kraft bag	8,000	4,000	2,400	7,000	3,000	1,800
Biscuit flour	2½-lb chipboard carton	52,000(20 cm)	44,000(10 cm)	48,000	10,000(20 cm)	29,000(5 cm)	30,000
Cake flour	17-oz chipboard carton	51,000(10 cm)	27,000(5 cm)	40,000	11,000(10 cm)	12,000(5 cm)	15,000
Wheat cereal	18-oz carton	46,000	21,000	9,000	35,000	18,000	9,000
Rolled oats	20-oz tin can	27,000	14,000	7,000	23,000	12,000	7,000
Rolled oats	20-oz round carton	32,000	15,000	6,000	31,000	14,000	8,000
Wheat flakes	8-oz newsboard carton	32,000(20 cm)	39,000(5 cm)	29,000	9,000(20 cm)	29,000(5 cm)	29,000
Grape Nuts	10½-oz newsboard carton	39,000(10 cm)	28,000(5 cm)	28,000	21,000(10 cm)	22,000(5 cm)	22,000
Corn pops	5-oz newsboard carton	49,000	21,000	8,000	41,000	17,000	5,000
Rice Krispies	8-oz newsboard carton	44,000(10 cm)	49,000	20,000	14,000(10 cm)	34,000	14,000
Chocolate mix candy	1-lb newsboard carton	27,000(5 cm)	27,000	10,000	35,000	18,000	7,000
Fudge bars	24-bar chipboard carton	42,000(5 cm)	39,000	14,000	22,000(5 cm)	27,000	11,000
Hard candy	1-lb polyethylene bag	22,000	12,000	4,000	13,000	6,000	2,200
Candy peanuts	3-lb window carton	38,000	14,000	5,000	12,000	7,000	4,000
Apples	5-lb polyethylene bag				6,000	3,000	1,100
Apples	1-bu fiberboard carton	48,000 to 20,000	30,000 to 14,000	11,000 to 5,000	14,000	3,000	900
Oranges	5-lb polyethylene bag	11,000	4,000	1,600	10,000	2,800	1,000
Oranges	0.7-bu fiberboard carton	42,000 to 15,000	16,000 to 8,000	3,800 to 2,200	18,000	4,000	1,300
Potatoes	10-lb mesh bag	25,000	10,000	3,300	22,000	13,000	2,400
Potatoes	50-lb kraft bag	46,000 to 23,000	15,000 to 8,000	5,000 to 3,000	33,000	13,000	4,200
Onions	5-lb polyethylene bag				9,000	5,000	1,700
Background		150	170	150	150	170	150

* Figures shown in parentheses after the readings indicate distance probe was held from product in cases where level of radioactivity was above capacity of instrument at guard contact.

Readings were also obtained on semiperishable produce and staples exposed in the kitchen of a house 4700 ft from GZ. At H + 52 hr only the glass jar and family carton of dry milk and the package of prepared biscuit mix showed measurable radioactivity. However, when removed from the package neither of these products showed any induced activity. It could, therefore, be assumed that products exposed in the basement of the same house, and thereby better protected from initial radiation, or those exposed in houses at greater distances from GZ would be free of induced radioactivity. Spot checks of foods in other houses at distances greater than 1 mile from the detonation showed this to be true.

Table 5.16—INDUCED RADIOACTIVITY (COUNTS/MIN) IN SEMIPERISHABLE FOODS EXPOSED IN TRENCH AT STATION B (2750 FT), SHOT II

Type of product	Type of container	Container and product*			Product alone*		
		H + 52 hr	H + 76 hr	H + 100 hr	H + 52 hr	H + 76 hr	H + 100 hr
Raisins	15-oz foil carton	1,200	500	250	800	320	140
Raisins	1-lb 450 K202 bag	1,500	450	260	1,200	320	160
Dry milk	9.6-oz newsboard carton	4,800	1,700	600	4,000	1,700	800
Dry milk	1-lb round carton	3,400	1,200	600	3,400	1,600	700
Dry milk	9.7-oz glass jar	36,000	14,000	4,500	3,800	1,500	800
Dry beans	4-lb polyethylene bag	2,500	900	400	1,500	600	300
Dry beans	1-lb cellophane 450 MST bag	1,800	800	320	2,100	700	300
Flour	25-lb kraft bag	320	BG	BG	300	BG	BG
Biscuit flour	2½-lb chipboard carton	9,000	3,000	1,200	2,400	700	500
Wheat cereal	18-oz carton	1,000	450	300	800	300	BG
Rolled oats	20-oz tin can	600	200	200	500	BG	BG
Rolled oats	20-oz round carton	800	230	220	500	BG	BG
Wheat flakes	8-oz newsboard carton	4,400	1,600	500	2,400	1,100	420
Grape Nuts	10½-oz newsboard carton	3,200	1,400	480	2,100	800	380
Corn pops	5-oz newsboard carton	1,300	400	220	700	320	BG
Rice Krispies	8-oz newsboard carton	2,500	1,000	360	1,800	800	280
Rice	1-lb cellophane bag	300	220	BG	200	BG	BG
Chocolate mix candy	1-lb newsboard carton	1,400	700	300	700	400	200
Fudge bars	24-bar chipboard carton	2,500	1,000	400	1,200	500	200
Hard candy	1-lb polyethylene bag	350	BG	BG	300	BG	BG
Candy peanuts	3-lb window carton	600	220	BG	400	200	BG
Apples	5-lb polyethylene bag	400	BG	BG	200	BG	BG
Apples	1-bu fiberboard carton	1,400 to 800	400	200	240	200	BG
Apples	1-bu wooden box	400	BG	BG	200	BG	BG
Oranges	5-lb polyethylene bag	350	200	BG	350	200	BG
Oranges	0.7-bu fiberboard carton	800	300	BG	350	BG	BG
Potatoes	10-lb mesh bag	1,000	300	150	800	260	BG
Potatoes	50-lb kraft bag	1,200	420	300	1,100	350	200
Onions	3-lb window bag	800	200	BG	300	200	BG
Onions	30-lb kraft bag	450	220	BG	350	200	BG
Background		125	125	100	125	125	100

*BG indicates radioactivity not above level of background.

5.5 FALL-OUT CONTAMINATION

No fall-out was recorded at either of the planned fall-out stations located 4¾ and 7 miles north of GZ (Fig. 15). The radioactive cloud from the detonation moved in another direction. However, fall-out did occur on an array of packaging materials 15 miles east of GZ in the Papoose Valley. The surface radioactivity of the different materials measured 82 hr after the explosion is recorded in Table 5.18. An effort was then made to remove the adhering radioactive particles by shaking and by brushing with paint brushes. A large percentage of the contamination was removed in this manner. For example, a chipboard carton of lard read 36,000 counts/min with the Alpha Beta Gamma Survey Meter before cleaning and 3,000 counts/min after brushing. However, as can be seen from Table 5.18, it was impossible to remove all the radioactivity, particularly from porous surfaces such as burlap and cotton bags.

Table 5.17—INDUCED RADIOACTIVITY (COUNTS/MIN) IN TRANSPARENT-FILM PACKAGING MATERIALS EXPOSED IN TRENCH AT STATION A (1270 FT), SHOT II

Type of film	H+62 hr	H+77 hr	H+100 hr
450 MST cellophane	9000	4000	2000
Mylar 100	4400	3200	2400
Polyethylene 150	BG*	BG*	BG*
Pliofilm 120FF	9000	4300	1800
Saran-coated cellophane	8000	3800	1700
Polyethylene-coated cellophane	4500	2400	1000
Background	170	125	100

* BG indicates radioactivity not above level of background.

Table 5.18—RADIOACTIVITY (COUNTS/MIN) OF PACKAGING MATERIALS EXPOSED IN FALL-OUT ZONE 15 MILES FROM GZ, BEFORE AND AFTER ATTEMPTED DECONTAMINATION*

Type of package or material	Before cleaning (H+82 hr)	After cleaning					
		H+84 hr		H+124 hr		H+152 hr	
		Clean surface	Grease spot	Clean surface	Grease spot	Clean surface	Grease spot
Burlap bag with contents	100,000+	12,000		7,000		1,500 to 15,000	
Burlap bag, empty	100,000+	15,000		10,000		10,000	50,000
Cotton bag with contents	100,000+	6,000		3,500		1,000	10,000
Cotton bag, empty	30,000+	6,000		2,200		10,000	50,000
Aluminum foil	60,000	3,000	50,000	1,200			
Kraft bag, empty	30,000	4,000	30,000	800	28,000	1,000	50,000
Polyethylene bag, empty	44,000	2,500	12,000	1,200	50,000		10,000
Cellophane bag, empty	100,000+	2,500		1,000		1,000	3,000
Chipboard carton of oleomargarine	32,000	2,500	40,000	800	13,000		
Chipboard carton of lard	36,000	3,000	12,000	1,000	4,200		
Pliofilm-wrap bacon	44,000	10,000	50,000	11,000	50,000		
Fiberboard sheet	50,000	6,000		1,500		1,000	2,000

* Radioactivity measured with Alpha Beta Gamma Survey Meter with probe shield open.

Some of the packages had grease spots on them due to melting of oleomargarine and lard. High radioactivity persisted on these spots nearly a week after the explosion, even after brushing. Where knots were tied in the burlap and cloth bags and in crevices of film windows in chipboard cartons, radioactivity was also high and was difficult to remove. From these limited observations it is apparent that fall-out contamination can be cleaned up fairly easily on some types of packages. On certain porous types of wholesale and retail packages fall-out contamination poses a serious problem. It was easiest to remove on less porous packaging materials such as aluminium foil, plastic film, paper, tin, and glass.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Ten types of semiperishable products (apples, oranges, potatoes, onions, raisins, dry beans, dry milk, cereals, flour, and candy) were exposed to nuclear explosions at distances of $\frac{1}{4}$ mile to 2 miles from the blast. Foods were placed in trenches at approximately 1270 and 2750 ft and covered with 1 to 2 in. of soil. At these locations foods were subjected to high initial radiation and blast overpressures. Foods also were placed on shelves in kitchens and basements of houses constructed at the test site at distances ranging from 4700 to 10,500 ft.

At the close-in buried positions many types of food packages were partially crushed; some were broken and the contents contaminated with radioactive dirt. A high percentage of the apples, potatoes, onions, and oranges were severely crushed and bruised at the 1270-ft location, greatly reducing their possible food value in an emergency. As a result of the mechanical damage to the produce, decay during subsequent storage was much higher than in nonexposed produce.

Many of the semiperishable foods recovered from the 1270- and 2750-ft trench positions were radioactive from the initial neutron bombardment. This was mostly induced radioactivity rather than the surface type of contamination from fall-out. Most of this induced radioactivity decayed within 3 to 4 days, and food in intact packages could then be used if needed in an emergency. Dry milk, dry beans, raisins, and ready-mixed cake and biscuit flours were types of semiperishable staples that were found to have high levels of induced radioactivity. Potatoes showed higher levels of induced activity than onions, apples, or oranges. The initial radiation caused no visible effect on the foods or packages, other than to cause a slight darkening of glass containers. However, potatoes exposed at 1270 and 2750 ft from the explosion failed to develop normal sprouts during subsequent storage. The high initial radiation from neutrons or gamma rays is assumed to have inhibited sprouting.

The type of package, whether glass, tin, chipboard, or plastic film, appeared to have no protective effect on the extent of induced radioactivity of the contents. For example, rolled oats in a tin can or in a chipboard carton showed a similar amount of radioactivity; and raisins in aluminum-foil packages or in transparent film packages showed similar radioactivity.

Food products in houses as close as 4700 ft were substantially free of induced radioactivity. No induced radioactivity was present in foods exposed in the houses at 5500, 7800, or 10,500 ft.

Damage to foods in kitchens of houses at 4700, 5500, and 7800 ft was due principally to gross dislodgment from cupboards by the blast, or from secondary missiles such as glass or wood splinters. The amount of bruising from the blast to perishable fruits and vegetables in these houses was negligible. At 10,500 ft foods were not thrown from kitchen cupboards. The main hazard to food at this distance would be from flying glass particles from the windows.

There was no bursting of food packages at any exposure location. As expected, houses provided considerable protection from the blast for packaged foods. Most types of consumer packages withstood the physical shock of falling from cupboards to the floor. Chipboard cartons with film windows and cellophane bags were two types of containers that broke most frequently on falling.

Generally, foods fared much better when stored on basement shelves than on kitchen shelves as far as blast damage from dislodgment was concerned. Foods did not fall from basement shelves even in houses where the above-ground portion of the house was destroyed. A basement food storage cabinet should be a relatively safe place for a family's emergency food supply.

The flavor of a few products was damaged when exposed in the forward trench positions. Rolled oats in chipboard cartons exposed at 1270 ft acquired a burnt metallic-like flavor, which made it unacceptable by normal standards. The nonfat dry milk samples from the 1270-ft position had a very strong stale flavor and odor when reconstituted. This off-flavor was less intense in dry milk samples exposed at 2750 ft but was still objectionable. In general, the palatability of foods exposed to the atomic detonation in houses at 4700 ft and beyond was unaffected.

A fairly elaborate study of fall-out contamination on different types of food packages was planned. However, the radioactive cloud drifted in a direction that did not pass over most of the fall-out food test stations. Only limited data were obtained. On some types of packages the surface contamination from fall-out was cleaned up fairly easily by dusting or brushing. Fall-out contamination was very difficult to remove from porous types of packages such as cloth or burlap. Fall-out on such packages poses a serious problem. Fall-out contamination was easiest to brush off less porous packaging materials such as aluminum foil, plastic film, paper, tin, and glass.

APPENDIX

FOOD AND CONTAINER DATA

TYPES OF SEMIPERISHABLE FOODS AND DESCRIPTION OF CONTAINERS FOR SHOT II

Item No.	Product	Container capacity	Type of container and size
1	Apples (Winesap, size 138)	1 bu	Northwestern wooden box ($10\frac{1}{2}$ by $11\frac{1}{2}$ by 18 in.) with chipboard liners, fiberboard pads, and individual mineral oil impregnated paper apple wraps
2	Apples	1 bu	Fiberboard (corrugated) apple carton ($12\frac{1}{2}$ by 12 by 20 in.), 200-lb bursting strength, individual mineral oil impregnated paper apple wraps
3	Apples	5 lb	Polyethylene 150 bag (6 by $3\frac{1}{2}$ by 17 in.), staple closure, thirty-two $\frac{1}{4}$-in. perforations, tubular film
4	Apples	5 lb	Paper open-mesh bag ($8\frac{1}{2}$ by 15 in.), purple $\frac{1}{4}$-in. mesh with band label drawstring closure
5	Apples	5 lb	Pliofilm 120FF bag (6 by $3\frac{1}{2}$ by 18 in.), staple closure, thirty-two $\frac{1}{4}$-in. perforations
6	Apples	5 lb	Mylar 100 bag (9 by 17 in.) solvent sealed seams, staple closure, twenty-four $\frac{1}{4}$-in. perforations
7	Oranges (Valencia, size 220)	0.7 bu	Fiberboard (corrugated) half carton ($11\frac{1}{2}$ by $10\frac{1}{2}$ by $17\frac{1}{2}$ in.), double-wall, 200-lb bursting strength
8	Oranges	5 lb	Polyethylene 150 bag (6 by $3\frac{1}{2}$ by 17 in.) tubular film, staple closure, forty $\frac{1}{4}$-in. perforations
9	Potatoes (Russet Burbank, unwashed, size 4, 10-oz)	50 lb	Kraft shipping bag (13 by 7 by 37 in.), double-wall, wet-strength, automatic type, containing five 10-lb double-wall kraft consumer bags
10	Potatoes	10 lb	Kraft bag ($7\frac{3}{4}$ by $4\frac{3}{4}$ by 17 in.) double-wall, wet-strength (2/60# W S), automatic type, staple closure
11	Potatoes	10 lb	Paper open-mesh bag ($10\frac{1}{2}$ by $16\frac{1}{2}$ in.) orange $\frac{1}{4}$-in. mesh with 8-in. band label, drawstring closure
12	Potatoes	10 lb	Polyethylene 200 bag (8 by 3 by 20 in.) staple closure, forty-eight $\frac{1}{4}$-in. perforations, tubular film
13	Potatoes	5 lb	Kraft bag ($6\frac{1}{2}$ by $3\frac{3}{4}$ by 14 in.), double-wall, wet-strength, automatic type, staple closure
14	Onions (White Crystal Wax, size $1\frac{1}{2}$ to 3 in.)	30 lb	Kraft shipping bag (15 by $9\frac{1}{2}$ by $30\frac{3}{4}$ in.) double-wall, wet-strength, automatic type, containing ten 3-lb polyethylene 150 consumer bags
15	Onions	3 lb	Polyethylene 150 bag (5 by $3\frac{1}{2}$ by 13 in.) staple closure, twenty-four $\frac{1}{4}$-in. perforations, tubular film

Item No.	Product	Container capacity	Type of container and size
16	Onions	3 lb	Kraft bag ($5\frac{1}{4}$ by $3\frac{1}{4}$ by $11\frac{1}{2}$ in.), single-wall, automatic type, cellulose acetate film window, staple closure
17	Onions	5 lb	Cotton open-mesh bag (11 by 16 in.) orange $\frac{3}{16}$-in. mesh, drawstring closure
18	Raisins (seedless)	15 oz	Chipboard carton overwrapped with waxed paper ($3\frac{3}{4}$ by $1\frac{7}{8}$ by 5 in.)
19	Raisins	15 oz	Chipboard carton overwrapped with a paper and aluminum-foil lamination ($3\frac{3}{4}$ by $1\frac{7}{8}$ by $5\frac{1}{4}$ in.), foil outside
20	Raisins	15 oz	Chipboard carton (4 by $1\frac{5}{8}$ by $5\frac{1}{2}$ in.) with a $2\frac{5}{8}$- by 4-in. cellophane window
21	Raisins	1 lb	Saran-coated cellophane bag, 450 K202 (6 by $7\frac{1}{2}$ in.), heat-sealed closure
22	Raisins	1 lb	Coated polyethylene bag, poly X-300 (5 by 8 in.), heat-sealed closure
23	Raisins	2 lb	Pliofilm bag (7 by $9\frac{1}{2}$ in.), heat-sealed closure
24	Raisins	2 lb	Kraft bag waxed on inside ($4\frac{1}{2}$ by $2\frac{1}{4}$ by 10 in.) sewn closure
25	Raisins	2 lb	Kraft bag with a paper-film inner liner (4 by $2\frac{3}{8}$ by 8 in.), sewn closure
26	Dry milk (nonfat solids)	9.7 oz	Flint glass jar ($3\frac{1}{4}$ in. diameter, 6 in. high, $22\frac{3}{4}$ oz overflow capacity), economy shape, tin plate screw cap with waxed chipboard insert and glassine inner seal
27	Dry milk	1 lb	Cardboard round carton with tin bottom and cover ($3\frac{5}{8}$ in. diameter, $5\frac{1}{4}$ in. high), body 2 plies 0.018-in. caliper
28	Dry milk	2 lb 3 oz	Chipboard carton ($7\frac{3}{8}$ by $3\frac{1}{4}$ by 6 in.) with ten 3.5-oz envelopes made of a lamination of 25-lb pouch paper to 0.00035 aluminum foil to polyethylene 150
29	Dry milk	9.6 oz	Newsboard carton ($4\frac{3}{8}$ by $1\frac{13}{16}$ by 6 in.) 0.024-in. caliper, with three 3.2-oz envelopes (envelopes are a lamination of 31.5-lb kraft outside to 0.0007-in. aluminum foil with an inside heat-sealed vinyl coating)
30	Dry milk	24 lb	Fiberboard shipping carton (18 by 12 by $6\frac{1}{2}$ in.) 200-lb test, containing 24 1-lb newsboard cartons ($4\frac{3}{8}$ by $1\frac{7}{8}$ by 6 in.) each with an envelope made of a lamination of 18-lb tissue to 0.00035-in. aluminum foil to polyethylene 100
31	Dry beans (baby limas)	4 lb	Polyethylene 250 bag (8 by 12 in.), flat style heat-sealed closure
32	Dry beans	1 lb	Newsboard carton ($3\frac{1}{4}$ by 2 by 6 in.), 0.020-in. caliper, with cellulose acetate film window
33	Dry beans	1 lb	Cellophane 450 MST bag ($2\frac{5}{8}$ by $1\frac{3}{4}$ by $7\frac{1}{2}$ in.), heat-sealed closure
34	Dry beans	2 lb	Cellophane 300 MST duplex bag ($4\frac{1}{4}$ by $8\frac{1}{2}$ in.), satchel bottom, heat-sealed closure
35	Dry beans	1 lb	Cellophane 600 MST bag ($4\frac{1}{4}$ by $9\frac{1}{2}$ in.), satchel bottom, heat-sealed closure
36	Dry beans	2 lb	Cellophane 600 MST bag ($5\frac{3}{4}$ by $10\frac{3}{4}$ in.), satchel bottom, heat-sealed closure
37	Dry beans	1 lb	Mylar-50 film bag ($3\frac{3}{4}$ by $1\frac{3}{8}$ by $10\frac{1}{2}$ in.), glued seams, staple closure
38	Dry beans	1 lb	Saran-coated cellophane bag (450 K202, 6 by $8\frac{1}{2}$ in.), satchel bottom, heat-sealed closure
39	Dry beans	1 lb	Muslin bag (8 by 12 in.)
40	Dry beans	1 lb	Canvas bag (5 by 10 in.)
41	Dry beans	2 lb	Burlap bag (6 by 9 in.)
42	Dry beans	2 lb	Cardboard round carton with tin plate bottom and cover
43	Dry beans	1 lb	Glass jar ($2\frac{3}{4}$ by $2\frac{3}{4}$ by $3\frac{3}{4}$ in.), with metal screw cover

Item No.	Product	Container capacity	Type of container and size
44	Flour (bleached enriched)	25 lb	Kraft bag (14 by 20 in.), single-wall, 85-lb basis weight, made from bleached kraft and Manila rope fibers with 75% rope fiber minimum, satchel bottom, pasted closure
45	Flour (bleached enriched)	5 lb	Kraft bag ($8\frac{1}{2}$ by 12 in.), single-wall, 65-lb basis weight, made from 100% bleached kraft, satchel bottom, pasted closure
46	Flour	2 lb	Kraft bag ($6\frac{1}{2}$ by $8\frac{7}{16}$ in.), single-wall, 60-lb basis weight, made from 100% bleached kraft, satchel bottom, pasted closure
47	Flour	2 lb	Polyethylene-coated cellophane bag (8 by 12 in.), polyethylene 250X cellophane 300 MSAT 80, pouch style, heat-sealed closure
48	Flour (biscuit)	$2\frac{1}{2}$ lb	Paper-covered chipboard carton (6 by $2\frac{1}{2}$ by 8 in.), 0.030-in. caliper, 25-lb unbleached greaseproof liner, liner waxed on outside
49	Flour (white cake)	17 oz	Paper-covered chipboard carton ($4\frac{3}{8}$ by $1\frac{1}{2}$ by 7 in.), 0.026-in. caliper, liner of laminated 47-lb amber glassine
50	Rolled oats	20 oz	Chipboard round carton $4\frac{1}{4}$ in. diameter and $7\frac{1}{8}$ in. high) with paper label
51	Rolled oats	20 oz	Export tin can ($3\frac{1}{2}$ in. diameter and 5 in. high), vacuum pack
52	Rice (whole grain)	1 lb	Manila newsboard carton ($3\frac{3}{4}$ by $1\frac{1}{2}$ by 6 in.), 0.020-in. caliper, oval cellulose acetate window
53	Rice	1 lb	Cellophane 300 MST-53 duplex bag ($2\frac{1}{2}$ by $1\frac{1}{2}$ by 8 in.), heat-sealed closure
54	Rice Krispies	8 oz	Eight 1-oz newsboard cartons ($5\frac{5}{8}$ by $2\frac{5}{8}$ by $8\frac{1}{4}$ in.), 0.0145-in. caliper overwrapped with printed 450 MST cellophane, inner liners of 25- to 32-lb cereal glassine
55	Corn pops	5 oz	Newsboard carton ($6\frac{1}{8}$ by $1\frac{3}{4}$ by $7\frac{1}{4}$ in.), 0.016-in. caliper, liner a lamination of 0.00035 aluminum foil with wax and tissue paper
56	Whole wheat cereal	18 oz	Paper-covered chipboard carton ($4\frac{7}{8}$ by $1\frac{3}{4}$ by $7\frac{3}{8}$ in.), 0.026-in. caliper, with Manila liner
57	Whole wheat flakes	8 oz	Newsboard carton ($6\frac{5}{8}$ by $2\frac{3}{8}$ by $8\frac{3}{8}$ in.), 0.016-in. caliper, lined with 31-lb waxed glassine
58	Grape Nuts	10.5 oz	Chipboard carton ($4\frac{3}{4}$ by $1\frac{7}{16}$ by $6\frac{1}{8}$ in.), 0.020-in. caliper, overwrapped with 37.5-lb waxed sulfite paper
59	Milk chocolate party mixture	1 lb	Cellophane-overwrapped carton ($6\frac{1}{4}$ by $1\frac{1}{4}$ by $6\frac{1}{4}$ in.)
60	Fudge (with nuts)	24 bars	Chipboard carton ($6\frac{3}{8}$ by 2 by $7\frac{1}{2}$ in.) contains 24 cellophane-wrapped bars
61	Candy-coated peanuts	3 lb	Chipboard carton ($10\frac{3}{8}$ by $1\frac{1}{4}$ by $7\frac{3}{8}$ in.), with cellulose acetate film window
62	Hard candy mixture	1 lb	Polyethylene 300 bag ($5\frac{3}{4}$ by 10 in.), tubular film, heat-sealed, stapled saddle label

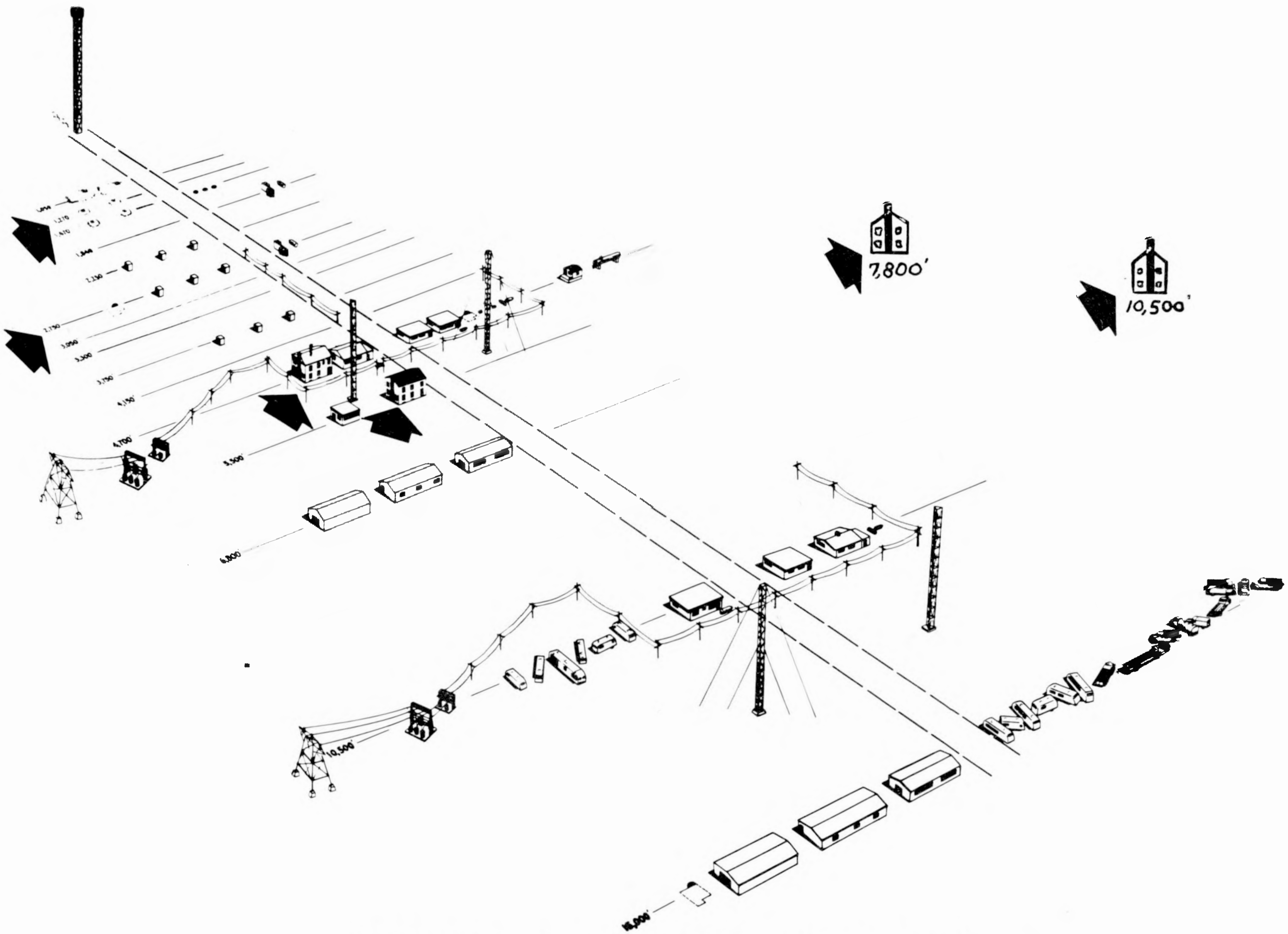

Fig. 1—Location of test foods in trenches and houses for Shot II (Operation Cue). Arrows indicate location.

Fig. 2—Trench at Station A (1100 ft) showing arrangement of semiperishables at different depths before covering with soil, Shot I.

Fig. 3—Semiperishable foods arranged on ground surface at Station C (1 mile), Shot I.

Fig. 4—Arrangement of consumer packages of semiperishable foods in tomato lug box used as an exposure box at trench positions, Shot I.

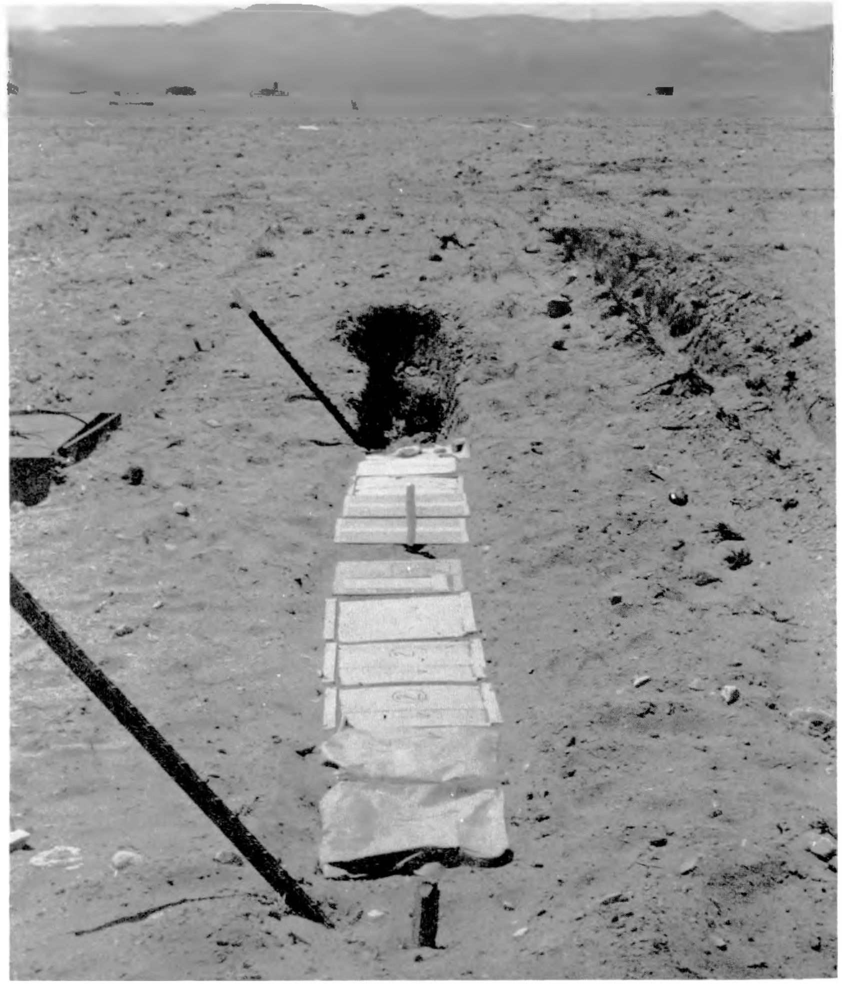

Fig. 5—Produce and semiperishable foods in trench at Station B (2750 ft) before covering with 1 in. of soil, Shot II.

Fig. 6—Types of potato packages exposed at several locations.

Fig. 7—Types of onion packages exposed at several locations.

Fig. 8—Types of apple packages exposed at several locations.

Fig. 9—Types of raisin packages exposed at several locations.

Fig. 10—Types of packages of nonfat dry milk solids exposed at several locations.

Fig. 11—Types of dry bean packages exposed at several locations.

Fig. 12—Types of flour packages exposed at several locations.

Fig. 13—Types of cereal packages exposed at several locations.

Fig. 14—Types of candy packages exposed at several locations.

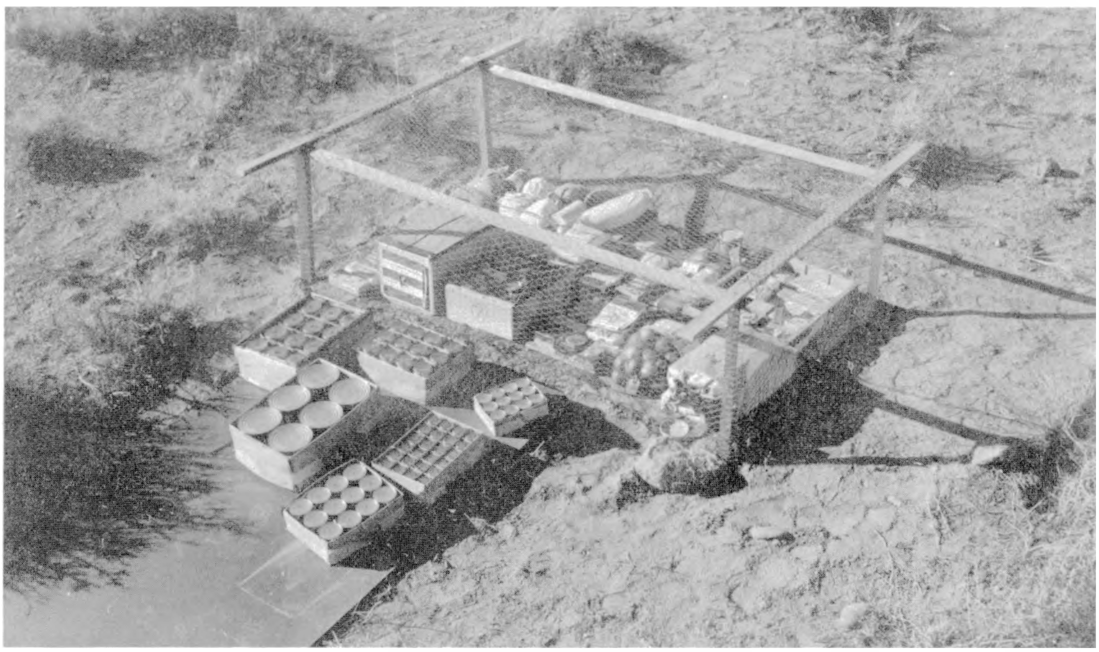

Fig. 15—Arrangement of different kinds of food packages on ground surface in expected fall-out zone 7 miles from GZ.

Fig. 16—Box buried flush with ground with no soil cover at Station A (1100 ft) (right). (Note destruction of cover and loss of polyethylene potato bag.) Check box not exposed (left).

Fig. 17—Physical damage to multiwall kraft bag of potatoes buried flush with ground with no soil cover at Station A (1100 ft) (right). Check bag not exposed (left).

Fig. 18—Blast caused greater damage to fiberboard box than to wooden box of apples in trench at Station A (1270 ft), but bruising was severe in both types of container.

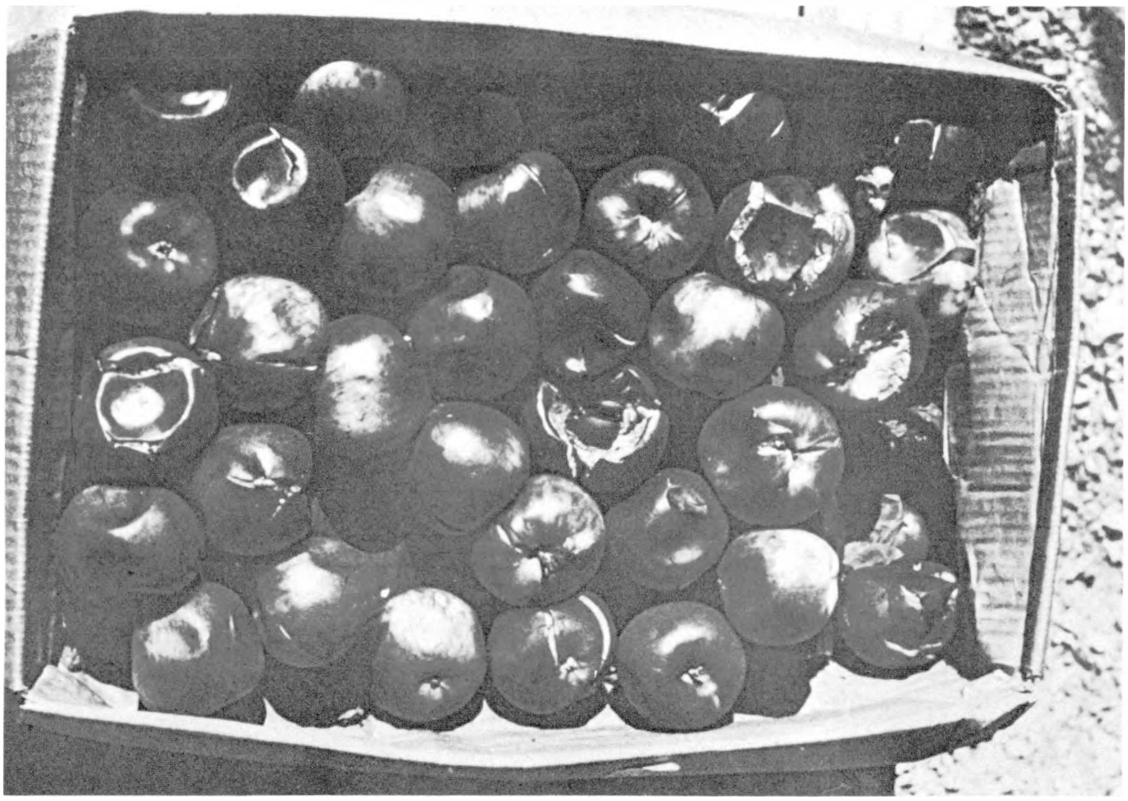

Fig. 19—Severe bruising and crushing of apples exposed in trench at Station A (1270 ft).

Fig. 20 — Physical damage to consumer bags of apples, oranges, potatoes, and onions after exposure in trench at Station A (1270 ft).

Fig. 21 — Severely bruised and crushed apples and oranges after exposure in consumer bags in trench at Station A (1270 ft).

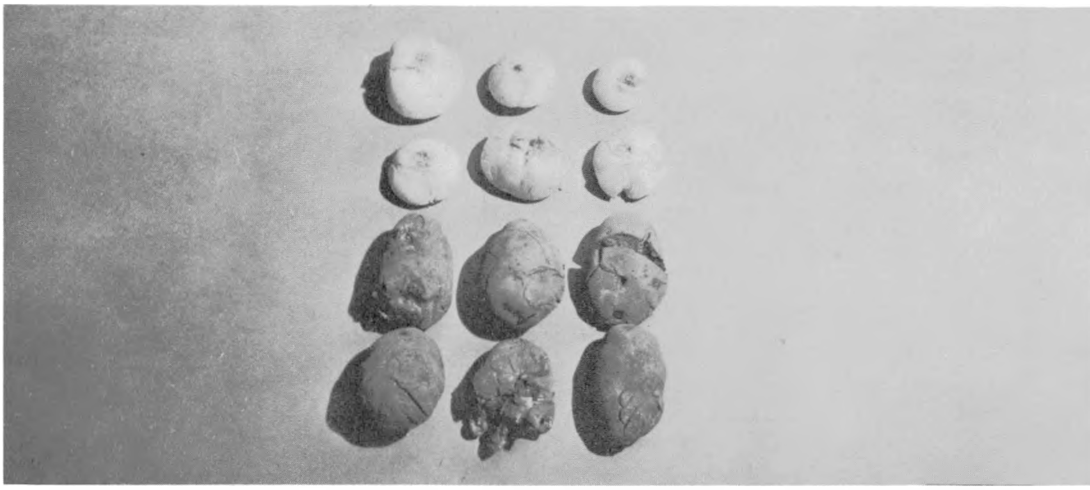

Fig. 22 — Severely bruised and crushed onions and potatoes after exposure in consumer bags in trench at Station A (1270 ft).

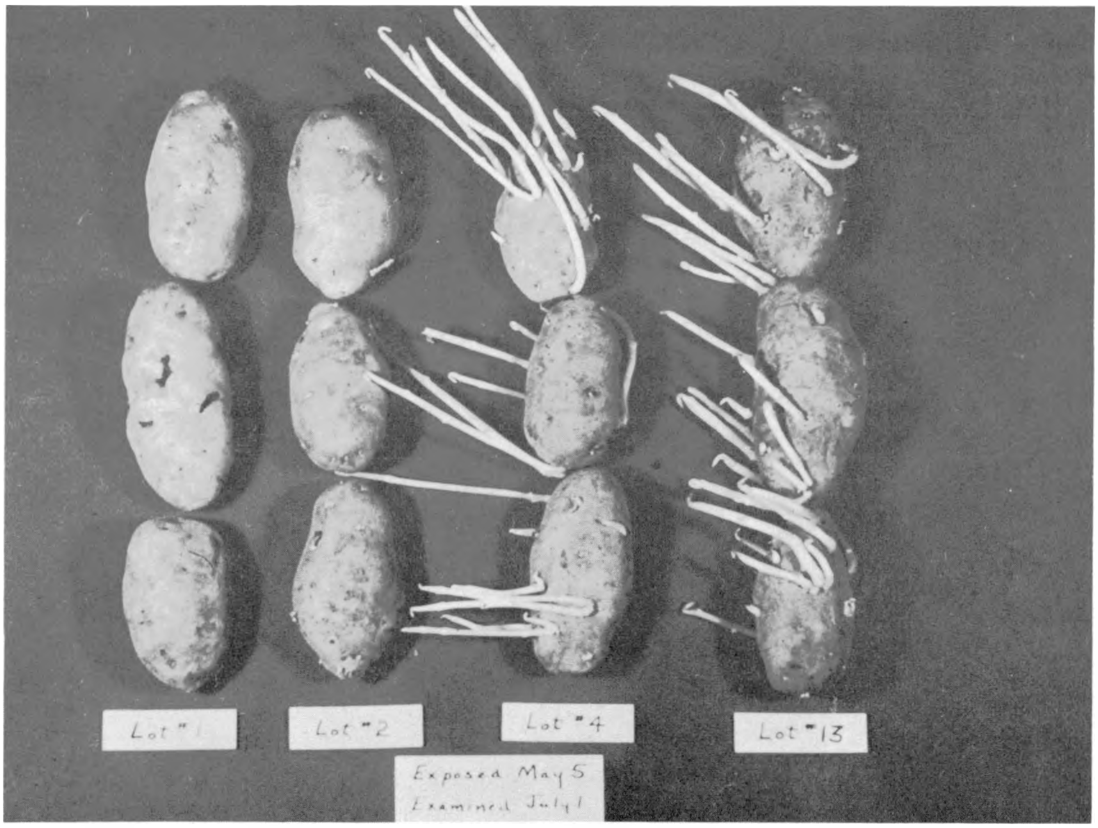

Fig. 23 — Initial radiation inhibited sprouting of potatoes exposed at nearer positions. Left to right: lot 1, trench 1270 ft; lot 2, trench 2750 ft; lot 4, basement 4700 ft; lot 13, unexposed. Exposed on May 5 and examined on July 1. Photographs were taken 2 months after tests.

Fig. 24—Packages of candy, flour, and dry beans after exposure at Station A (1270 ft). Some show slight physical damage.

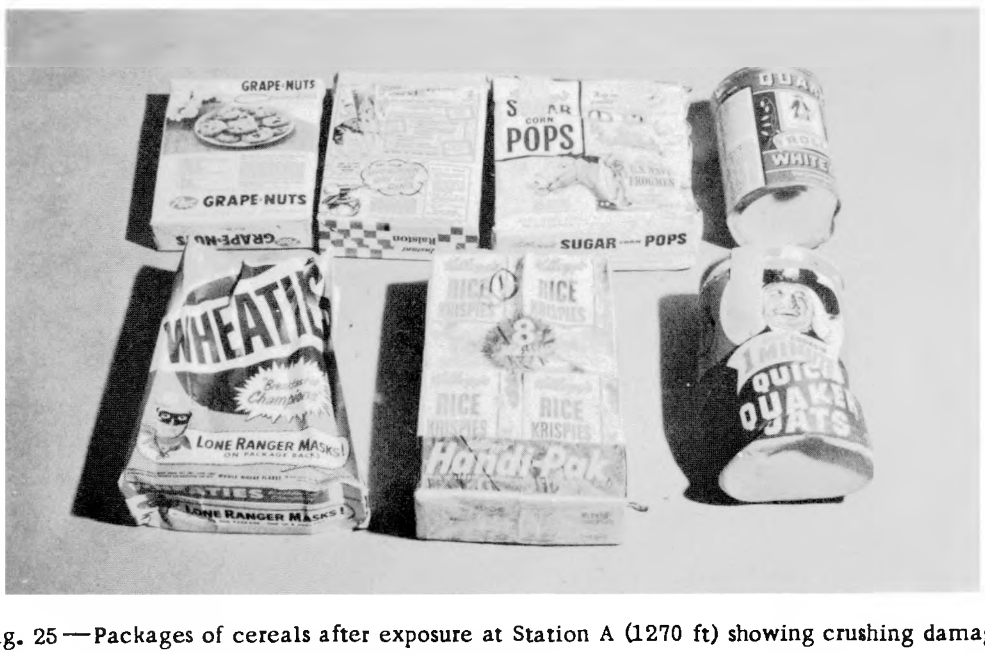

Fig. 25—Packages of cereals after exposure at Station A (1270 ft) showing crushing damage. Contents were intact in most packages.

Fig. 26 — Foods were placed in kitchen and basement of a two-story brick house located 4700 ft from the explosion.

Fig. 27 — Two-story brick house used in food test at 4700 ft after the explosion.

Fig. 28—Produce and staples on shelves in kitchen of brick house 4700 ft from GZ before the explosion.

Fig. 29—Wreckage of kitchen showing food shelves in brick house at 4700 ft after the explosion.

Fig. 30—Produce and semiperishable staples on open shelves in basement of brick house at 4700 ft before the explosion. Note the film dosimeters along the right edge of the shelves.

Fig. 31—Produce and semiperishable staples still on shelves in basement of destroyed brick house at 4700 ft after the explosion. Most foods and food packages were undamaged in the basement.

Fig. 32—Produce and canned foods in kitchen of frame house at 5500 ft before the explosion.

Fig. 33—Wreckage in kitchen of frame house at 5500 ft. Many foods were thrown to floor causing some breakage.

Fig. 34—Produce, staples, and canned foods on open shelves in basement of frame house at 5500 ft before the explosion.

Fig. 35—Produce, staples, and canned foods still on shelves in basement wreckage of frame house at 5500 ft. Most foods were undamaged in the basement.

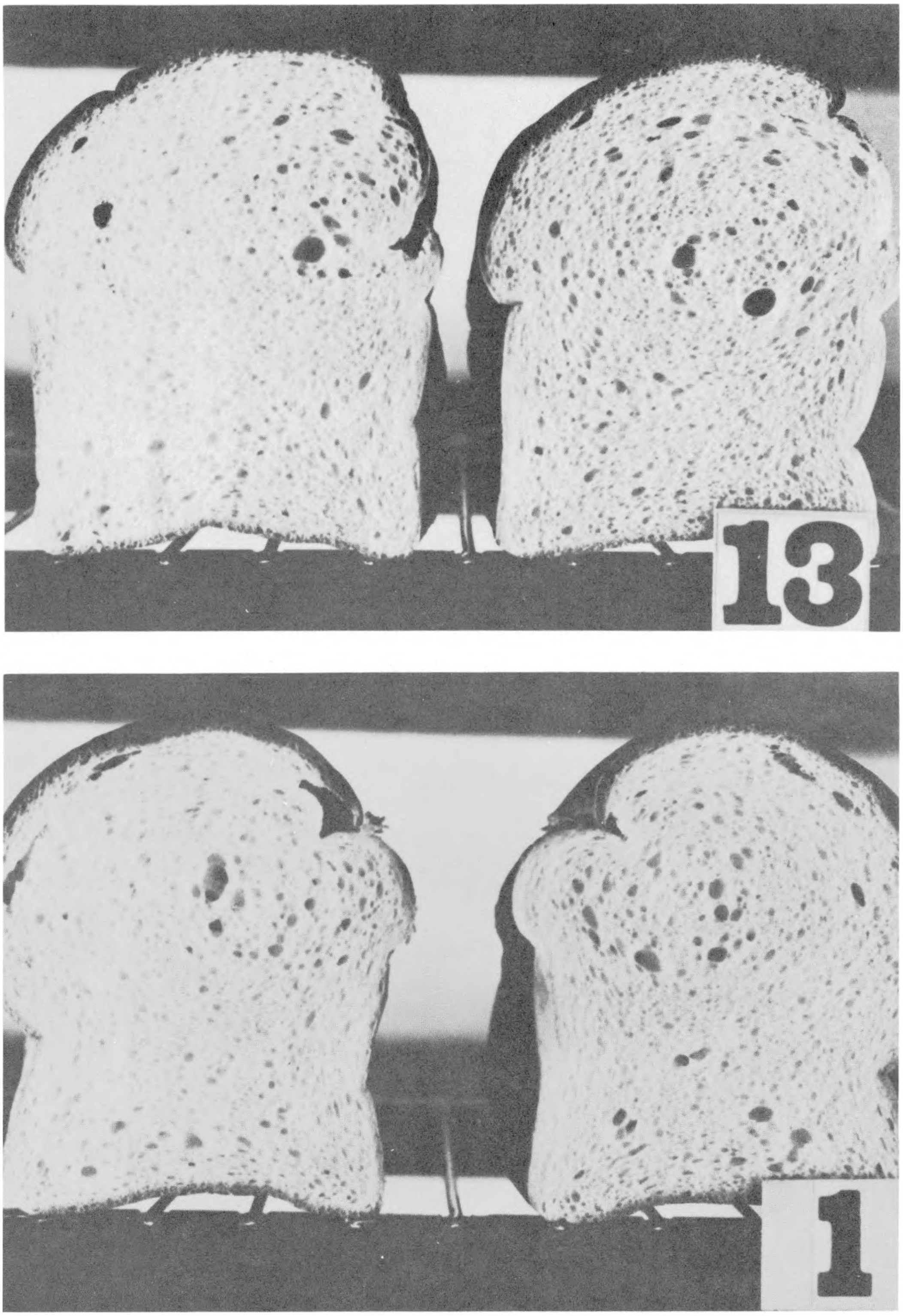

Fig. 36—Comparison of bread made from flour exposed (1) at 1270 ft from blast and bread made from unexposed flour (13). No appreciable difference noted.

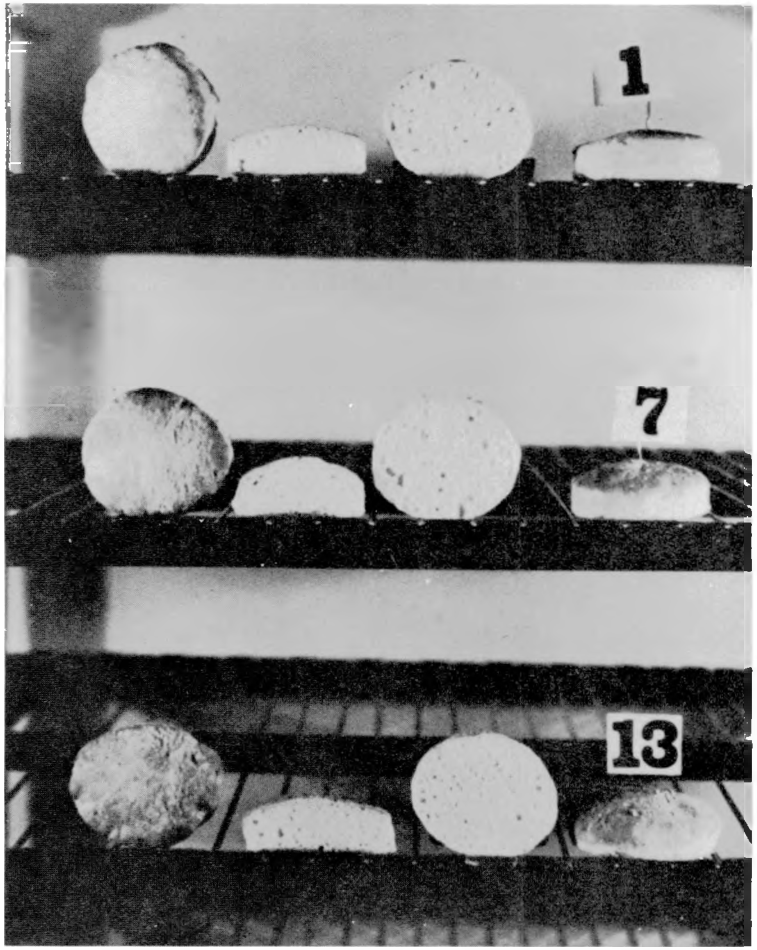

Fig. 37—Comparison of baking powder biscuits made from prepared biscuit flour exposed in trench at 1270 ft (1), in house at 7800 ft, (7), and biscuits made from unexposed flour (13). No difference in baking quality noted.

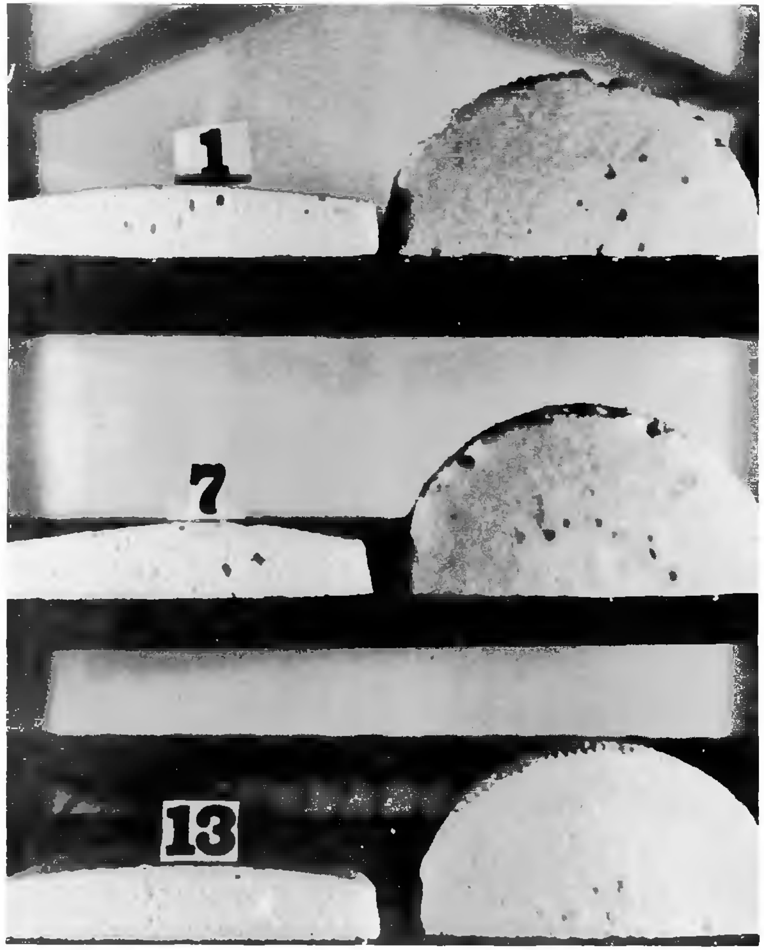

Fig. 38—Comparison of the grain, texture, and tenderness of white cakes made from flour exposed in trench at 1270 ft (1), in house at 7800 ft (7), and in cake made from unexposed flour (13).