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DISTRIBUTION OF VOLCANIC FALLOUT IN AND ABOUT A ONE-STORY RESIDENCE

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SUMMARY OF RESEARCH REPORT

DISTRIBUTION OF VOLCANIC FALLOUT IN AND ABOUT A ONE-STORY BUILDING

USNRDL-TR-953 , dated 11 August 1965

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PURPOSE AND OBJECTIVES

The purpose of these tests was to study the behavior of fallout in the environment of a one-story residence, using as a fallout simulant naturally deposited volcanic fallout, produced by Volcano Irazu, Costa Rica.

The experimental objectives were to determine: (1) The ingress of the particulate matter from flow through an entry window and an exit window under three entry conditions; (a) natural ventilation, (b) forced ventilation, and (c) forced ventilation with filtered intake air, and (2) the rate of deposition, size and mass distribution of particles on exterior concrete surfaces, galvanized sloped roofs, and a patio which represented any partially enclosed area.

SCOPE

The experimental site was a one-story residence surrounded by concrete walks and situated within the area which was covered with volcanic ash fallout. The effects of deposition rate and rain (both during and after fallout deposition) on the ingress, deposition, and redistribution were studied. Daily fallout collections were made, measured and observed to determine debris distributions in and about the residence.

SIGNIFICANT FINDINGS AND CONCLUSIONS

It was found that the particle size distribution of material collected inside the home was similar to that outside the home. The mass loadings inside were a factor of 50 less than those outside. It was concluded that, in the case of radioactive fallout, the ratio of outside dose to inside dose may be reduced significantly in the vicinity of the window through which air is moving.

For studies conducted outside and in the absence of any precipitation, the particle size distribution and mass deposited was uniform from one sample location to another. On this basis, it was concluded that reclamation tests using uniform distributed synthetic fallout are realistic even when the surface configurations are quite complex.

RECOMMENDATIONS

Any further eruptions by this volcano or any other volcano which creates sand-like fallout should be utilized for studies requiring large-scale simulation of fallout distribution.

ABSTRACT

The sand-like debris from Volcano Irazu in Costa Rica closely resembles the type of fallout produced by a near-surface or underground nuclear detonation. The activity of the volcano during April and May 1964 presented an opportunity to use this phenomenon in a field-scale study of some relationships between urban reclamation and nuclear fallout contamination. The eruptions of the volcano were frequent and the rates of arrival at the test site were dependent on wind direction and the severity of the eruptions.

The investigation was divided into two phases: (I) distribution of debris inside a one-story residence; and (II) distribution outside the residence. Phase I was concerned with the ingress of particles through open windows under conditions of: (a) natural ventilation, (b) forced ventilation, and (c) forced ventilation with minimal filtering. Phase II was concerned with the deposition and redistribution by wind, of particles on concrete walks, corrugated metal roofs, and partially exposed tile floors - each with and without rain.

In Phase I, it was observed that particle size distributions inside the house did not differ greatly from those deposited outside. Mass loadings inside were a factor of 50 less than those outside. It was concluded that, if this were a case of radioactive fallout, the ratio of outside dose to inside dose would be reduced significantly in the vicinity of the window through which air is moving.

In Phase II, it was observed that in the absence of rain, the particle size distribution and mass deposited was uniform from one sample location to another, only minor variations having been observed from day to day. On this basis, it was concluded that reclamation tests using uniformly distributed synthetic fallout are realistic even when the surface configurations are quite complex.

When rain accompanied the debris deposition, however, different results were observed. Particle size distributions and mass loadings

were a function of redistribution and varied with sample location. Deposits on roof surfaces will be significantly reduced but will accumulate in the gutters. In the case of radioactive fallout, a concentrated radiation source would result.

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INTRODUCTION

In the development of protective and reclamation procedures for use in reducing the effects of fallout from nuclear detonations, information on specific contamination situations is required to supplement the knowledge of gross weapon effects. Such information includes the deposition and distribution of nuclear debris in and about a residence. The production by a volcano of debris resembling fallout provided large-scale simulated fallout conditions for obtaining such information. A study was made of the distribution of the debris particles inside and outside a typical residence during April and May 1964. The information obtained can provide an essential link between theoretical studies of fallout and the actual nuclear situation.

BACKGROUND

Limited study, in reclamation experiments, has been made of the deposition and distribution of synthetic fallout on surfaces about buildings.[1-4] The buildings were Army barracks, and synthetic fallout was uniformly dispersed on horizontal surfaces around them and on their roofs. One investigation,[1] with the primary interest of determining the overall cost and effectiveness of recovery operations, provided the only data on the redistribution effects of wind and rain.

No tests were made of interior contamination of buildings during the aforementioned reclamation studies. However, some were made of fallout shelters. At Camp Parks, simulated fallout was allowed to enter the ventilation intake of an underground shelter.[5] At Operation PLUMBBOB, during actual nuclear fallout, a shelter ventilation intake configuration was tested[6] which was designed to eliminate the need for air filtration.

In the reclamation studies mentioned, synthetic fallout with a uniform particle size distribution was used. Uniformity of the mass level dispersed was emphasized but little study was made on the effects of wind and rain on the redistribution of the particles after they were initially deposited. Nor were wind and rain effects on particle size distribution studied, although it was known that the configuration of buildings, curbs, and other surroundings influenced the local surface winds, which in turn, influenced the particle deposition and redistribution.

The experiments utilizing synthetic fallout material have yielded conclusions which were extrapolated into radiological situations, through theoretical calculations based on a mathematical fallout model. An example of this has been the conversion of mass data into radiation readings by the use of mass-contour ratios.[7,8] Conversely, a fallout model[8] has been used to determine realistic fallout environments for reclamation experiments. The fallout model[7] idealized some of the indeterminable variables to simplify the approach to the problem of determining particle size distributions and mass depositions resulting from nuclear detonations. For example, the mass distributions under these idealized conditions were assumed to be uniform and no consideration was given to redistribution by weather and its effect on particle redistribution. Data still remain to be determined which would allow the evaluation of non-idealized situations and their effects on particle distribution in and about a typical residential building, before and after redistribution by wind and rain.

Since 13 March 1963, Volcano Irazu in Costa Rica had been erupting almost continuously. The sand-like debris (called ceniza) from this volcano closely resembles the fallout that would be produced by near-surface or underground nuclear detonations.[9] This resemblance and the falling out of the debris in populated areas afforded an opportunity to study the distribution of particulate matter in ventilated spaces and on exterior surfaces. Thus an experiment, using a residence with grounds, was undertaken to determine mass and particle size distribution of volcanic fallout, in interior spaces due to air flow, and on exterior surfaces. The distribution of particles on exterior surfaces was determined as a function of the different surfaces, and the interior particulate distribution due to air flow was compared with the exterior distributions.

OBJECTIVES

The specific objectives were to: (1) Study the ingress of particulate matter resulting from air flow through an entry window and an exit window under three ventilation conditions: (a) natural ventilation, (b) forced ventilation, and (c) forced ventilation with filtered intake air. (2) Study the rate of deposition, size and mass distributions of debris on exterior concrete surfaces, galvanized sloped roofs, and a patio representing partially enclosed areas. These depositions were studied on rainy days as well as rain-free days.

A secondary objective was to observe the current methods employed by the city of San Jose for mass removal of debris from buildings and streets in densely built-up areas.

EXPERIMENTAL PROCEDURES

TEST SITE SELECTION

The experiments had to be started as quickly as possible while the volcano eruptions continued. Also, most of the experiments had to be completed before the seasonal rains started. Detailed experimental planning had to await the selection of an adequate test area and the arrival of the test personnel.

The most suitable house obtainable was a one-story house (Fig. 1) outside the city where the sidewalks and paved roads were limited and foot traffic was practically non-existent. The house was within the fallout pattern, 10 miles downwind from the volcano (Fig. 2).

TEST EQUIPMENT

To determine the effect of surface winds on deposition or redeposition of particles on the exterior surfaces, wind speed and direction data were recorded continuously. Bendix-Friez Model 130 wind-measuring sets were used, which had wind direction-velocity transmitters and wind direction-velocity recorders.

Temperature and humidity were measured to determine what effect, if any, they might have on the mass and/or particle size distributions obtained. Records were obtained with a Brown Hygrothermograph Recorder, Model 612X21K1X84. The amount of precipitation in the tests on redistribution by rain was determined with standard 6-in. rain gauges.

The weights of samples collected were determined on a Mettler B-5 Balance or a Mettler K-7 Balance, depending on the size of the sample and the degree of accuracy desired.

Fig. 1 Northeast View of House Used for Experimental Station

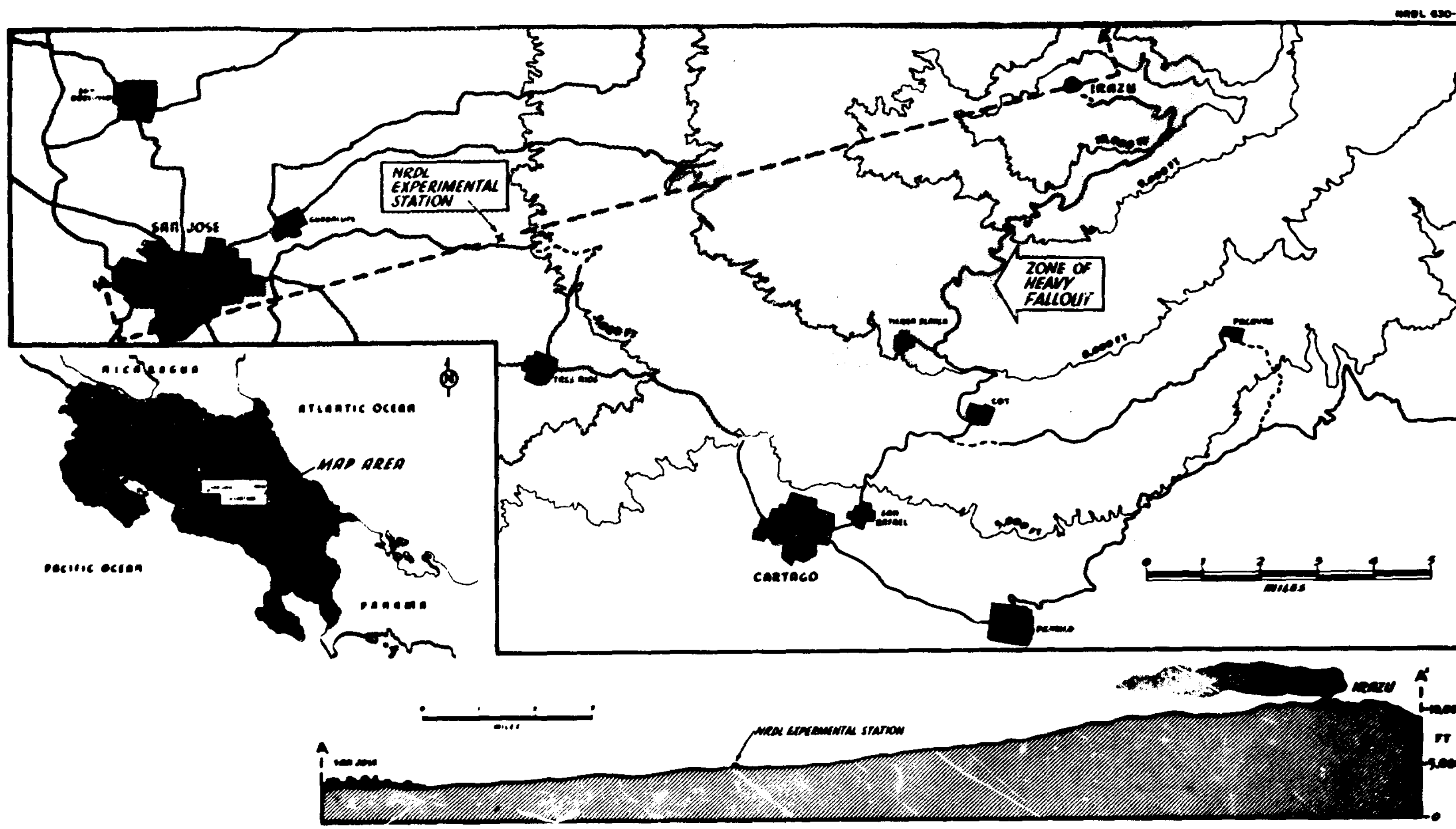


Fig. 2 Map of Fallout Area in Costa Rica

Cameras were used to document the experiments conducted at the house. Also obtained through photography were qualitative observations on the removal of debris from the streets of San Jose. A 16-mm movie camera (Cinema Beaulieu RC-16) and a 35-mm still camera (Besseler Topcon BT 300) were used.

SAMPLE COLLECTION

To obtain mass distribution data, an always-open collector (AOC) was used. This type of collector had been previously field tested and consisted of aluminum louvers placed at 45° inside a 2 x 2-ft, 2-in. deep aluminum tray. The AOCs were used in all tests, except one, with the louvers slanted northward, the direction of the prevailing winds. In the one exception, in which the objective was to determine whether direction of roof slope affected the mass distribution, the AOCs were placed with the louvers pointing up toward the roof ridge.

On the patio floor, vacuum cleaning was used to collect samples. This avoided alteration of the wind pattern at the surface of the floor, by trays on the floor. The vacuum cleaner used was a Filter Queen with a new, tared, debris-collector bag used for each test run.

To obtain data on the mass distribution on concrete and roof surfaces, the material deposited on a measured area was brushed into a tared container.

SAMPLE PROCESSING

To determine the gross weights of fallout collected in the AOCs, the debris collected was transferred into small aluminum weighing pans and weighed. To determine the amounts obtained by the brushing and vacuuming techniques, the amounts collected were placed in tared plastic bags and weighed. Mass per unit area was calculated by dividing the total mass collected by the total area swept or vacuumed.

Dry sieving, using standard sieves, was conducted in the field on samples to determine their particle size distribution. The sample was shaken in a Ro Tap Shaker for 10 minutes. The amounts retained on the various sieves were carefully brushed into tared aluminum weighing dishes and weighed.

INGRESS TEST PROCEDURES

Three tests of debris ingress into the interior spaces were conducted (see Table 1 for details, Fig. 3 for sample locations). In Test Alpha, two windows on opposite walls of the house were left open for 19 hr, and the amount of fallout entering the space under conditions of natural ventilation was determined.

In Test Bravo, an exhaust fan was placed in one window and 3900 ft^3 air/min (face velocity, 425 ft/min) was pulled through the other window. This experiment ran for 19 hr.

In Test Charley, the conditions were similar to those of Bravo, except that inexpensive furnace-type filters (Fram Aire Filters, 1-in. thick fiberglass) were put into the intake window. The filters lowered the intake air flow rate to 2800 cfm. The experiment ran for 25 hr.

EXTERIOR TEST PROCEDURES

The conditions for all exterior tests are listed in Table 1 (Fig. 4 shows plan view of sampler locations). Preliminary tests (Tests Delta and Echo) were conducted to develop procedures and techniques for the subsequent, main tests. In the latter each surface was examined with and without rain and with different mass loadings. One of the tests was run for the photographic documentation of the movement of the particles by rain.

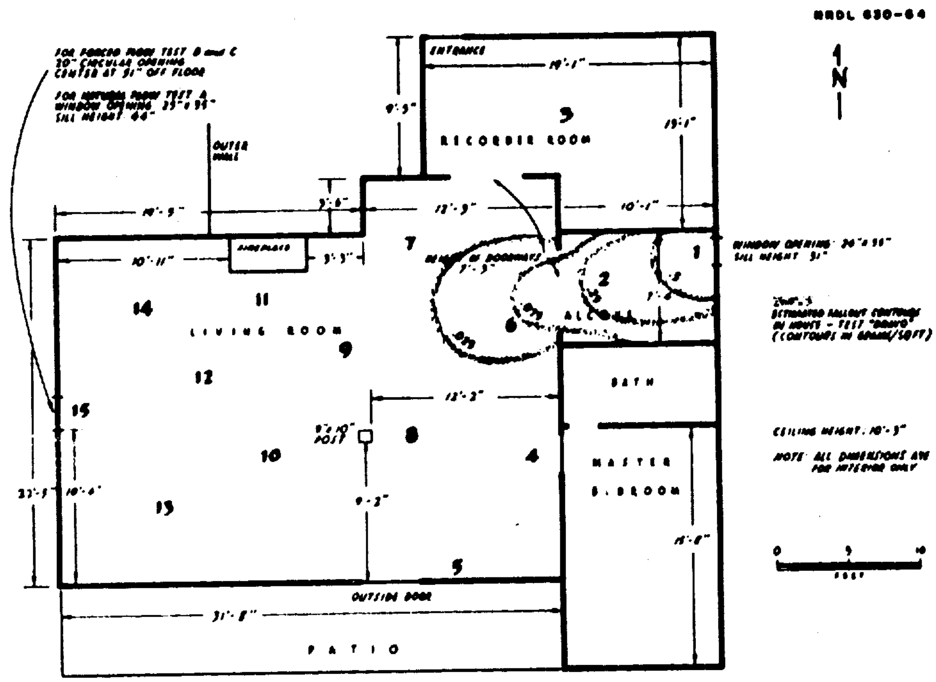
As shown in Table 1, Tests Foxtrot, Hotel, and Juliet were conducted on the patio surfaces. One of the determinations from the preliminary tests (Delta) had indicated that placement of AOCs on the surface of the patio would alter the natural air flow pattern. Therefore during all tests conducted on the patio surface, fallout trays were located outside of the patio area, and vacuuming techniques were used to determine the mass loadings within it. Foxtrot was run to determine mass deposited and particle size distribution of fallout around the patio in the absence of rain. Juliet was a repeat of Foxtrot but with the

TABLE 1

Summary of Conditions and Equipment Used for Particle Distribution Tests

Test	Date (1964)	Duration (hr)	Location	Condition	Equipment
			Ingress		
Alpha	9 April	19	Interior	Natural ventilation	19 AOCs,* 4 WVD sets**
Bravo	10 April	19	Interior	Forced vent., 3900 cfm	19 AOCs, 4 WVD sets
Charley	14 April	25	Interior	Forced vent. with minimal filtering, 2800 cfm	19 AOCs, 4 WVD sets
			Exterior		
Delta	19 April	19	Patio	No rain	AOCs, WVD sets
Echo	19 April	19	Concrete walkway (sloped)	No rain	AOCs, WVD sets
Foxtrot	22 April	22-1/2	Patio	No rain	10 AOCs, 4 WVD sets
Golf	22 April	22-1/2	Concrete walkway (sloped)	No rain	9 AOCs
Hotel	25 April	44	Patio	Rain	10 AOCs, 4 WVD sets, rain gauges
India	25 April	44	Concrete walkway (sloped)	Rain	9 AOCs, rain gauges
Juliet	28 April	6	Patio	No rain	10 AOCs, 4 WVD sets
Kilo	28 April	6	Concrete walkway (sloped)	No rain	9 AOCs
Lima	28 April	6	Roof	No rain	4 AOCs
Mike	30 April	25-3/4	Concrete walkway (horizontal)	Rain	2 AOCs, rain gauges
November	30 April	25-1/2	Roof	Rain	5 AOCs, 4 WVD sets
Oscar	30 April	1-1/2	Concrete walkway (sloped)	Rain	Rain gauges, cameras
Papa	30 April	8-1/2	Concrete walkway (horizontal)	No rain	3 AOCs
Quebec-1) Quebec-2) Quebec-3)	2 May	18 total	Roof	With and without rain	Brush collection
Romeo	2 May	4	Concrete walkway (sloped)	No rain	5 AOCs

* Always Open Collector.
**Wind Velocity and Direction Transmitter and Recorder sets.



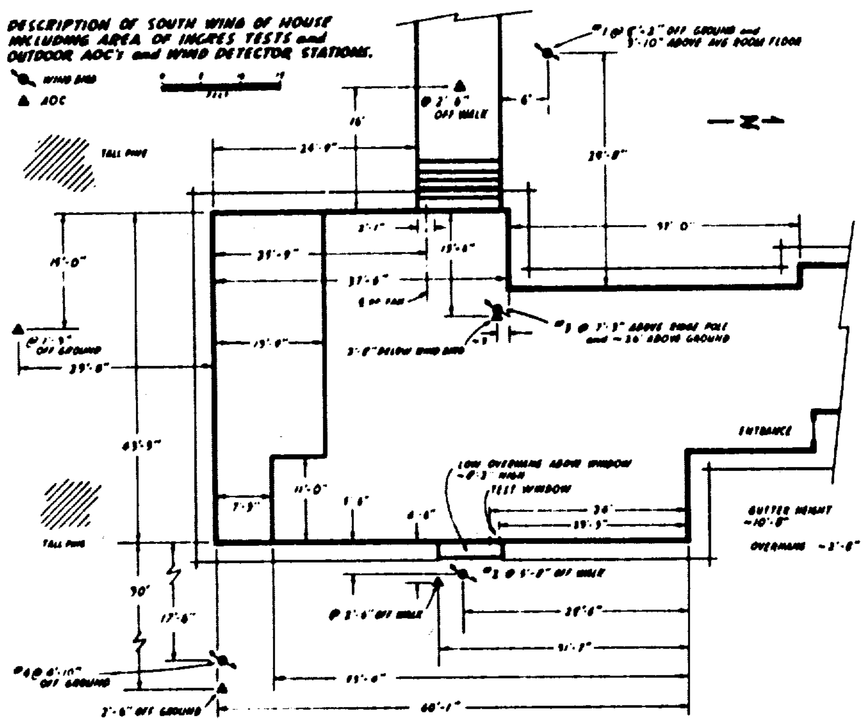


Fig. 3 Plan of Interior of Experimental Space and Plan of Experimental Space

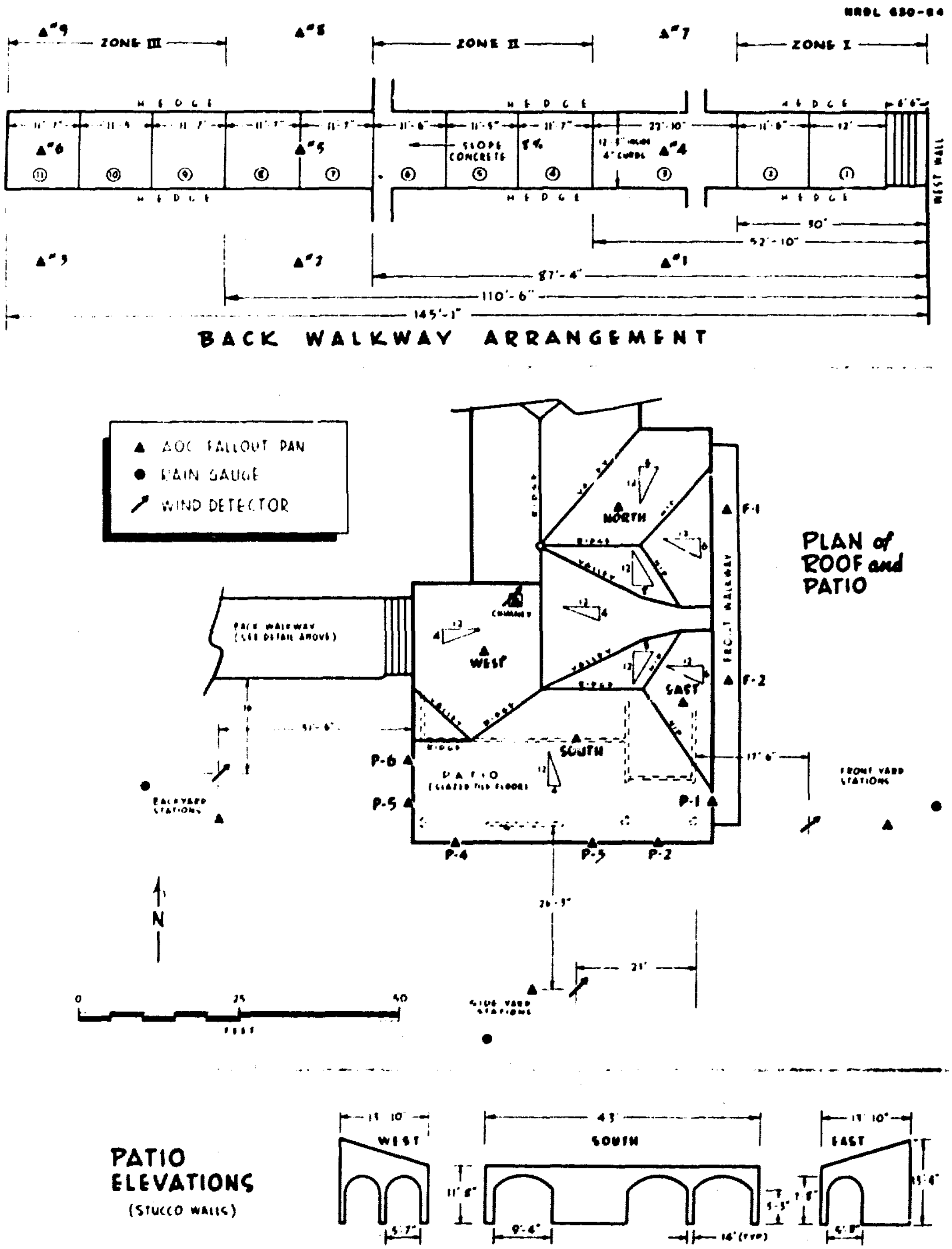


Fig. 4 Plans of House and Grounds

debris falling at a different mass loading rate. Test Hotel was run with rain to see whether this altered the distribution of particles.

Tests Golf, India, Kilo, Oscar and Romeo were conducted on the sloped (8 %) concrete walkway. The purpose of the first three of these tests was to determine the mass deposited and the particle size distribution, Golf and Kilo being run without rain and India with rain.

The purpose of Test Oscar was to record on movie film the action of rain on particles. The amount of rainfall was documented with rain gauges. No experimental data on mass deposited was taken.

Test Romeo was run to determine deposition amounts as a function of distance from the house. Fallout trays were placed at known distances in a row from the house. If the prevailing wind remained constant for a specified period, the amount deposited was expected to be a function of distance from the house.[10] The configuration of the house was expected to alter the mass distribution and the amount would vary with distance from the house.

Tests Mike and Papa were conducted on the horizontal concrete walkway located in front of the house, with and without rain, respectively. The mass deposited and the particle size distributions were determined.

Tests Lima, November, and Quebec-1, Quebec-2, and Quebec-3 were conducted on the roof. For Test Lima, one AOC was placed on each of four slopes facing north, east, south, and west respectively. The purpose of the test was to determine whether direction of slope introduced any difference in the amount collected. Test November was a repeat of Test Lima with rain. The three Quebec tests were conducted to determine the effect of rain on the particles already deposited on the slanted roof. The amount of debris deposited was determined by brushing and weighing material within an area of known dimensions. The amount of material collected or deposited before and after rain was weighed. No particle size analyses were made of Quebec samples. Visual estimates were also made on the amount of material removed from the roof and redeposited in the gutters.

RESULTS AND DISCUSSION

Particle size distributions (Appendix A) were obtained through sieve analysis of some samples at the test site. Sieve analysis data from interior and exterior stations, for several test runs, were plotted (Figs. 5-9) to determine the mass median particle sizes.

The mass per unit area determined for each sample is presented in Appendix B.

For ingress studies, the total amount of fallout entering the experimental space for each of the three tests was estimated by sketching contours (based on fallout collections and visual estimations) on a plan of the space, determining their areas, and multiplying by the mass per unit area values of the contours. Figure 3 includes, as an example, the contours estimated for Test Bravo.

Rain, temperature, and relative humidity data are presented in Appendix C. These data show only minor variations during the period of these tests, and no correlation with particle size distribution is apparent.

INGRESS STUDIES

The data in Table 2 and the interior data in Appendices A and B show that the amount of debris collected and the particle size distributions (Figs. 5-7) were fairly similar at the roof and exterior window stations for Tests Alpha and Bravo. However, for Test Charley the roof station collected only half as much debris as did the exterior window station. This was due to the low deposition rate during this test and to the collection at the yard stations of material blown down from the roof and from nearby trees by strong winds during part of the test. Although the exterior window station was relatively close to the intake window, it was far enough away so that under the conditions of Test Charley, its collection could not be relied upon to represent the debris

TABLE 2

Summary of Selected Field Data and Derived Data for Ingress Tests

Station	Total Mass (g)	Mass Loading (g/ft^2)	Mass Med. Diam. (μ)
		Test Alpha Wind: Light (< 3 knots) and variable. Ventilation: Natural. Total Debris Entering Test Space: 16 g	
Roof	42.9	10.7	82
Window	50.1	12.5	85
1	1.9	0.47	57
2	0.48	0.12	47
15	1.6	0.40	60
		Test Bravo Wind: Light (< 3 knots) and variable. Ventilation: Forced, 3900 cfm. Total Debris Entering Test Space: 21 g.	
Roof	21.5	5.4	56
Window	23.9	6.0	55
1	2.3	0.57	66
2	1.1	0.27	53
		Test Charley Wind: 6 to 12 knots - north to northeast during the day; light and variable at night. Ventilation: Forced with filtered intake, 2800 cfm. Total Debris Entering Test Space: 27 g.	
Roof	14.9	3.7	94
Window	25.8	6.5	110
1	5.3	1.3	90
2	1.1	0.27	60
15	1.2	0.29	100

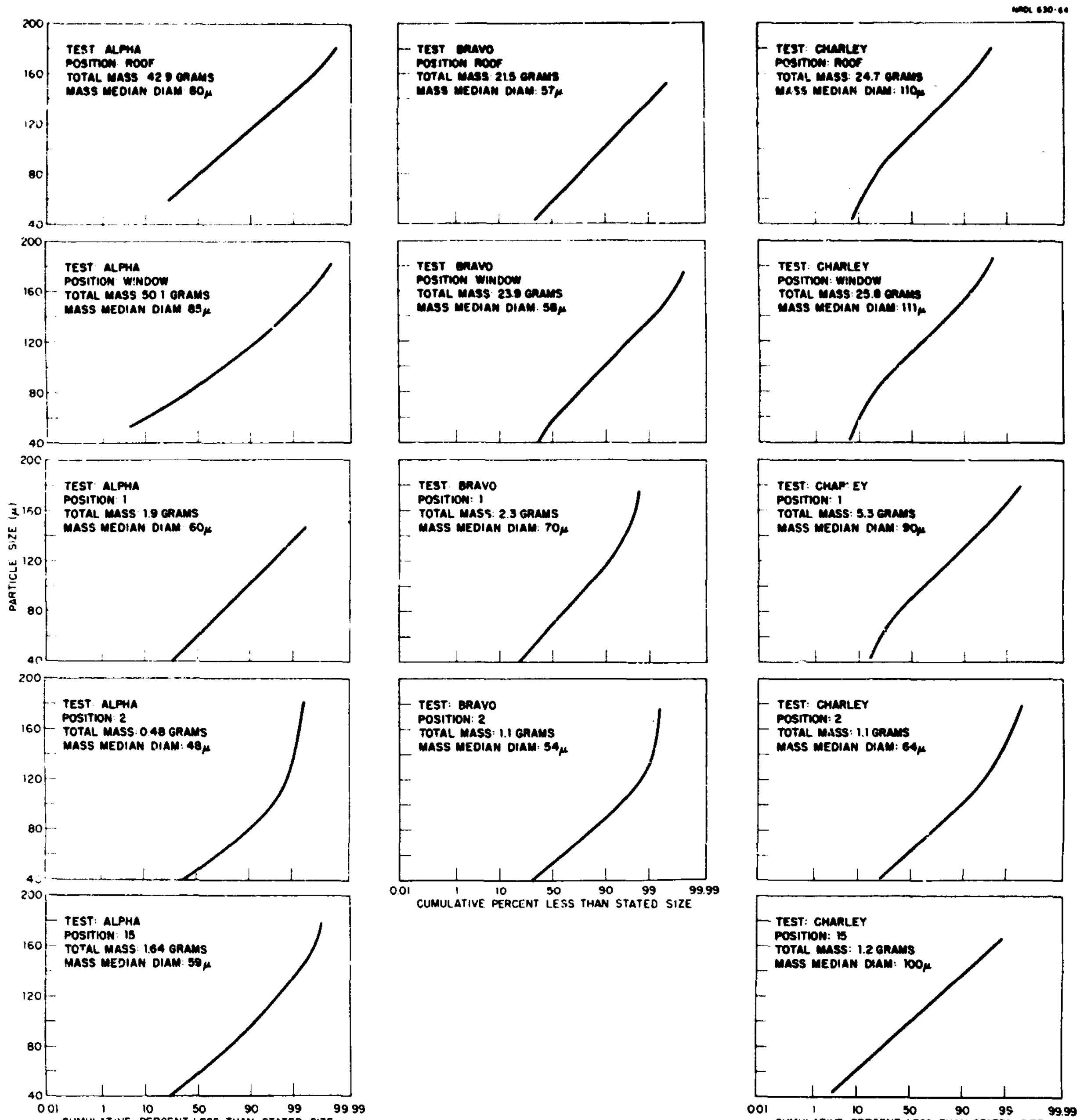
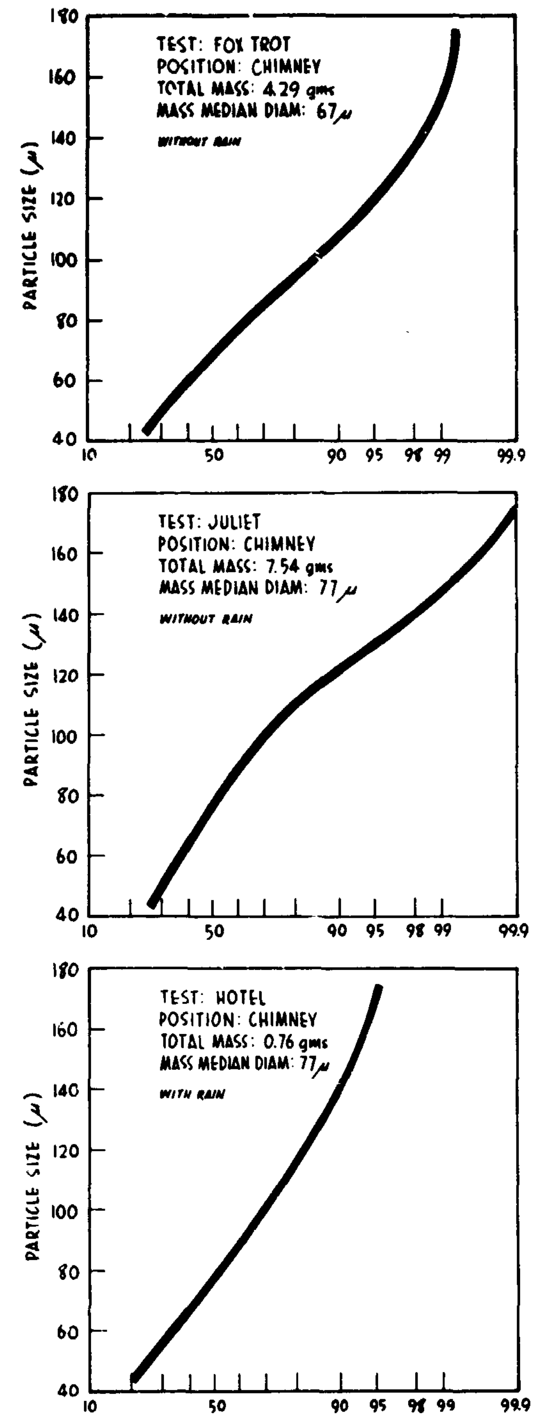


Fig. 5 Particle Size Distribution Test Alpha.

Fig. 6 Particle Size Distribution Test Bravo.

Fig. 7 Particle Size Distribution Test Charley.



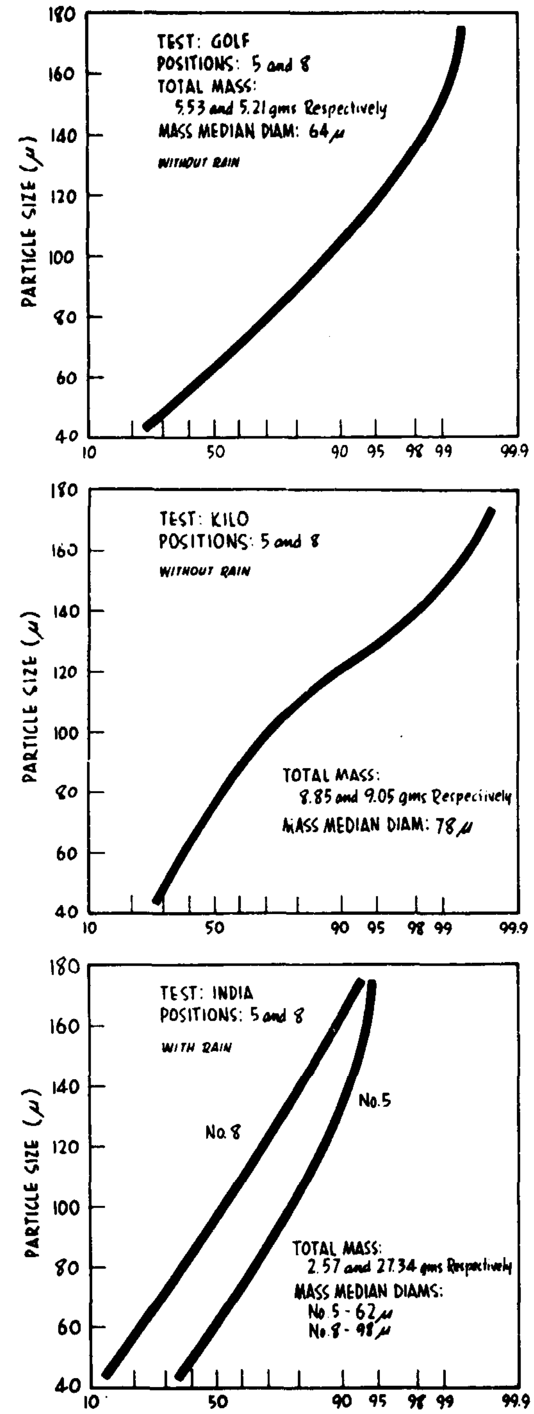


Fig. 8 Particle Size Distribution of Foxtrot, Juliet and Hotel.

Fig. 9 Particle Size Distribution of Golf, Kilo, and India.

close to the window. Thus, while the uniformity of deposition during Alpha and Bravo allows semi-quantitative evaluations to be made of their data, the variable deposition of Charley (along with uncertainties of flow rate caused by a component of the wind blowing into the intake window) allows only qualitative evaluations of the latter test. Table 2 shows that, as would be expected, considerably more total mass entered the house (in relation to that deposited outside) under the Bravo than under the Alpha conditions. Test Bravo, therefore, will be discussed below as being the "worst reasonable case."

Figure 6 shows that the particle size distributions within the house (those accounting for the majority of the mass) do not differ greatly from those outside. Therefore, if this debris were radioactive fallout, the specific activity (curies per gram) would be expected to be the same inside and outside the house. If all other sources are temporarily ignored, it is possible to estimate the radiation field due only to interior contamination in the vicinity of the window relative to an assumed uniform radiation field, I_o, outside the building. Figure 3 indicates that most of the fallout in the house was confined to an area of about 200 ft^2. Dividing the total mass that entered the room by 200 shows the mass loading near the window to be about 0.1 g/ft^2, compared to the 5.5 g/ft^2 outside the window. Due to its finite extent of 200 ft^2, the radioactive field near the window in the room would be less by a factor of about 5 than that due to a field infinite in extent.[5] With a mass loading in the house reduced by a factor of 55 (i.e., 5.5 g/ft^2 outside/0.1 g/ft^2 inside) and a reduction of 5 due to geometry, the field I_1 near the window (due to ingress of fallout) would be less than that outside by a factor of about 250.

Now, for the case of no fallout ingress, the radiation inside would be less than that outside, because of the shelter effectiveness inherent in most buildings. This protective effectiveness can be expressed by the ratio of the outside radiation field I_o to the interior field I_2 contributed from outside, thus

$$I_o/I_2 = X$$

By neglecting small contributions from sky shine and other sources the total interior radiation field I_T is then represented by the sum of I_1 and I_2, or

$$I_T = \frac{I_o}{250} + \frac{I_o}{X}$$

$$I_T = I_o \left[\frac{1}{250} + \frac{1}{X}\right]$$

Therefore, the actual protective effectiveness

$$X_T = \frac{I_o}{I_T} = \frac{250\ X}{250 + X}$$

From this expression it is apparent that the radiation protection originally provided in the region of the window is reduced when air is drawn into the room during a fallout event. The following table contains a solution of the above equation for a number of arbitrary X values. A comparison of X and X_T values clearly shows how serious interior contamination could become for the more highly protective structures. The ratio of X_T to X is also given in the table to further demonstrate this effect.

X	X_T	X_T/X
5	4.9	.98
10	9.6	.96
50	42	.83
100	71	.71
500	167	.33
1000	200	.20

However, due to the small area occupied by the majority of the fallout, it appears that it could be swept up easily and disposed of outside in a relatively short time (a few minutes). It may be that, because the inhabited space is located away from the open window, even this simple expedient is not required.

The amount of debris entering the room per square foot of window opening relative to the amount falling outside was 0.08 g/ft^2 per g/ft^2 for the natural ventilation condition of Test Alpha and 0.4 g/ft^2 per g/ft^2 for the 420 ft/min forced ventilation of Test Bravo. From Test Charley data, it appears that inexpensive furnace-type filters are ineffective in preventing ingress of fallout.

PARTIALLY ENCLOSED SPACE (PATIO)

For 19 hr during Tests Delta and Echo, the patio and the concrete walkway in front of the building collected 0.5 and 4.0 g/ft^2, respectively, or a ratio of mass deposited on a covered area to the mass deposited in an open area of 1:8.

During Test Foxtrot the average mass loading on the patio as determined by vacuuming was 0.2 g/ft^2. Pans placed on the perimeter collected from 0.7 to 1.2 g/ft^2. The pan closest to the front concrete walkway collected 1.0 g/ft^2, indicating a ratio of 1:5 between the patio and the front concrete walkway. Test Juliet gave 0.5 to 2.0 g/ft^2 around the perimeter, with the pan closest to the front concrete walkway giving 1.7 g/ft^2. Figure 8 shows the particle size distribution for samples taken during Tests Foxtrot and Juliet.

During the patio test with rain (Test Hotel), the collectors around the perimeter collected 0.8 to 10.6 g/ft^2. This wide variation of mass deposited was the result of run-off from the roof and splash-in from the ground surrounding the pans. Therefore, the results from pans close to the ground must be neglected. The more realistic results were obtained from the collectors located in the yard areas, on top of wooden boxes where collections of 0.2 to 0.8 g/ft^2 were observed. The particle size distributions of a sample from Test Hotel are shown in Fig. 8 for comparison with results from Tests Foxtrot and Juliet. Visual observations of tests on the patio indicated gradual buildup of windrows with time. These windrows were parallel to the direction of the wind and approximately 2-5 in. apart for winds of 5-10 knots. The amounts redeposited by the winds flowing through the open spaces of the patio were lower than those deposited in collectors located on the roof or in the yard area, but they were much greater than those which entered the interior test spaces. Thus, the protection offered by the partial cover of the patio might represent a "worst possible" interior case, in which all the windows are blown out.

OUTDOOR STUDIES

Grounds and Walks

Figure 9 shows the particle size distributions of typical samples from the back concrete walkway during Tests Golf, Kilo (without rain), and India (with rain). The masses deposited for Golf and Kilo were very uniform, 1.3 to 1.4 g/ft^2 and 1.7 to 2.4 g/ft^2, respectively. The mass deposited in Test India varied widely, 0.6 to 15.3 g/ft^2, and was a function of the lawn "density" - amount of grass versus amount of bare soil - near the fallout collector. Where the lawn "density" was greater, the collections were lighter.

In Test Romeo, which was intended to show variation of mass deposited as a function of distance from a building, the results were very inconclusive because of variable winds. All samples taken between 12 and 60 ft west of the house amounted to 0.5 to 0.6 g/ft^2.

Tests Mike and Papa on the front concrete walkway, with and without rain, respectively, essentially confirmed previous test results from Golf and India on the back walkway.

Roofs

For tests on the roof surfaces, it was found that deposition without rain (Test Lima) on the four different slopes of the roof was approximately the same. All collections ranged from 1.9 to 2.3 g/ft^2. Sample location did not appear to have any bearing on the mass deposited or the particle size distribution. However, when rain fell (Test November), the mass deposited varied with sampling location. The south slope collected approximately 1/2 the amount collected on each of the other three slopes, although the size distributions were approximately the same.

In Test Quebec-1, the north, east, and south slopes all indicated 2.3 to 2.6 g/ft^2 deposited. After approximately 24 hr the same (cleaned) areas gave 3.0 to 3.4 g/ft^2, while adjacent areas not previously sampled showed 4.3 to 6.3 g/ft^2. After a light rain (< 0.01 in.) these same (cleaned) areas gave 4.2 to 5.7 g/ft^2 and 5.2 to 6.8 g/ft^2, respectively, indicating not only that no redistribution occurred but that additional debris came down with the rain.

In Test Quebec-2, the roof deposit before rain showed 27 to 32 g/ft^2 as determined by brushing an area clean. After a heavy rain (0.15 in.) this same (cleaned) area showed 5.3 g/ft^2, while an adjacent unsampled area showed 5.7 g/ft^2. Quebec-3 was a continuation of Quebec-2.

After about 0.20 in. of rain, the residual on the roof was only 0.03 g/ft^2 on all areas sampled. Although the roof itself was cleaned by the rain, the majority of the debris became concentrated in the gutters, below the roof surfaces. The flowing rain water did not remove the debris from the gutters, and manual methods were employed to remove the debris after the rain.

WEATHERING EFFECTS

Examination of the wind speed and direction data indicated zero or very little winds during the night and variable wind speed and direction during the day. Small gusts of winds were detected during the day but these gusts were always below 10 knots.

The observations on the movement of debris particles by rain and wind were extrapolated to a radiological situation. Since the radioactivity is associated with the particles and removal of the particles means removal of the radioactivity, the removal of the fallout from the sloped galvanized roof to the roof gutters does not alleviate the radiation problem for a person living in this house. The material merely is more concentrated. The 0.15 in. of rain observed removed a very high percentage of particles from the roof but drained little from the gutters. A redesign of the gutter system to include some slope in the gutters is indicated to help remove much of the debris. The removal of the debris to a greater distance from the house also would have to be considered.

RADIOLOGICAL CONSIDERATIONS

Further extrapolation of the data obtained from these tests to a similar nuclear fallout situation was made using the information presented in Reference 8. It was assumed that the test station was located on the hot line of the fallout pattern from one detonation, 10 miles downwind from the point of detonation. Other input values (mass and particle size) determined from the concrete walkway tests (Tests Golf and Kilo) were specified. The input values used were as follows:

Mass deposited: 1.3-1.4 g/ft^2 (Test Golf)
1.7-2.4 g/ft^2 (Test Kilo)

Maximum particle size: Approximately 300 μ
Distance downwind: 10 miles

With the mass deposited determined from the tests assumed to be the deposited initial mass, the solution, for a weapon yield of 10 KT from Table C.2, Reference 8 is:

Downwind Distance (ft)	Standard Intensity (r/hr)	Particle Diameter Range (μ) Minimum	Maximum	Deposited Initial Mass (mg/ft^2)	Mass Contour Ratio (mg/ft^2/r/hr at 1 hr)
50017	206.53	238.6	351.0	1704.9	8.255
54093	190.72	222.5	320.4	1474.97	7.734

Thus with the conditions assumed, this home would be in a radiation field of approximately 200 r/hr at 1 hour after detonation. Radioactive decay (assuming a $t^{-1.2}$ decay relation) would bring the radiation field down to approximately 13 r/hr at 10 hr after detonation. Removal of a large mass of material during this period would mean a sacrifice of large doses.

MASS REMOVAL FROM CITY STREETS

Visual observation of the reclamation problems in the city of San Jose[11] indicated that a critical situation exists for the inhabitants which will compound itself as long as these volcanic eruptions continue. Lack of sufficient mechanized equipment required to remove large volumes of debris imposes a tremendous drainage on manpower availability and is costly. The bulk of the material from the streets is swept by hand and accumulated in several locations for later pickup by trucks. Care has to be taken to keep as much of the debris as possible out of the storm drains in order to keep them open. Considerable redistribution results when accumulated piles of debris are shoveled into dump trucks.

If the debris were radioactive fallout, the slow manual methods employed to remove the volcanic debris could not be used to remove radioactive debris if radiation doses are to be minimized.

CONCLUSIONS

The study with volcanic debris indicated similar conditions would exist in the case of comparable contamination with radioactive fallout.

From the ingress tests it was determined that, an otherwise high protection factor may be reduced to as low as 250, in the vicinity of an open window into which air is moving. Because of the limited area occupied by the major portion of the fallout inside the house, it appears feasible to re-establish high protection factors by such simple countermeasures as rapid sweeping and disposition outside. This would apply only in situations where only a few windows are open and air flow through them is of moderate velocity. Those situations in which a large number of windows are open and large amounts of air flow into shelter spaces would give rise to very different conditions. For example, if Tests Echo and Delta (Patio) are indicative of large areas of open windows,as much as 1/10 of the outside deposit level could be deposited near the windows.

From the exterior tests it was concluded that, in the absence of rain:

1. Particle size distribution is essentially constant for any one day's collection, and varies only slightly from day to day.
2. Mass loading is relatively constant in uncovered areas such as roofs and grounds.
3. Areas, such as the patio, that are covered but exposed to the free movement of outside air, are contaminated by fallout to a lesser degree (about 1/10) than fully exposed surfaces but to a greater degree than ventilated indoor spaces.

On the basis of conclusions 1 and 2, it is further concluded that reclamation tests using uniformly distributed fallout are realistic even when the areas are quite complex.

When rain accompanied a "fallout" event, a different set of conditions existed. Particle size distributions and mass loadings were largely a function of redistribution processes; hence, both varied with location. Accumulations on sloped roofs and walks were significantly reduced by rain. However, the material from these surfaces was redeposited in gutters and other collection points down slope. Extrapolated to a nuclear fallout situation, this means the creation of concentrated radiation sources. Preparations must be made for the non-manual removal of materials from such places as the gutters to locations remote from the building, if habitation in such a building is required during a fallout event.

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APPENDIX A

PARTICLE SIZE DISTRIBUTIONS

TABLE A.1

Particle Size Analysis by Sieving - Test Alpha

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve						
		Exterior Collectors				Interior Collectors		
		Roof	Side Yard	Front Yard	Intake Window	1	2	15
495		-	0.0227	-	-	-	-	-
295		-	0.0058	-	-	0.0011	0.0004	0.0013
246		0.010	0.0180	0.009	0.010	0.0013	0.0004	0.0013
175		0.022	0.0403	0.047	0.034	0.0015	0.0014	0.0009
147		0.300	0.3915	0.495	0.403	0.0035	0.0014	0.0038
104		8.56	9.57	12.32	11.57	0.1418	0.0100	0.0979
88		7.67	6.03	8.54	9.94	0.2023	0.0184	0.1484
61		15.25	13.15	21.27	18.74	0.5361	0.1040	0.5072
43		1.60	3.51	0.677	1.38	0.4645	0.1399	0.3829
On Pan		9.52	9.40	3.80	8.03	0.5147	0.2032	0.4717
Total		42.9320	42.1383	47.1580	50.107	1.8668	0.4794	1.6144

*See Fig. 3.

TABLE A.2

Particle Size Analysis by Sieving - Test Bravo

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve						
		Exterior Collectors					Interior Collectors	
		Roof	Back Yard	Side Yard	Front Yard	Intake Window	1	2
495		-	-	-	-	-	-	-
295		0.0018	0.0017	0.0040	0.0015	0.0012		0.0036
246		0.0014	0.0019	0.0037	0.0017	0.0021	0.0056	0.0007
175		0.0088	0.0116	0.0094	0.0081	0.0132	0.0159	0.0010
147		0.0643	0.0795	0.0624	0.0576	0.0840	0.0276	0.0017
104		1.74	2.14	1.60	0.1907	1.89	0.3059	0.0367
88		2.14	2.74	1.90	2.27	2.40	0.3014	0.0727
61		5.77	7.44	5.28	5.98	6.58	0.6300	0.2907
43		3.53	3.47	3.65	4.32	3.74	0.4384	0.3002
On Pan		8.20	8.77	8.29	9.77	9.17	0.5317	0.3863
Totals		21.4563	24.6547	20.7995	22.5996	23.8805	2.2565	1.0936

*See Fig. 3.

TABLE A.3

Particle Size Analysis by Sieving - Test Charley

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve							
		Exterior Collectors					Interior Collectors		
		Roof	Back Yard	Side Yard	Front Yard	Intake Window	1	2	15
295		0.0139	0.0292	0.0368	0.0355	0.0186	0.0014	0.0005	0.0016
246		0.0413	0.0780	0.0750	0.0458	0.0578	0.0012	0.0005	0.0005
175		0.7353	1.02	0.9079	0.8807	0.81	0.0236	0.0036	0.0067
147		2.31	3.13	2.81	2.75	2.47	0.1574	0.0080	0.0566
104		1.31	15.74	14.39	13.86	12.01	1.56	0.0836	0.4652
88		4.09	5.41	5.14	5.14	4.35	1.04	0.1335	0.2492
61		3.32	5.69	4.84	4.34	3.33	1.11	0.3372	0.2863
43		1.27	1.89	1.84	1.46	1.15	0.5371	0.2463	0.0567
On Pan		1.77	3.21	2.49	2.08	1.63	0.7809	0.2449	0.0515
Total		14.8605	36.1972	32.5297	30.5920	25.8264	5.2616	1.0581	1.1743

*See Fig. 3.

TABLE A.4

Particle Size Analysis by Sieving - Test Foxtrot

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve						
		P-2	P-3	P-6	Back Yard	Side Yard	Front Yard	Chimney
295		0.0252	0.0146	0.0177	0.0023	0.0099	0.0047	0.0065
246		0.0148	0.0046	0.0059	0.0009	0.0025	0.0007	0.0067
175		0.0417	0.0146	0.0091	0.0046	0.0044	0.0033	0.0142
147		0.0433	0.0175	0.0193	0.0228	0.0160	0.0129	0.0274
104		0.1743	0.2181	0.4082	0.4492	0.4048	0.4763	0.4792
88		0.2141	0.3822	0.6170	0.6517	0.6340	0.8067	0.6732
61		0.5288	0.8353	1.2150	1.5714	1.4418	1.7583	1.2645
43		0.3911	0.5034	0.7450	1.0895	0.9635	1.2145	0.7926
< 43		0.4509	0.7659	1.0102	1.5464	1.4243	1.7199	1.0275
Loss (+) or gain (-)**		-0.0325	-0.0037	+0.0438	+0.0153	+0.0457	+0.0191	-0.0148
Total		1.8517	2.7525	4.0912	5.3541	4.9012	6.0165	4.2770

* See Fig. 4.
**Uncontrollable losses or gains due to sieving operations.

TABLE A.5

Particle Size Analysis by Sieving - Test Golf

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve		
		AOC-3	AOC-5	AOC-8
295		0.0079	0.0140	0.0086
246		0.0057	0.0052	0.0065
175		0.0126	0.0128	0.0155
147		0.0337	0.0407	0.0429
104		0.5651	0.5794	0.5282
88		0.8072	0.7732	0.6991
61		1.7241	1.7527	1.6209
43		1.1325	1.0201	0.9933
< 43		1.4561	1.3281	1.2997
Loss**		0.0291	0.0495	0.0736
Total		5.7740	5.5757	5.2883

* See Fig. 4.
**Uncontrollable losses due to sieving operations.

TABLE A.6

Particle Size Analysis by Sieving - Test Hotel

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve	
		P-1	Chimney
295		0.1045	0.0084
246		0.0805	0.0043
175		0.2765	0.0220
147		0.3050	0.0344
104		0.7173	0.1317
88		0.4111	0.0999
61		0.5831	0.1922
43		0.3453	0.1085
< 43		0.5095	0.1568
Loss**		0.0270	0.0009
Total		3.3598	0.7591

* See Fig. 4.
**Uncontrollable losses due to sieving operations.

TABLE A.7

Particle Size Analysis by Sieving - Test India

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve			
		AOC-5	AOC-6	AOC-8	AOC-9
295		0.1018	0.0848	0.2035	0.3641
247		0.0104	0.0373	0.2948	0.5326
175		0.0335	0.1459	1.5047	2.8355
147		0.0527	0.2120	2.7420	5.4074
104		0.3147	0.7026	7.9056	17.0675
88		0.3603	0.5955	3.8255	7.7098
61		0.3632	0.9564	4.9649	10.5651
43		0.4689	0.5782	2.4097	4.0964
< 43		0.8600	0.9143	3.4883	7.0116
Loss**		0.3294	0.0313	0.0700	0.1686
Total		2.8949	4.2583	27.4090	55.7581

* See Fig. 4.
**Uncontrollable losses due to sieving operations.

TABLE A.8

Particle Size Analysis by Sieving - Test Juliet

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve			
		P-2	P-5	Front Yard	Chimney
295		0.0316	0.0031	0.0014	0.0010
246		0.0052	0.0040	0.0001	0.0013
175		0.0143	0.0110	0.0060	0.0064
147		0.0278	0.0726	0.0807	0.0701
104		0.4079	2.0337	2.4088	1.9975
88		0.2687	1.2321	1.4263	1.1363
61		0.4022	1.3989	1.7269	1.4290
43		0.2518	0.9398	1.0761	0.9010
< 43		0.4659	2.2160	2.5787	1.9974
Loss**		0.0204	0.0235	0.0362	0.0114
Total		1.8958	7.9347	9.3412	7.5514

* See Fig. 4

**Uncontrollable losses due to sieving operations.

TABLE A.9

Particle Size Analysis by Sieving - Test Kilo

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve			
		AOC-2	AOC-5	AOC-6	AOC-8
295		0.0049	0.0081	0.0050	0.0032
246		0.0028	0.0060	0.0010	0.0015
175		0.0165	0.0104	0.0087	0.0120
147		0.0910	0.1185	0.0688	0.1039
104		2.3982	2.4884	1.7263	2.3932
88		1.4398	1.4412	1.0302	1.3323
61		1.8763	1.5580	1.2518	1.7126
43		0.9294	1.0039	0.7527	1.0065
< 43		2.5104	2.2117	1.7842	2.4880
Loss**		0.0305	0.0309	0.0118	0.0278
Total		9.2998	8.8771	6.6405	9.0810

* See Fig. 4

**Uncontrollable losses due to sieving operations.

TABLE A.10

Particle Size Analysis by Sieving - Test Lima

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve AOC-North	AOC-East	AOC-South	AOC-West
295		0.0020	0.0074	0.0122	0.0009
246		0.0048	0.0046	0.0011	0.0010
175		0.0102	0.0075	0.0077	0.0062
147		0.0870	0.0873	0.0866	0.0823
104		2.1945	2.1398	2.3786	2.3497
88		1.3673	1.3135	1.4207	1.3434
61		1.5896	1.5431	1.7674	1.7828
43		1.0685	0.9818	0.9372	0.9447
< 43		2.0851	2.3299	2.4781	2.4137
Loss**		0.0363	0.0188	0.0285	0.0180
Total		8.4453	8.4337	9.1181	8.9427

* See Fig. 4

**Uncontrollable losses due to sieving operations.

TABLE A.11

Particle Size Analysis by Sieving - Test Mike

Sieve Size (μ)	Collector Location*	Grams Remaining on Sieve F-1
295		0.1110
246		0.1198
175		0.3801
147		0.4900
104		3.1577
88		3.7056
61		15.8761
43		6.2842
< 43		11.5671
Loss**		0.0667
Total		41.7583

* See Fig. 1.

**Uncontrollable losses due to sieving operations.

TABLE A.12

Particle Size Analysis by Sieving - Test November

Sieve Size (μ)	Collector Location*:	Grams Remaining on Sieve				
		Chimney	AOC-North	AOC-Fast	AOC-South	AOC-West
295		0.0023	0.0045	0.0041	0.0017	0.0039
247		0.0120	0.0023	0.0015	0.0011	0.0032
175		0.0116	0.0104	0.0102	0.0042	0.0133
147		0.0730	0.0562	0.0662	0.0196	0.0663
104		1.5846	1.3106	1.6503	0.6766	1.4124
88		2.1977	1.9292	2.3365	0.9596	1.7960
61		8.7030	7.0282	9.6215	3.6765	7.8197
43		7.8810	7.1045	6.7644	4.3278	5.7160
< 43		9.8653	7.2709	9.1794	4.6528	6.9190
Loss**		0.0660	0.0445	0.0534	0.0473	0.0350
Total		30.3305	24.7613	29.6875	14.3672	23.7848

* See Fig. 4.
**Uncontrollable losses due to sieving operations.

TABLE A.13

Particle Size Analysis by Sieving - Test Papa

Sieve Size (μ)	Collector Location*:	Grams Remaining on Sieve	
		Chimney	F-1
295		0.0026	0.0044
246		0.0017	0.0025
175		0.0133	0.0188
147		0.0650	0.0827
104		0.2570	0.4297
88		0.3426	0.6352
61		1.1720	2.4216
43		0.9797	2.1774
< 43		1.3111	2.8010
Loss**		0.0120	0.0480
Total		4.1570	8.6213

* See Fig. 4

**Uncontrollable losses due to sieving operations.

APPENDIX B

MASS DEPOSITED

TABLE B.1

Summary of Mass Deposited

Station*	Mass (g/ft^2)		
	Test Alpha	Test Bravo	Test Charley
Roof	10.74	5.36	3.72
Back Yard	lost	6.17	9.05
Side Yard	10.53	5.20	8.13
Front Yard	11.79	5.65	7.65
Intake Window	12.53	5.97	6.46
1	0.468	0.5650	1.32
2	0.1199	0.2725	0.265
3	0.0047	0.0094	0.0009
4	lost	0.0046	0.0030
5	0.0036	0.0051	0.0025
6	0.0064	0.1044	0.1235
7	0.0035	0.0086	0.0143
8	0.0241	0.0074	0.0107
9	0.0055	0.0160	0.0393
10	0.0065	0.0244	0.0081
11	0.0065**	0.0120**	0.0227
12	0.0207	0.0038	0.0128
13	0.0085	0.0073	0.0057
14	0.0039**	0.0077	0.0494
15	0.4025	0.0044	0.2925***

* See Fig. 3.
**Contained paint chips.
***Leak in sealing tape near fan.

TABLE B.2

Summary of Mass Deposited

Location*	Mass (g/ft^2)					
	Foxtrot	Golf	Hotel	India	Juliet	Kilo
Patio P-1	0.986		0.833		1.722	
P-2	0.464		10.605		0.474	
P-3	0.690		7.711		0.904	
P-4	0.732		7.506		1.211	
P-5	1.175		1.622		1.983	
P-6	1.041		1.661		1.770	
Back Walk AOC-1		1.409		2.883		2.355
AOC-2		1.420		6.843		2.317
AOC-3		1.445		15.285		2.296
AOC-4		1.378		0.832		2.319
AOC-5		1.396		0.641		2.212
AOC-6		1.309		1.057		1.657
AOC-7		1.338		0.609		2.290
AOC-8		1.324		6.835		2.263
AOC-9		1.413		13.898		2.146
Back Yard	1.340		0.786		2.342	
Side Yard	1.287		0.617		1.844	
Front Yard	1.506		0.209		2.335	
Chimney	1.070		0.190		1.888	

*See Fig. 4 for sample locations.

TABLE B.3

Summary of Deposit Collected

Location*	Mass (g/ft^2) Lima	Mike	November	Papa	Romeo
Front Walk F-1		9.839		1.985	
F-2		10.432		2.143	
Back Walk R-1**					0.586
R-2**					0.509
R-3**					0.528
R-4**					0.506
R-5**					0.476
Roof Chimney			7.583	1.036	
AOC North	2.102		6.179		
AOC East	2.104		7.409		
AOC South	2.272		3.580		
AOC West	2.231		5.938		

* See Figure 4 for sample locations.
**See Figure B.1 for Romeo sample locations.

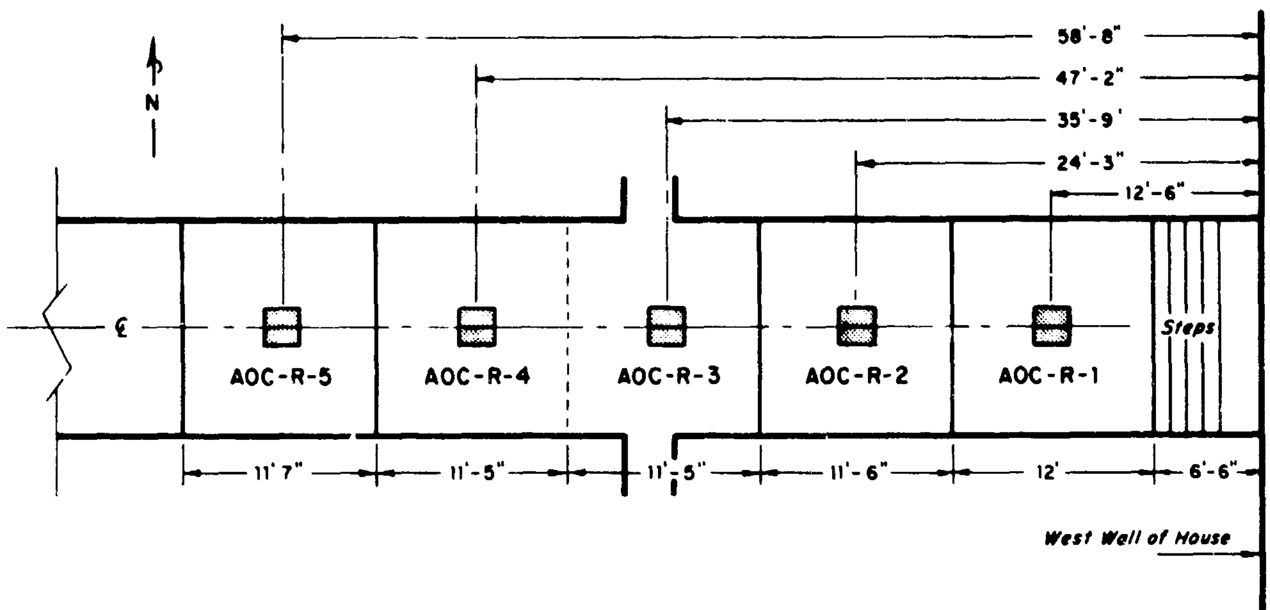

Fig. B.1 Test Romeo Station Locations Back Walkway - Concrete Surface

APPENDIX C

WEATHER DATA

TABLE C.1

Relative Humidity and Temperature

Time	April 24 Rel. Hum. (%)	April 24 Temp. (°F)	April 25 Rel. Hum. (%)	April 25 Temp. (°F)	April 26 Rel. Hum. (%)	April 26 Temp. (°F)	April 27 Rel. Hum. (%)	April 27 Temp. (°F)
0800			80	68	76	69	78	69
0900			81	69	77	69	81	70
1000	76	71	80	69	78	70	80	70
1100	78	72	77	70	76	70	77	72
1200	79	72	77	71	76	70	76	72
1300	77	72	76	71	76	71	75	75
1400	77	72	77	71	77	71	76	71
1500	78	71	76	71	77	71	86	67
1600	79	70	77	72	77	71	90	67
1700	80	70	77	71	77	71	90	67
1800	80	70	77	71	78	71	90	67
1900	80	70	77	71	78	71	90	67
2000	80	69	77	70	79	71	90	67
2100	80	69	76	70	79	71	90	66
2200	80	69	77	70	79	70	90	66
2300	80	69	77	69	79	70	90	66
2400	80	69	77	69	79	70	90	65
0100	80	68	76	69	79	70	90	65
0200	80	68	76	69	79	70	88	65
0300	80	69	76	69	79	70	88	64
0400	80	68	76	69	79	69	88	63
0500	80	68	76	69	79	70	87	63
0600	80	68	76	69	78	69	86	63
0700	80	68	76	69	78	69	87	64
	28 April		29 April		2 May		4 May	
0800	80	70	90	66	85	65	81	68
0900	72	68	86	69	83	70	78	72
1000	74	72	81	70	-	-	72	74
1100	74	72	77	72	72	75	70	74
1200	76	[illegible]	73	74	72	75	70	75
1300	77	72	72	74	73	73	70	75
1400	77	73	69	76	77	71	73	77
1500	83	71	69	75	81	70	75	75
1600	82	70	73	72	90	70	85	73
1700	85	68	81	71	87	68	84	70
1800	87	67	85	69	87	67	87	68
1900	88	66	86	68	88	67	88	68
2000	89	66	87	66	88	66	91	67
2100	88	66	87	67	88	65	90	67
2200	88	66	88	67	88	64	91	67
2300	88	66	88	66	87	63	90	66
	April 29		May 1		May 3		May 5	
0000	88	65	88	66	87	[illegible]	89	64
0100	88	65	88	65	88	62	86	61
0200	88	65	86	64	89	63	85	59
0300	88	65	86	64	89	63	85	62
0400	89	65	85	63	88	62	85	59
0500	89	66	84	63	88	61	85	59

Continued

TABLE C.1 (Cont'd)

Relative Humidity and Temperature

Time	April 29 Rel. Hum. (%)	April 29 Temp. (°F)	May 1 Rel. Hum. (%)	May 1 Temp. (°F)	May 3 Rel. Hum. (%)	May 3 Temp. (°F)	May 5 Rel. Hum. (%)	May 5 Temp. (°F)
0600	89	[illegible]	83	63	88	62	85	61
0700	89	66	83	65	87	65	84	64
0800	88	67	83	67	84	70	80	68
0900	87	69	79	72	78	70	74	71
1000	82	69	70	76	74	72	74	73
1100	82	68	67	77	71	74	74	74
1200	84	70	67	76	73	72	71	75
1300	81	73	69	75	77	72	71	75
1400	80	73	70	77	77	73	68	77
1500	77	73	70	76	79	71	74	73
1600	78	73	70	73	81	70	80	72
1700	81	70	75	71	83	68	81	70
1800	84	63	[illegible]	69	86	67	83	69
1900	87	67	[illegible]	68	87	66	*	*
2000	88	67	[illegible]	67	88	65		
2100	88	67	84	67	87	[illegible]		
2200	89	66	85	66	87	63		
2300	89	66	85	65	86	63		
			May 2		May 4			
0000	89	65	85	64	87	62		
0100	89	65	85	63	87	61		
0200	89	65	86	63	86	60		
0300	89	64	87	62	87	61		
0400	89	63	87	61	83	60		
0500	89	62	87	61	83	60		
0600	88	62	87	61	84	61		
0700	88	64	87	63	82	63		
	May 6		May 7		May 8			
0800					85	67		
0900	73	73	76	71	80	69		
1000	71	75	72	71	73	73		
1100	71	76	71	74	73	71		
1200	70	78	72	72	73	73		
1300	69	78	72	72	75	72		
1400	69	78	71	73	75	71		
1500	76	74	76	69	73	71		
1600	75	73	78	67	78	67		
1700	77	70	81	66	78	68		
1800	80	68	82	65	79	67		
1900	85	67	83	64	81	66		
2000	84	66	86	64	83	66		
2100	83	66	86	63	84	65		
2200	85	64	87	63	85	64		
2300	86	65	89	62	86	64		
0000	86	64	89	61	85	63		
0100	86	63	89	62	86	63		
0200	86	63	87	62	86	63		
0300	86	63	88	62	87	62		
0400	86	63	90	61	87	61		
0500	[illegible]	63	89	61	87	61		
0600	84	63	89	61	87	61		
0700	83	65	89	63	88	62		
					May 9			
					86	66		

TABLE C.2

Rain Data

Date and Time	Amount of Rain (in.) Front Yard	Side Yard	Back Yard	Roof	Average	Remarks
Apr 23						
0900	0.00	0.00	0.00	0.00	0.00	No rain during night.
1145						Rain starts.
1245	0.14	0.12	0.125	0.135	0.13	Rain stops. (15 min. heavy rain)
Apr 24						
0930	0.14	0.12	0.13	0.14	0.13	Rainfall during night.
1400						Rain started.
1415	0.04					
1440	0.08					
1500	0.14					
1530	0.24					
1605	0.39					
1620	0.43					
1830						Approximate time rain stops.
Apr 25						
0930	0.62	0.61	0.61	0.61	0.61	Rain since 0930 Apr 24 ≈ 0.18–0.19 in. rain since 1830 Apr 24
1232						Light drizzle, stopped after few minutes.
Apr 26						
0930	0.84	0.83	0.81	0.82	0.82	Rain at night, duration unknown.
Apr 27						
0900	0.01	trace	trace	trace	trace	Rainfall during night.
1052						Light sprinkle starts.
1400						Heavy rain starts.
1405	0.09					Medium rain.
1410	0.12					
1415	0.155					
1430	0.29					
1438	0.66					
1445	0.81					
1450	0.82					
1455	0.83					
1500	0.84					
1525	0.85					
1600	0.87					
Apr 28						
0615	0.87	0.85	0.87	0.84	0.85	Rain since 0900 Apr 27.
1240						Light rain starts.
1245	trace					Light rain stops.
1410						Rain starts.
1415	0.04					
1420	0.05					
1425	0.06					
1430	0.09					
1445	0.09					Rain stops.
Apr 29						
0845	0.10	0.07	0.10	0.095	0.10	Rain since 0615 Apr 28.
0940						Light rain starts. Approx. 0.1 in. of rain since 1445 Apr. 28.
1000	0.01					
1005	0.08					
1010	0.09					
1030	0.095					

Continued

TABLE C.2 (Cont'd)

Rain Data

Date and Time	Amount of Rain (in.) Front Yard	Side Yard	Back Yard	Roof	Average	Remarks
1055	0.105					
1100	0.11					
1105	0.12					
1115	0.17					
1130	0.19					
1135	0.215					
1145	0.225					Rain stops.
Apr 30						
0945	0.225	0.19	0.225	0.22	0.22	No measureable rain since 1145 Apr 29.
1452						Light drizzle starts.
1600	Trace					Light drizzle stops.
May 1						
0915	0.01	0.005	0.01	0.005	0.005	Rain during night.
May 2						
0845	0.00	0.00	0.00	0.00	0.00	No rain since 0915 May 1.
1300						Light drizzle starts.
1310						Light drizzle stops.
1400						Light drizzle starts.
1405	trace					Ceniza noted in rain drops.
May 2						
1410	0.005					
1420	0.01					
1425	0.015					
1430	0.025					
1435	0.04					
1440	0.05					
1450	0.05					Rain stops.
May 3						
0800	0.05	0.04	0.05	0.05	0.05	Rain since 1300 May 2. No measureable rain since 1450 May 2.
May 4						
0900	0.05	0.055	0.05	.05	0.05	Rain during night.
1550						Rain starts.
1555	0.025					
1600	0.055					
1605	0.07					
1615	0.07					
1620	0.09					
1640	0.10					
1645	0.125					
1650	0.135					
1705	0.135					
1710	0.1[illegible]					
1725	0.15					Rain stops.
May 5						
0900	0.15	0.15	0.15	0.15	0.15	Rain since 0900 May 4. No measureable rain since 1725 May 4.
1425						Hard rain starts.
1430	0.05					
1435	0.16					
1440	0.20					
1455	0.20					Rain stops.

Continued

TABLE C.2 (Cont'd)

Rain Data

Date and Time	Amount of Rain (in.) Front Yard	Side Yard	Back Yard	Roof	Average	Remarks
May 6						
0900	0.20	0.08	0.20	0.19	0.19	Rain since 0900 May 5. No rain since 1455 May 5.
May 7						No precipitation.
May 8 1545						First precipitation since rain gage was cleaned at 0900 May 6.
May 9						
0900	Trace					Rain at 1545 8 May was very slight.
May 10						
0900	0.00					No rain since 1545 8 May.
1600						Rain starts.
1605	0.005					
1610	0.035					Light sprinkle starts.
1615	0.05					
May 11						
1100	0.15					Total precipitation since 0900 10 May.

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DISTRIBUTION OF VOLCANIC FALLOUT IN AND ABOUT A ONE-STORY RESIDENCE

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

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Crew, Robert J.

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13. ABSTRACT The sand-like debris from Volcano Irazu in Costa Rica closely resembles the type of fallout produced by a near-surface or underground nuclear detonation. The activity of the volcano during April and May 1964 presented an opportunity to use this phenomenon in a field-scale study of some relationships between urban reclamation and nuclear fallout contamination. The eruptions of the volceno were frequent and the rates of arrival at the test site were dependent on wind direction and the severity of the eruptions.

The investigation was divided into two phases: (I) distribution of debris inside a one-story residence; and (II) distribution outside the residence. Phase I was concerned with the ingress of particles through open windows under conditions of: (a) natural ventilation, (b) forced ventilation, and (c) forced ventilation with minimal filtering. Phase II was concerned with the deposition and redistribution by wind, of particles on concrete walks, corrugated metal roofs, and partially exposed tile floors - each with and without rain.

In Phase I, it was observed that particle size distributions inside the house did not differ greatly from those deposited outside. Mass loadings inside were a factor of 50 less than those outside. It was concluded that, if this were a case of radioactive fallout, the ratio of outside dose to inside dose would be reduced significantly in the vicinity of the window through which air is moving.

In Phase II, was observed that in the absence of rain, the particle size distribution and mass deposited was uniform from one sample location to another, only minor variations having been observed from day to day. On this
(Abstract continued on last page)

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basis, it was concluded that reclamation tests using uniformly distributed synthetic fallout are realistic even when the surface configurations are quite complex.

When rain accompanied the debris deposition, however, different results were observed. Particle size distributions and mass loadings were a function of redistribution and varied with sample location. Deposits on roof surfaces will be significantly reduced but will accumulate in the gutters. In the case of radioactive fallout, a concentrated radiation source would result.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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