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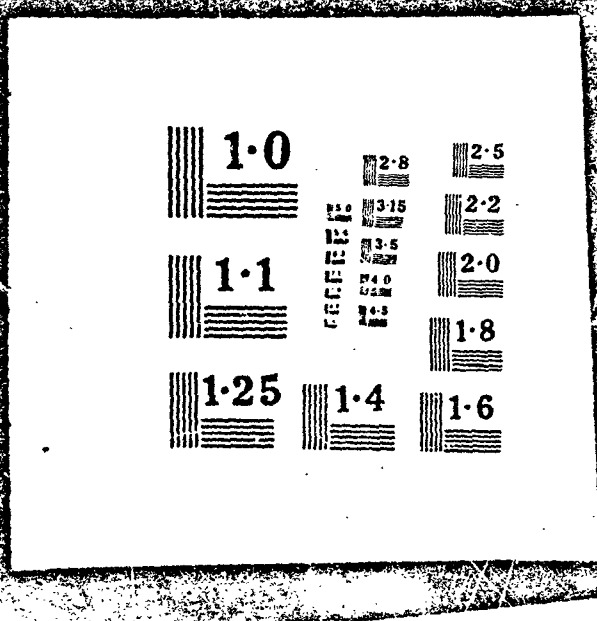

WT-928

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 No. 143 of 250 copies, Series A

OPERATION CASTLE

Project 6.5

DECONTAMINATION AND PROTECTION

REPORT TO THE SCIENTIFIC DIRECTOR

by

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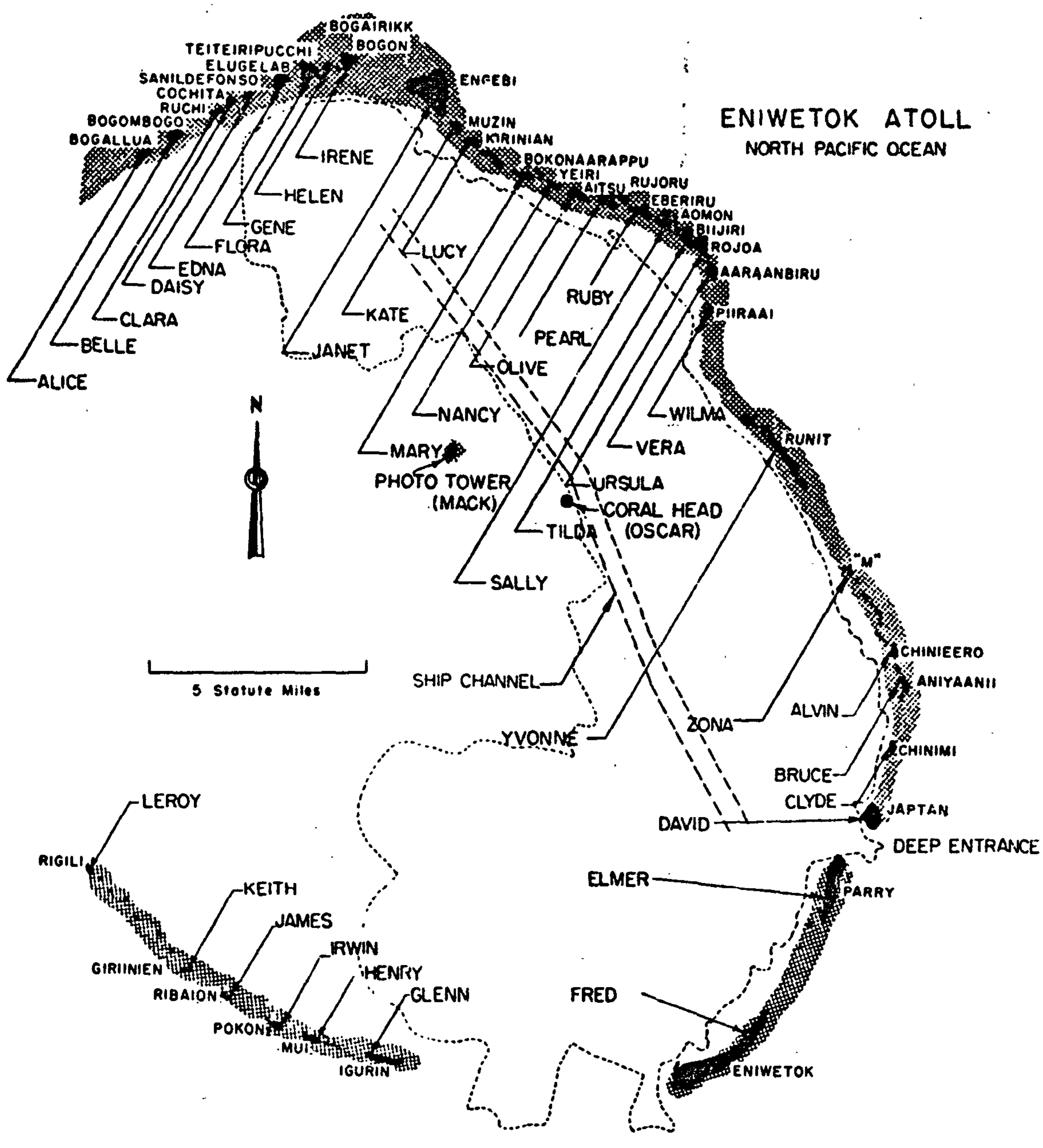

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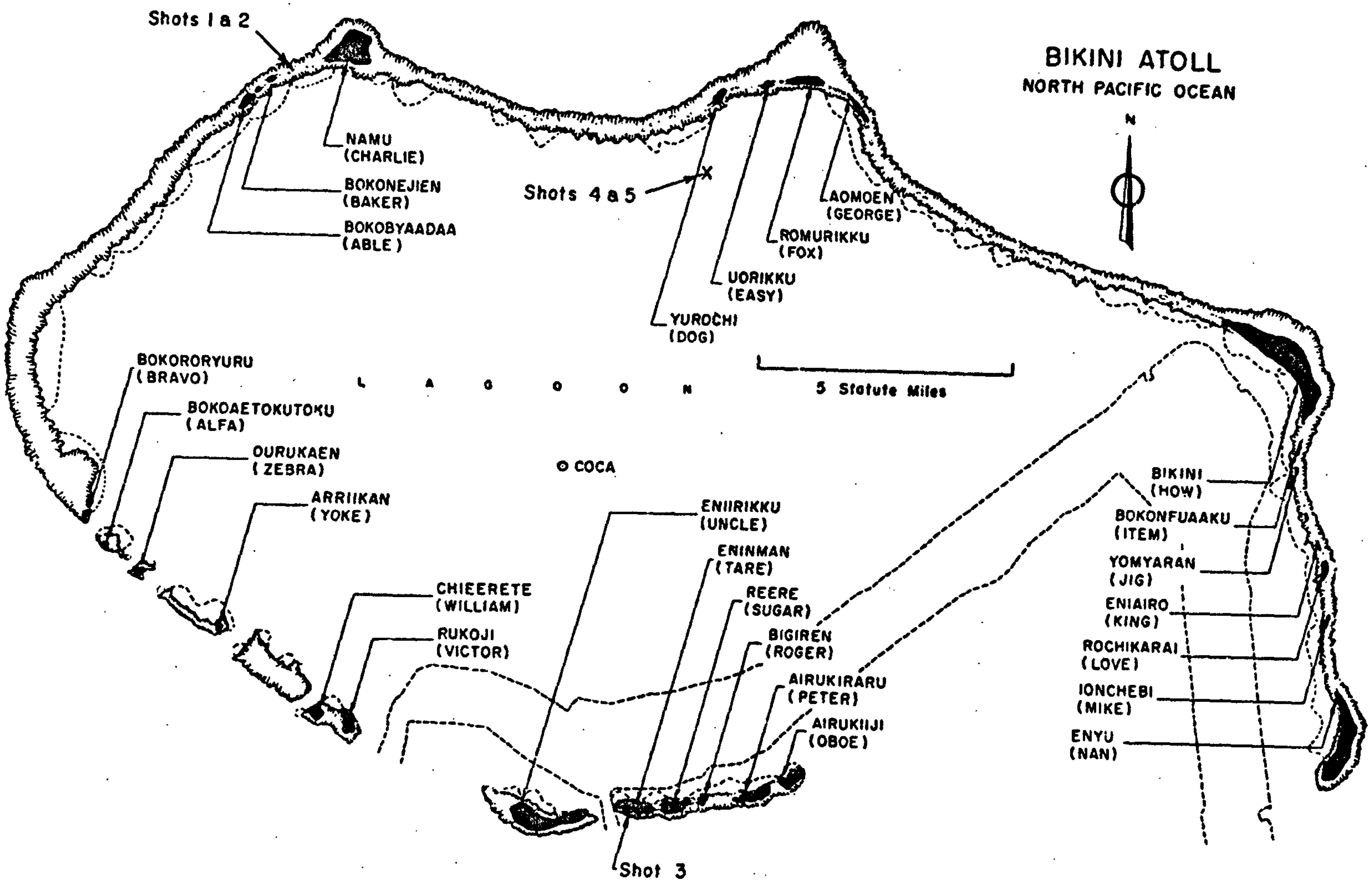
BIKINI ATOLL
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N
Shots I & 2
NAMU
(CHARLIE)
BOKONEJIEN
(BAKER)
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(ABLE)
Shots 4 & 5
AOMOEN
(GEORGE)
ROMURIKKU
(FOX)
UORIKKU
(EASY)
YUROCHI
(DOG)
BOKORORYURU
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(TARE)
REERE
(SUGAR)
BIGIREN
(ROGER)
AIRUKIRARU
(PETER)
AIRUKIIJI
(OBOE)
CHIEERETE
(WILLIAM)
RUKOJI
(VICTOR)
Shot 3
BIKINI
(HOW)
BOKONFUAAKU
(ITEM)
YOMYARAN
(JIG)
ENIAIRO
(KING)
ROCHIKARAI
(LOVE)
IONCHEBI
(MIKE)
ENYU
(NAN)

GENERAL SHOT INFORMATION

	Shot 1	Shot 2	Shot 3	Shot 4	Shot 5	Shot 6
DATE	1 March	27 March	7 April	26 April	5 May	14 May
CODE NAME (Unclassified)	Bravo	Romeo	Koon	Union	Yankee	Nectar
TIME*	06:40	06:25	06:15	06:05	06:05	06:15
LOCATION	Bikini, West of Charlie (Namu) on Reef	Bikini, Shot 1 Crater	Bikini, Tare (Eninman)	Bikini, on Barge at Intersection of Arcs with Radii of 6900' from Dog (Yurochi) and 3 Statute Miles from Fox (Aomoen).		Eniwetok, IVY Mike Crater, Flora (Elugelab)
TYPE	Land	Barge	Land	Barge	Barge	Barge
HOLMES & NARVER COORDINATES	N 170,617.17 E 76,163.98	N 170,635.05 E 75,950.46	N 100,154.50 E 109,799.00	N 161,698.83 E 116,800.27	N 161,424.43 E 116,688,15	N 147,750.00 E 67,790.00

* APPROXIMATE

ABSTRACT

The objectives of this project were to investigate:
1. the contaminability of widely used building materials,
2. the effectiveness of practical decontamination techniques,
3. the effectiveness of painting and sealing of joints in reducing contamination,
4. the effect of slope on contamination retentivity, and
5. the effectiveness of pre-attack surface washdown in reducing contamination.

Test panels, four ft square, of 14 building materials were mounted on the weather surfaces of two remotely controlled liberty ships and on a stationary barge. One of the ships was protected by a washdown system.

All surfaces were contaminated significantly with tenacious fallout. Vertical surfaces facing upwind became equally or more highly contaminated than horizontal or pitched surfaces, probably due to wind currents impacting the tenacious contaminant onto surfaces normal to it. A sequence of hosing and vigorous scrubbing operations resulted in contamination reductions of 40 to 70 per cent, but with reductions on most surfaces being less than 50 per cent. The most effective decontamination method was scrubbing. Under the conditions of this test, painting and joint sealing had little effect while the washdown countermeasure reduced the initial contamination over 90 per cent.

It is concluded that contamination from fallout encountered in these tests presents a serious decontamination problem on buildings and paved areas and further development of effective countermeasures is necessary.

FOREWORD

This report is one of the reports presenting the results of the 34 projects participating in the Military Effects Tests Program of Operation CASTLE, which included six test detonations. For readers interested in other pertinent test information, reference is made to WT-934, Summary Report of the Commander, Task Unit 13, Programs 1 - 9, Military Effects Program. This summary report includes the following information of possible general interest.

a. An over-all description of each detonation, including yield, height of burst, ground zero location, time of detonation, ambient atmospheric conditions at detonation, etc., for the six shots.

b. Discussion of all project results.

c. A summary of each project, including objectives and results.

d. A complete listing of all reports covering the Military Effects Tests Program.

ACKNOWLEDGMENTS

The authors of this report wish to express their appreciation to all personnel of Project 6.4 for logistic support in the preparation and execution of test operations.

The advice and services of Major D. A. Kellogg, CE, AFSWP, and Major J. Irvine, CE, USA, contributed vitally to the successful completion of this project.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The objectives of Project 6.5 were:

a. To determine the relative contaminability of widely used building construction materials exposed to the type of wet contaminant fallout which, it is believed, would result from nuclear detonations in harbors.

b. To evaluate the effectiveness of various practical decontamination techniques, particularly readily available methods, and to estimate the practicability of such techniques in the tactical and industrial recovery of military installations.

c. To evaluate the relative effectiveness of simple protective measures such as painting of surfaces and sealing of joints, in reducing the contaminability and/or facilitating the decontamination of such surfaces.

d. To ascertain the effect of slope on the contamination retentivity of surfaces.

e. To evaluate the effectiveness of pre-attack surface washdown countermeasures in reducing the contamination of surfaces.

1.2 BACKGROUND

The contaminating effects of Shot Baker at Operation CROSSROADS demonstrated that the wet contamination resulting from a shallow underwater detonation of an atomic weapon, such as in a harbor, would present a serious and complex problem of decontamination of ships as well as of building structures of nearby shore installations. This trend has also been indicated in subsequent laboratory studies conducted at the Army Chemical Center and the United States Naval Radiological Defense Laboratory. However, with the exception of Operation JANGLE, which produced a dry particulate contamination, all subsequent field tests were conducted under essentially noncontaminating conditions. No contamination-decontamination studies were conducted at Operation IVY where the first thermonuclear device was detonated. Operation CASTLE provided the much needed opportunity to study the contamination-decontamination problems associated with building construction materials subjected to wet contamination under field conditions reasonably equivalent to those which would be produced by the detonation of a nuclear weapon in a harbor or in shallow coastal waters.

While CROSSROADS yielded some information relative to the contaminability of surfaces, no systematic study of these effects or of specific decontamination techniques was conducted.[1,2] Decontamination efforts were of an emergency nature only.[3] On the other hand, at Operation GREENHOUSE, some effort was made to study contamination effects by mounting small-scale panels of a limited variety of construction material surfaces on the wings of drone aircraft which were flown through the radioactive clouds of relatively high yield fission detonations.[4] It was found that the roughest surfaces became contaminated to the highest levels and were the least responsive to decontamination. Surface parameters such as porosity, contact angle, and dye retentivity appeared to be of lesser effect. However, due to the high impact velocity of the contaminant on these surfaces, the contamination effects so obtained were not too realistic and were not, therefore, of direct value in the development of practical recovery criteria.

An extension of the GREENHOUSE studies was conducted at JANGLE where similar panels, but of larger scale, were exposed to the fallout from a shallow underground detonation.[5] While the roughest surfaces again became more highly contaminated, the dry, powder-like contaminant was loosely adherent and could be removed readily with water. Candidate RW agents of the dry particulate type, during tests conducted at the Army Chemical Center[6] have exhibited similar decontamination characteristics as JANGLE contaminants. The effect of surface slope was such that horizontal surfaces retained from five to three hundred times the activity retained on vertical surfaces.

1.3 BASIC THEORY

At CASTLE, it was anticipated that the contaminant would consist of liquid droplets containing fission products, bomb debris, and other debris depending on the detonation ground zero environment. In the case of barge detonation over shallow water, it was believed that iron from the barge and calcium carbonate bottom material would be in the fallout. From a land surface detonation, larger percentages of calcium carbonate from the island soil would be present. It was believed that most of this debris would arrive as calcium hydroxide resulting from the hydration of calcium oxide which was formed by the heat of the detonation from the original calcium carbonate.[7,8] These particles would have a calcium carbonate surface layer. Subsequent wetting of deposited fallout particles by sea water was believed to produce outer layers of precipitated magnesium hydroxide, hydrated calcium sulfate, and calcium carbonate.[7] Experimental evidence indicated that this form of contaminant would be extremely retentive.

The Stanford Research Institute, under Chemical Corps contract, has deduced from available data that the average type of wet clay contaminant expected in the typical harbor detonation, but not encountered on this operation, would cause a very difficult decontamination problem.[9] It is felt that the data obtained in CASTLE approximates this condition; however, these data should only be used as interim yardsticks in planning protective criteria and decontamination countermeasures for harbor installations, subject to subsequent verification.

At present work is being conducted to prepare simulants of contaminants resulting from nuclear detonations in harbors in order to conduct further laboratory studies on this problem.[10]

CHAPTER 2

EXPERIMENTAL DESIGN

2.1 OPERATIONAL CONCEPT

Project 6.5 was conducted in close coordination with Project 6.4 which operated two especially equipped liberty ships by remote radio control through regions of high intensity fallout following each of several surface thermonuclear detonations on land and over relatively shallow water. The two ships, designated as the YAG 39 (Transit Able) and the YAG 40 (Transit Baker), respectively, were identical externally except that the YAG 39 was equipped with a salt water washdown countermeasure system, designed to operate prior to and during the contaminating event, to minimize the residual contamination level. Previous work in the laboratory[11] and in field tests on ships[12,13] using simulants indicates that washdown countermeasures are highly effective.

Sets of 14, four foot square test panels (Table 2.1) of widely used building construction surfaces were mounted on tubular steel racks (to facilitate removal from the ships). These racks were mounted on the weather surfaces of each of the two ships, near the stern, in such manner as to be exposed to the fallout. Fig. 2.1 shows the rack and panel set on board the YAG 40. After the contaminating event and following recovery of the ships, the panels were transferred to a clean land area on Parry Island where decontamination operations were performed free from the excessive radiation background found on the ships.

Participation of Project 6.5 on board the above ships included Shots 1, 2 and 4. Shot 1 occurred on land and the remaining two shots were on barges in shallow water. Shots 2 and 4 produced desirable amounts of contamination on the panels while the levels resulting from Shot 1 were negligible and of practically no value for analytical purposes. For participation in Shot 6, a complete set of the same panels, mounted on one of the racks, was placed on a Navy Type YC 500 ton barge which was anchored in the Eniwetok Lagoon at Station 650. This location was estimated to be beyond serious thermal and blast effects, but well within the area of fallout. An additional set of small scale (16 in. × 32 in.) painted wood panels

TABLE 2.1 Construction Materials Panels

Panel No.	Material	Slope	Comments and Protective Countermeasures
1	Asphalt Pavement	Horizontal	Control **
2	Concrete Pavement	Horizontal	One section - Control ** One section - Transparent seal coat
3	Asphalt and Gravel Built-up Roofing	Horizontal	Three fourths of panel-Control** One fourth of panel - PVA * pigmented coating
4	Smooth Surface Roll Roofing	3" per ft	Half of panel - Control ** Half of panel - PVA * pigmented coating
5	Asphalt Protected Corrugated Metal Roofing	3" per ft	Control **
6	Mineral Surface Strip Shingle Roofing	6" per ft	Half of panel - Control ** Half of panel - Vertical joints caulked
7	Asbestos Cement Shingles	Vertical	Half of panel - Control ** Half of panel - Vertical joints caulked
8 & 9	Wood Siding - Clapboard (2 panels)	Vertical	Half of panel - Control ** Half of panel - Alkyd resin coating Half of panel-Lead and Oil Coating Half of panel - Phenolic resin coating
10	Sheet Metal	Vertical	Half of panel-Alkyd resin coating Half of panel - Phenolic resin coating
11	Brick-Medium Density	Vertical	One section - Control ** One section-Resin emulsion coating
12	Concrete Block	Vertical	One section - Control ** One section-Resin emulsion coating
13	Cinder Block	Vertical	One section - Control ** One section-Resin emulsion coating
14	Geometry Effects (wood)	Vertical	One fourth of panel-Plane, alkyd resin coating Three fourths of panel-Raised and milled configurations, alkyd resin coating

* Polyvinyl Alcohol
** "Control" surfaces were untreated and represented basic material.

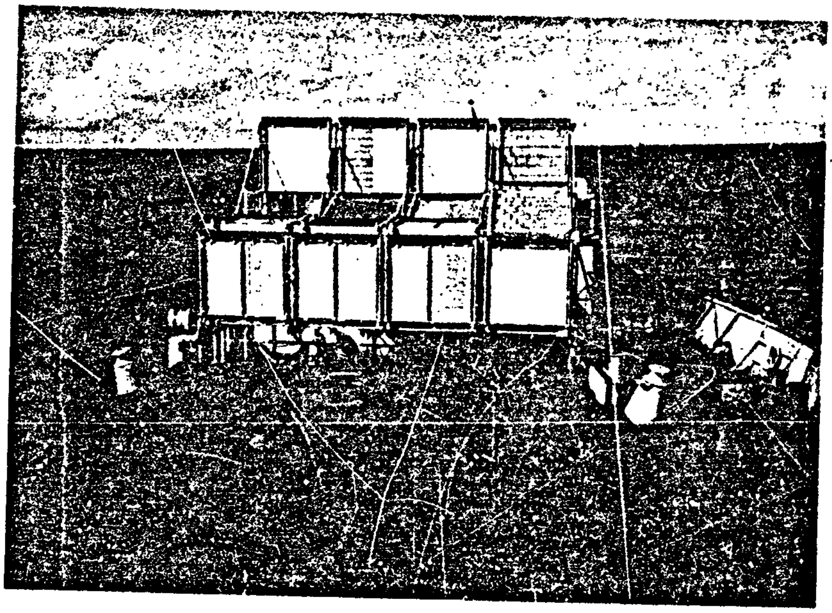

Fig. 2.1 Rack and Panel Set, YAG 40

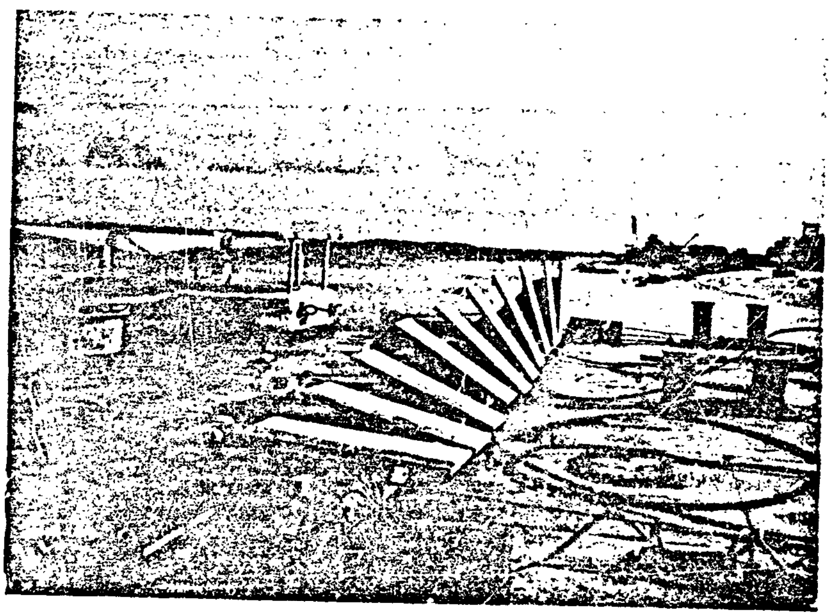

Fig. 2.2 Arrangement of Slope Panels

was mounted on the barge to obtain information relative to the effect of slope (pitch) on the retentivity of contamination. These panels were arranged in 10 degree increments of slope ranging from horizontal to vertical as shown in Fig. 2.2. The barge participation was originally contemplated for Shot Echo, and the barge was moored in a favorable downwind location with respect to ground zero selected for this shot. In view of the cancellation of this shot, however, the barge was moved to as favorable an anchorage as possible for participation in Shot 6. Besides the data expected to be derived from the panels themselves, additional operational decontamination information was expected to be obtained from the clean-up of the barge itself.

2.2 DESCRIPTION OF TEST SURFACES AND EQUIPMENT

2.2.1 Test Panels

Four identical sets of test panels were fabricated. Each set consisted of 14, four foot square panels of widely used outside construction material surfaces. Table 2.1 contains a description of the type of surfaces, preprotection measure, and mounting position of each of the panels. The relatively heavy masonry and concrete pavement panels were fabricated in two sections to facilitate handling, but their mounting was in pairs for proper comparison purposes. Figures A.1 through A.14 show a view of each panel. These photographs were taken subsequent to decontamination and on some surfaces clearly show the effects of weathering and decontamination efforts.

2.2.2 Panel Mounting Racks

To expedite handling, and thereby to reduce the exposure of recovery personnel to a minimum, each set of panels was mounted on a lightweight tubular steel rack designed to fit a predetermined space on board ship. The test panels were mounted in such manner as to retain their normal orientation under fallout exposure conditions, i.e., pavement panels were placed horizontally, wall panels vertically, and roofing panels on slopes consistent with their normal use. Each rack was equipped with a lifting ring and a quick unfastening device to facilitate recovery under contaminated conditions. This assembly was handled as a single unit from shore to ship initially, and from ship to shore following contamination.

2.2.3 Panel Weather Covers

It was anticipated that several days would elapse following exposure to contamination before the panels could be recovered from the ships. To preserve the original contamination patterns on the panels of the YAG 40 (unprotected ship) from the effects of weather during this period, delayed action, flexible, waterproof covers were provided. These covers, similar in operation and general appearance to conventional window shades, were rolled up and suspended above the panels. Metal guides were provided along the edges of each panel.

Each cover was secured in a rolled-up position by a short length of nickel-chromium (n-c) wire. Release of the spring tension maintained by this wire was controlled by a battery operated, alarm clock timing mechanism which, at a predetermined time, applied an overload current to the wire. This fused the wire which in turn released the springs and permitted the cover to close over the face of the panel. Unfortunately, the long delay which occurred between the time of setting of the clock mechanism and the firing of the shot so depleted the battery that insufficient current remained to actuate the fusing mechanism. No attempt was made to use the weather covers following this experience on Shot 2.

2.2.4 Decontamination Stands

After recovery, the contaminated panels were mounted on simple 2 in. × 4 in. wood stands at the Parry Island decontamination area, ready for decontamination operations. During Shot 2 decontamination operations, it was found that the ground underneath the panels became significantly contaminated. Therefore, a drainage ditch for contaminated run-off liquid was provided for all subsequent decontamination operations.

2.2.5 Decontamination Apparatus

The apparatus for decontamination consisted of the following items:

1. Pump, centrifugal, gasoline engine driven, Engineer Stock #11-4619.240.100.
2. Vapor Clarkson Heavy Duty Cleaner, Model X1-4992 with Sellers Hi-Pressure Jet Cleaner.
3. Decontaminating Apparatus Power-Driven Truck-Mounted M3A2, TM 3-223.
4. Brush, GI scrub, with handle.
5. Detergent, household, trade name "Tide".

2.2.6 Radiological Instrumentation

The following radiological survey instruments were used:

1. Radiac Training Set AN-PDR/T1B
2. Beta Directional Instrument, NRDL Model RB1-12. (This is a light, self-contained, battery operated portable instrument with a 4 in. × 4 in. window, which measures beta activity when placed against a surface. Four sensitivity ranges in decades provide readings from 0 to 20,000 microcuries.)

CHAPTER 3

OPERATIONS

3.1 CONTAMINATION

Panels were placed on the YAG 39 and the YAG 40 for Shot 1 and Shot 2, and on the YAG 40 only for Shot 4. Panels were not placed on the YAG 39 for Shot 4 since the effect of a contaminating situation involving an immovable structure was desired. Therefore, arrangements were made for the placement of these panels on an anchored barge for participation in Shot Echo as herein before described. When Shot Echo was canceled, this participation was changed to Shot 6.

Details of the YAG maneuvers and the intensity levels encountered on board ship during Shots 1, 2, and 4 are recorded in the report of Project 6.4. Following Shot 2 the YAG 39 and the YAG 40 received different amounts of contamination. It has been estimated by Project 6.4 that the YAG 39 received approximately 10 per cent as much fallout as the YAG 40 (12% based on gamma surveys, 9.2% based on beta surveys). The average radiation level on the barge for Shot 6 was 15 mr/hr at H + 10 hr. The initial contamination level of the panels for Shots 2, 4, and 6 are summarized in Table 4.1.

3.2 RECOVERY

Following the above referenced maneuvers in the fallout areas, the ships were recovered by Navy craft and towed to anchorage in the Eniwetok Lagoon off Parry Island. This was accomplished in each case within a few days after detonation.

Shot 1 - Panel contamination was so low as not to warrant unloading from the ships.

Shot 2 - All panels were removed from the ships and monitored. The extremely light contamination found on the YAG 39 panels did not justify their further investigation. However, a complete series of decontamination operations was performed on the panels from the YAG 40.

Shot 4 - The panels, which had been placed on the YAG 40 only, were removed to the decontamination site, monitored, and decontamination operations performed.

Shot 6 - The panels on the barge were unloaded, monitored, and limited decontamination operations performed.

3.3 DECONTAMINATION

3.3.1 Monitoring

Each panel was monitored for beta and gamma radiation separately at 16 equally spaced points marked on the panel on approximately a one foot grid. This was done initially before decontamination operations were begun, after each such operation, and at the beginning and end of each day. An NRDL designed instrument was used for measuring beta radiation, and the Radiac Training Set AN-PDR/T1B was utilized for gamma measurements. Beta radiation was measured directly on the surface and gamma radiation was measured 1 in. above the surface. An instrument mounting jig was attached to the gamma instrument to insure accuracy of position for all readings. Background readings were taken periodically for purposes of data correction.

3.3.2 Decontamination Methods

Each panel was subjected to a variety of decontamination techniques, applied in the order given below. This order was based on initial employment of the mildest method known - as determined by previous laboratory investigations - progressing to more and more severe treatments. (Economic considerations and limited availability of space on the test ships precluded the furnishing of a separate panel for each decontamination operation.) In several instances two trials were made with identical techniques in an effort to determine the optimum efficiency of each such technique.

3.3.2.1 Decontamination Methods Employed

a. Low pressure hosing - for a period of 1 minute/panel, (1/4 in. nozzle, with a nozzle pressure of 8 psi).

b. Water scrubbing, followed by a low pressure water rinse, for a period of 1 minute/panel.

c. Fire pressure hosing, for a period of 30 sec/panel, (1/4 in. nozzle with a nozzle pressure of 40 psi).

d. Water and detergent (Tide 0.3 per cent solution) scrubbing, followed by a low pressure water rinse, for a period of 1 min/panel.

e. High pressure hosing for a period of 30 sec/panel, (Chemical Corps Decontamination Truck, 350 psi hose pressure).

f. Hot rinse for a period of 30 sec/panel (Sellers Hi-Pressure Jet Cleaner, 200 psi hose pressure).

Shot 6 panels were treated by applying high pressure hosing and then water scrubbing (methods "e" and "b" above) only. Low contamination and inclement weather precluded additional decontamination effort. The order of hosing and scrubbing was reversed to check an observation made during previous panel decontamination to the effect that hosing seemed inefficient following water scrubbing.

3.4 OPERATIONS AT ARMY CHEMICAL CENTER

After completion of operations in the forward area, selected panels were returned to the Army Chemical Center for investigations concerned with the nature of the residual contaminant. Attempts were made to determine the particle size and distribution of activity over the surfaces by radioautographs and optical methods. Limited investigations were conducted in decontamination by brushing with detergents and complexing agents; and determination of depth of penetration of the contaminant into protective coatings.

CHAPTER 4

RESULTS

4.1 RESULTS

4.1.1 Calculations

Radiation intensity readings for each surface were averaged and corrected for background. These were then corrected for decay to H + 24 hr. Decay corrections plotted from Project 6.4 data (see Fig. 4.1) were applied to Shot 2 and Shot 4 data, and the -1.2 decay law was utilized for Shot 6 data. In order to be able to compare the YAG 39 panel contamination levels with the YAG 40 levels for Shot 2, the intensity levels of the YAG 39 panels were multiplied by the ratio of the activity of the fallout to which the ships were exposed.

Average residual percentages for each surface were calculated by dividing the average residual intensity (times 100) after decontamination by the average initial intensity as received in the decontamination area, all intensities having been corrected to a common time basis of H + 24 hr. Some of the contamination as originally retained on the panels may have been removed by weathering and handling prior to the initial survey. It is believed that this removal, if any, is small and of such a non-tenacious nature that low pressure hosing would have removed it. Also, it is quite possible in a real situation that there would be weathering effects during the emergency and waiting periods between detonation and the start of recovery operations. In view of these facts, it is believed that data presented are realistic. Residual percentages for the washdown protected panels on the YAG 39 were calculated by dividing the normalized YAG 39 panel average initial intensities (times 100) by the YAG 40 panel average initial intensities.

4.1.2 Summary

Table 4.1 is a summary of average gamma initial intensities per panel for Shots 2, 4, and 6 corrected to H + 24 hr.

Tables 4.2, 4.3, and 4.4 summarize residual percentages after decontamination based on gamma data for surfaces contaminated after

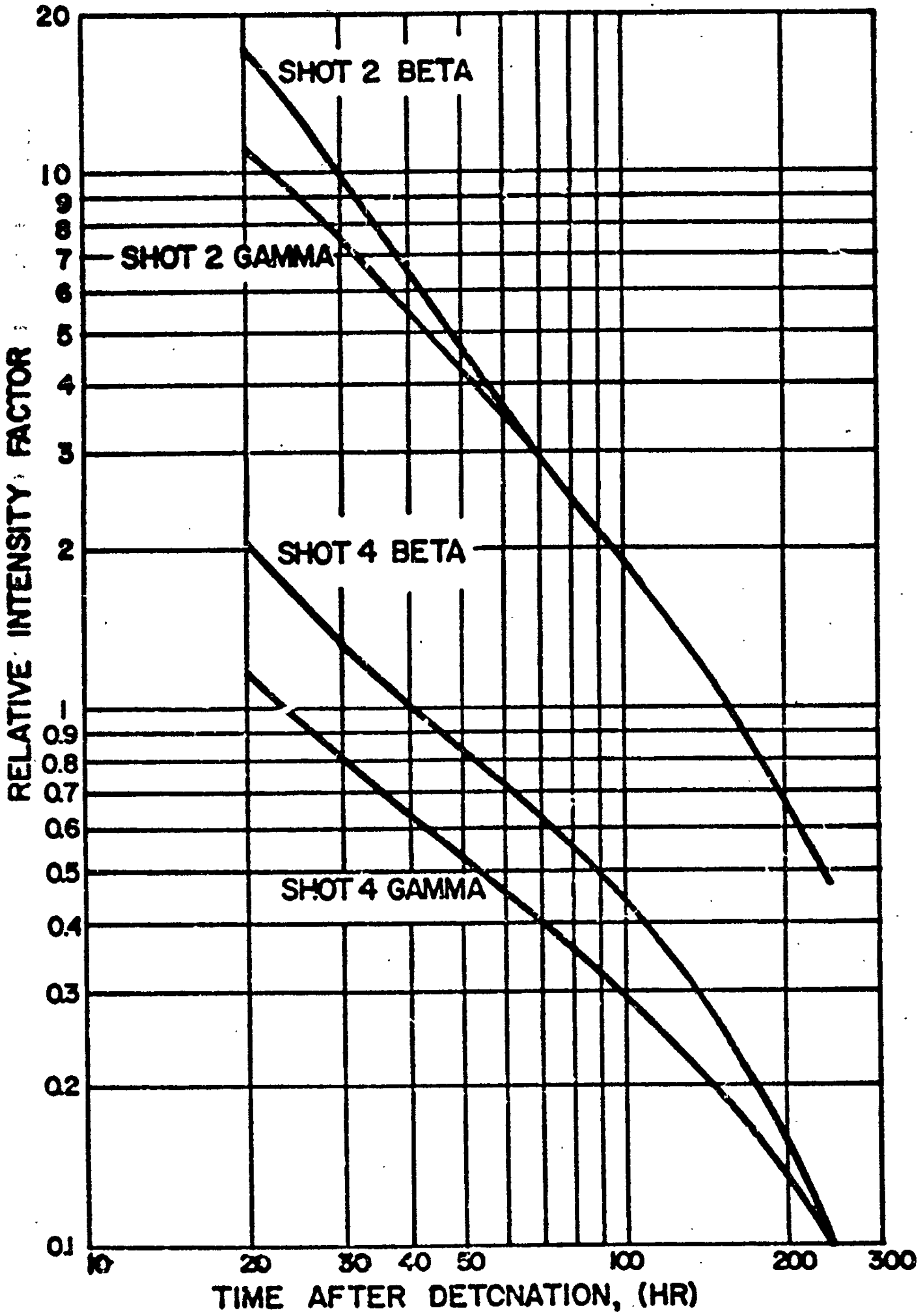

Fig. 4.1 Decay Corrections for Shots 2 and 4

TABLE 4.1 Average Gamma Initial Contamination Per Panel

		INITIAL CONTAMINATION (Corrected to H + 24 hr) mr/hr			
		Shot #2		Shot #4	Shot #6
MATERIAL	SURFACE	YAG 39	YAG 40	YAG 40	STA. 650
Asphalt Pavement	Control	255	5760	425	8
Concrete Pavement	Control	130	7930	570	9
	Seal Coat	85	5400	650	11
Asphalt and Gravel Built-up Roofing	Control	85	3770	400	9* / 7*
	PVA **	60	2550	375	8* / 7*
Smooth Surface Roll Roofing	Control	105	11070	335	7
	PVA **	150	9330	265	8
Corrugated Roof	Control	60	7210	230	8
Strip Shingle Roof	Control	285	8290	640	10
	Sealed Joints	340	8120	605	10
Asbestos Shingle	Control	620	18010	1470	16
	Sealed Joints	490	15130	1360	15
Wood Siding	Control	340	18840	920	11
	Alkyd Resin	300	18120	690	9
	Lead and Oil	255	22830	1040	9
	Phenolic Resin	60	18670	515	7
Sheet Metal	Alkyd Resin	150	14770	640	5
	Phenolic Resin	105	16380	415	4
Brick	Control	105	16570	965	9
	Resin Emulsion	105	27320	640	10
Concrete Block	Control	105	18640	1470	10
	Resin Emulsion	60	12120	765	10
Cinder Block	Control	85	12050	1290	10
	Resin Emulsion	43	13270	815	10
Geometry Effects	Plane	85	2000	280	6
	Configurations	60	2060	320	8

* Two identical panels were exposed
** Polyvinyl Alcohol

Shots 2, 4, and 6 respectively.

Table 4.5 compares averaged residual percentages of panels grouped into usage and surface characteristics.

Table 4.6 lists residual gamma percentages of washdown protected panels compared to unprotected panels exposed to Shot 2.

Figure 4.2 is an illustration of initial gamma contamination versus panel slope. Initial contamination levels of all panels of the same slope were averaged for each shot. These averages were compared with the average intensity level of horizontal panels, and the corresponding ratios were plotted against panel angle.

Figure 4.3, 4.4, and 4.5 represent graphically the initial gamma intensities and residual percentages of panels for Shots 2, 4, and 6 respectively.

Appendix B summarizes the data obtained from beta readings. These results were not used because they were felt to be misleading. Further discussion on this point is contained in Chapter 5.

These charts and graphs, in a few cases, indicate higher activity levels after decontamination than before. This is attributable to instrument error, decay correction error, and changes in instrument geometry due to redistribution of contaminant. In all cases, however, the actual deviation is less than instrument tolerance error alone.

TABLE 4.2 Shot 2-Residual Percentages After Decontamination - γ

MATERIAL	SURFACE	Shot 2 - Residual Percentages (Corrected for Decay & Background) Before Decon-tamination	Low Pressure Hose	Scrub With Low Pressure Rinse	Fire Pressure Hose	Scrub With Detergent	High Pressure Hose	Hot Rinse
Asphalt Pavement	Control	100	74-72*	66-64*	64	58	63	56
Concrete Pavement	Control	100	72-75	47-44	46	46	49	48
	Seal Coat	100	63-72	46-45	49	48	53	51
Asphalt and Gravel Built-up Roofing	Control	100	86-77	62-56	59	62	66	63
	PVA **	100	79-73	56-50	54	61	64	68
Smooth Surface Roll Roofing	Control	100	80-70	39-37	31	25-26*	24	21
	PVA **	100	81-76	46-46	38	37-40	38	23
Corrugated Roof	Control	100	98-83	64-63	61	55-46	45	43
Strip Shingle Roof	Control	100	93-73	64-54	53	55	56	58
	Sealed Joints	100	85-71	62-53	53	52	61	55
Asbestos Shingle	Control	100	68-60	56-52	48	50	54	44
	Sealed Joints	100	70-60	58-55	50	52	54	44
Wood Siding	Control	100	61-58	50-38	39	35-35*	37	34
	Alkyd Resin	100	72-69	42-32	32	25-26	27	24
	Lead and Oil	100	58-53	34-23	22	20-17	17	16
	Phenolic Resin	100	56-55	33-24	22	14-14	15	14
Sheet Metal	Alkyd Resin	100	48-53	23-27	23	10-8	7	7
	Phenolic Resin	100	46-44	22-21	21	10-10	8	8
Brick	Control	100	75-69	52-43	43	44	55	46
	Resin Emulsion	100	67-61	45-40	41	39	48	45
Concrete Block	Control	100	63-64	38-37	40	41	43	45
	Resin Emulsion	100	65-71	38-34	40	40	43	42
Cinder Block	Control	100	68-58	40-45	45	51	44	43
	Resin Emulsion	100	69-58	37-40	40	45	41	36
Geometry Effects	Plane	100	84-84	47-33	25	30	31	32
	Configuration	100	80-79	45-33	24	27	30	33

* When two (2) percentages are listed in the same column, the second percentage represents the result of repeating the operation.

** Polyvinyl Alcohol

TABLE 4.3 Shot 4-Residual Percentages After Decontamination - γ

MATERIAL	SURFACE	Shot 4 Residual Percentages (Corrected For Decay and Background) Before Decontamination	Low Pressure Hose	Scrub With Low Pressure Rinse	Fire Pressure Hose	Scrub With Detergent	High Pressure Hose	Hot Rinse
Asphalt Pavement	Control	100	93	86	88	60	64	69
Concrete Pavement	Control	100	92	65	66	57	58	58
	Seal Coat	100	93	66	74	65	66	66
Asphalt and Gravel Built-up Roofing	Control	100	88	83	76	68	68	71
	PVA *	100	97	85	81	75	70	71
Smooth Surface Roll Roofing	Control	100	87	51	50	31	30	32
	PVA *	100	93	52	52	42	42	37
Corrugated Roof	Control	100	100	70	68	53	53	58
Strip Shingle Roof	Control	100	89	71	67	52	53	57
	Sealed Joints	100	85	69	65	53	53	55
Asbestos Shingle	Control	100	99	88	87	83	85	84
	Sealed Joints	100	102	85	87	83	83	81
Wood Siding	Control	100	95	77	74	67	62	65
	Alkyd Resin	100	103	74	73	56	55	56
	Lead and Oil	100	93	68	62	52	48	48
	Phenolic Resin	100	94	85	74	60	48	52
Sheet Metal	Alkyd Resin	100	81	69	71	29	32	30
	Phenolic Resin	100	63	61	59	30	31	32
Brick	Control	100	89	78	72	73	68	67
	Resin Emulsion	100	97	90	80	73	71	75
Concrete Block	Control	100	97	74	74	72	73	74
	Resin Emulsion	100	85	86	86	83	85	88
Cinder Block	Control	100	98	83	81	78	77	76
	Resin Emulsion	100	102	84	86	80	82	82
Geometry Effects	Plane	100	121	93	87	73	69	67
	Configurations	100	116	85	83	80	68	70

* Polyvinyl Alcohol

TABLE 4.4 Shot 6 Residual Percentages After Decontamination—γ

MATERIAL	SURFACE	Shot 6 RESIDUAL PERCENTAGES (Corrected for Decay and Background): Before Decontamination	High Pressure Hose	Scrub With Low Pressure Rinse
Asphalt Pavement	Control	100	100	98
Concrete Pavement	Control	100	86	71
	Seal Coat	100	92	82
Asphalt and Gravel Built-up Roofing	Control	100	81* / *79	75* / 83*
	PVA **	100	82* / *77	75* / 83*
Smooth Surface Roll Roofing	Control	100	74	56
	PVA **	100	71	54
Corrugated Roof	Control	100	86	54
Strip Shingle Roof	Control	100	94	92
	Sealed Joints	100	89	86
Asbestos Shingle	Control	100	99	89
	Sealed Joints	100	99	84
Wood Siding	Control	100	87	78
	Alkyd Resin	100	73	41
	Lead and Oil	100	84	68
	Phenolic Resin	100	89	70
Sheet Metal	Alkyd Resin	100	93	46
	Phenolic Resin	100	97	68
Brick	Control	100	90	85
	Resin Emulsion	100	72	57
Concrete Block	Control	100	89	70
	Resin Emulsion	100	89	51
Cinder Block	Control	100	92	92
	Resin Emulsion	100	92	75
Geometry Effects	Plane	100	78	37
	Configurations	100	66	43

* Two identical panels were exposed.
** Polyvinyl Alcohol

TABLE 4.5 Comparison of Panel Residual Percentages Grouped Into Usage and Surface Characteristics - γ

Shot No.	PANEL GROUP	RESIDUAL PERCENTAGES (Corrected for Decay and Background)								
		Before Decontamination	Low Pressure Hose	Repeat Low Pressure Hose	Scrub With Low Pressure Rinse	Repeat Scrub With Low Pressure Rinse	Fire Pressure Hose	Scrub With Detergent	High Pressure Hose	Hot Rinse
2	All Panels	100	72	67	47	42	41	40	41	38
	Pavement Panels	100	70	73	53	51	53	51	55	52
	Roof Panels	100	86	75	56	51	50	50	51	47
	Wall Panels	100	66	62	41	36	35	33	35	32
	Uncoated	100	72	67	47	43	43	43	45	43
	Coated	100	68	65	42	37	38	37	33	35
	Open Joints	100	81	67	60	53	51	53	55	51
	Sealed Joints	100	78	66	60	54	52	52	58	50
	Permeable	100	64	61	37	33	32	23	20	19
	Impermeable	100	70	68	49	47	48	48	51	48
4	All Panels	100	94		76		74	63	61	62
	Pavement Panels	100	93		72		76	61	63	64
	Roof Panels	100	91		69		66	53	53	54
	Wall Panels	100	96		80		77	67	65	65
	Uncoated	100	92		73		70	64	62	63
	Coated	100	95		77		74	65	63	64
	Open Joints	100	94		80		77	68	69	71
	Sealed Joints	100	94		77		76	68	68	68
	Permeable	100	88		72		69	46	44	46
	Impermeable	100	94		77		76	68	68	69

TABLE 4.6 Residual Percentages of Washdown Protected Panels - γ

MATERIAL	SURFACE	RESIDUAL PERCENTAGES (After Washdown)
Asphalt Pavement	Control	4.4
Concrete Pavement	Control	1.6
	Seal Coat	1.6
Asphalt and Gravel Built-up Roofing	Control	2.3
	PVA *	2.4
Smooth Surface Roll Roofing	Control	1.0
	PVA *	1.6
Corrugated Roof	Control	0.9
Strip Shingle Roof	Control	4.6
	Sealed Joints	4.2
Asbestos Shingle	Control	3.4
	Sealed Joint	3.2
Wood Siding	Control	1.8
	Alkyd Resin	1.6
	Lead and Oil	1.1
	Phenolic Resin	0.3
Sheet Metal	Alkyd Resin	1.0
	Phenolic Resin	0.6
Brick	Control	0.6
	Resin Emulsion	0.4
Concrete Block	Control	0.6
	Resin Emulsion	0.5
Cinder Block	Control	0.7
	Resin Emulsion	0.3
Geometry Effects	Plane	4.3
	Configurations	3.0

* Polyvinyl Alcohol

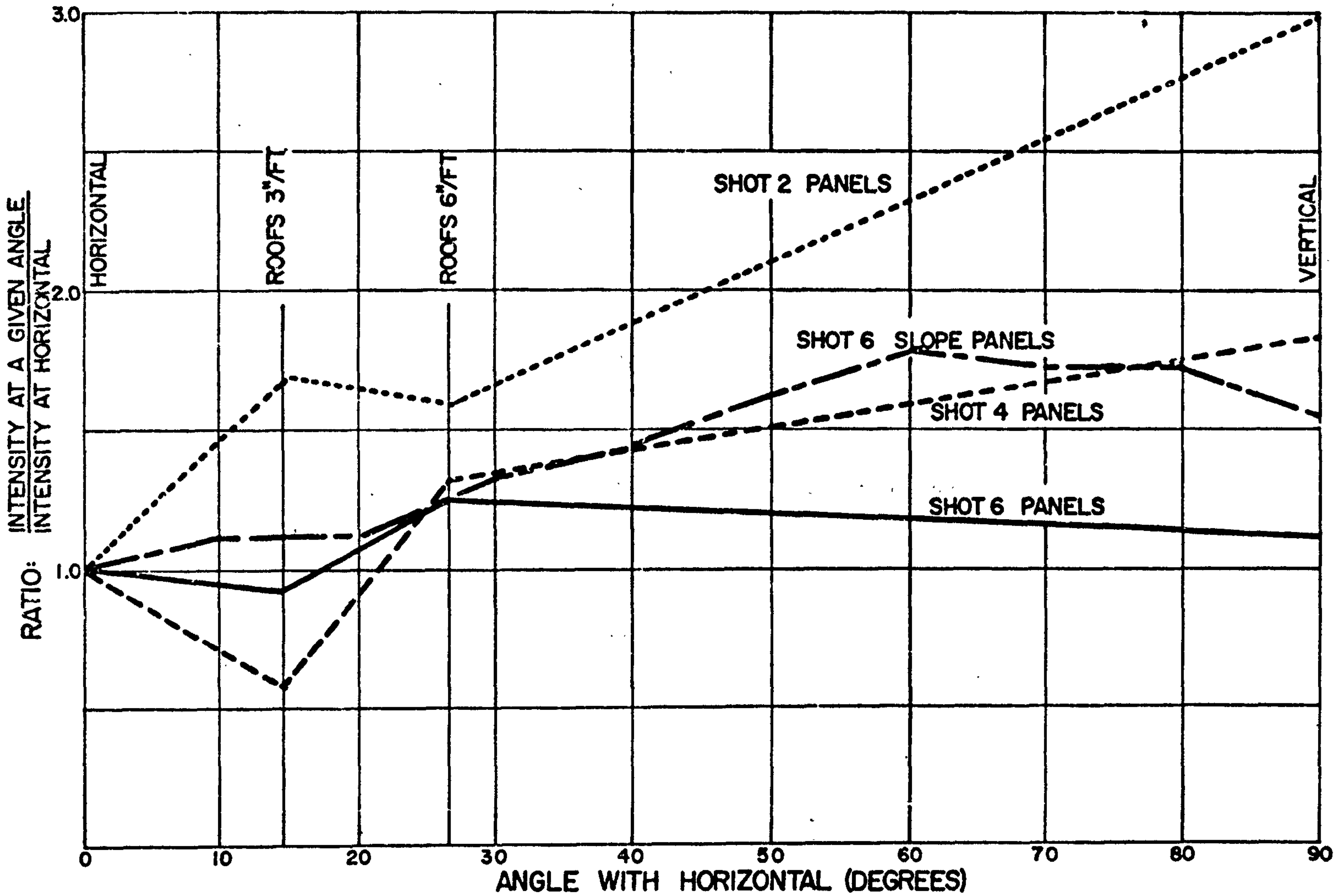

Fig. 4.2 Effect of Slope on Initial Contamination

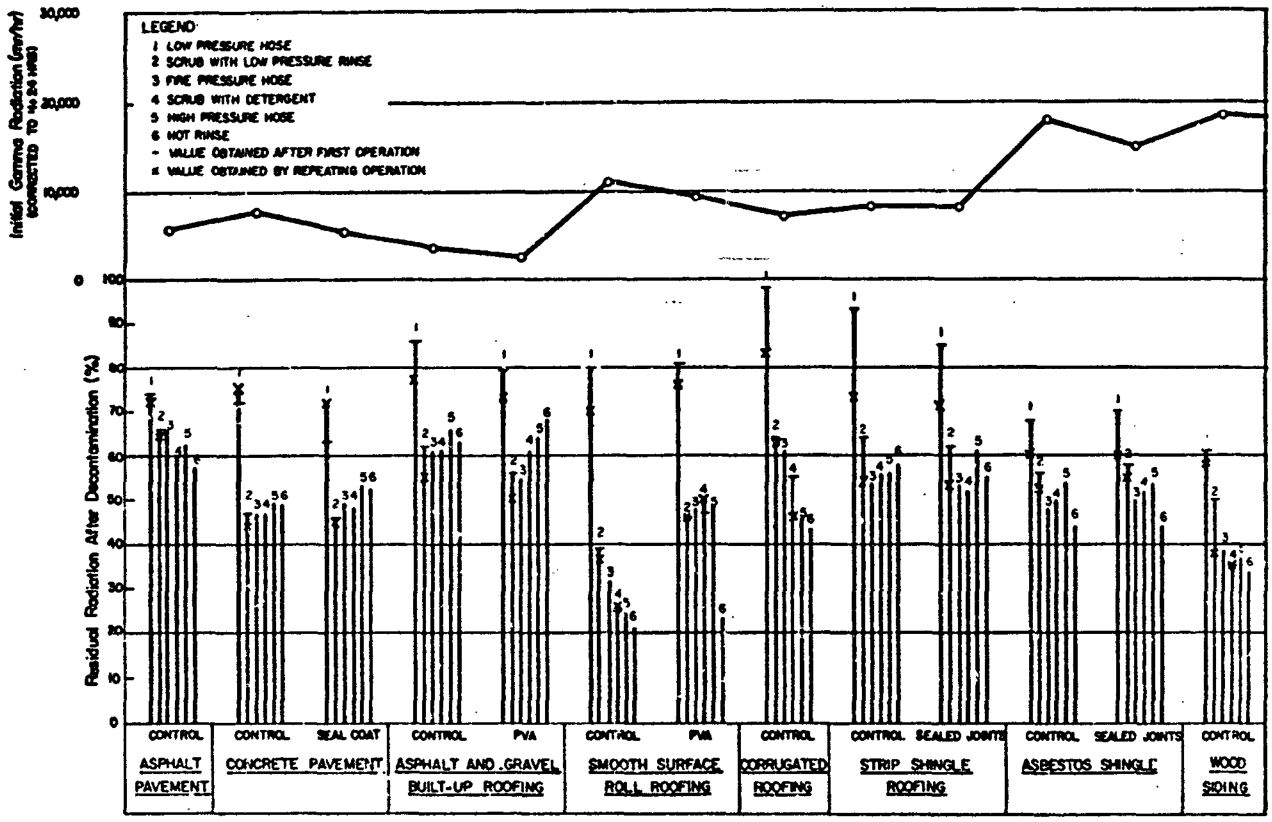

Fig. 4.3 Shot 2 Initial Gamma Contamination and Residual Percentages After Decontamination Operations

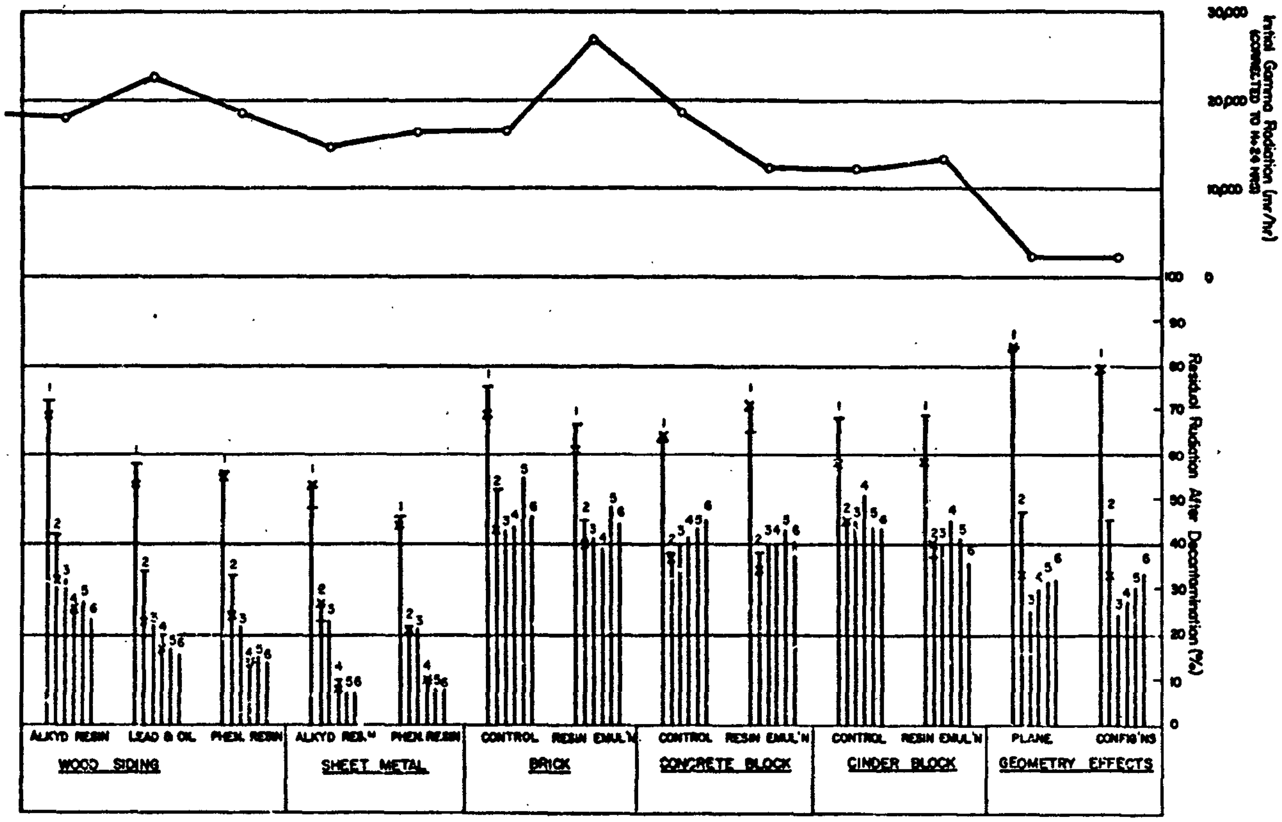

Fig. 4.3 (Contd) Shot 2 Initial Gamma Contamination and Residual Percentages After Decontamination Operations

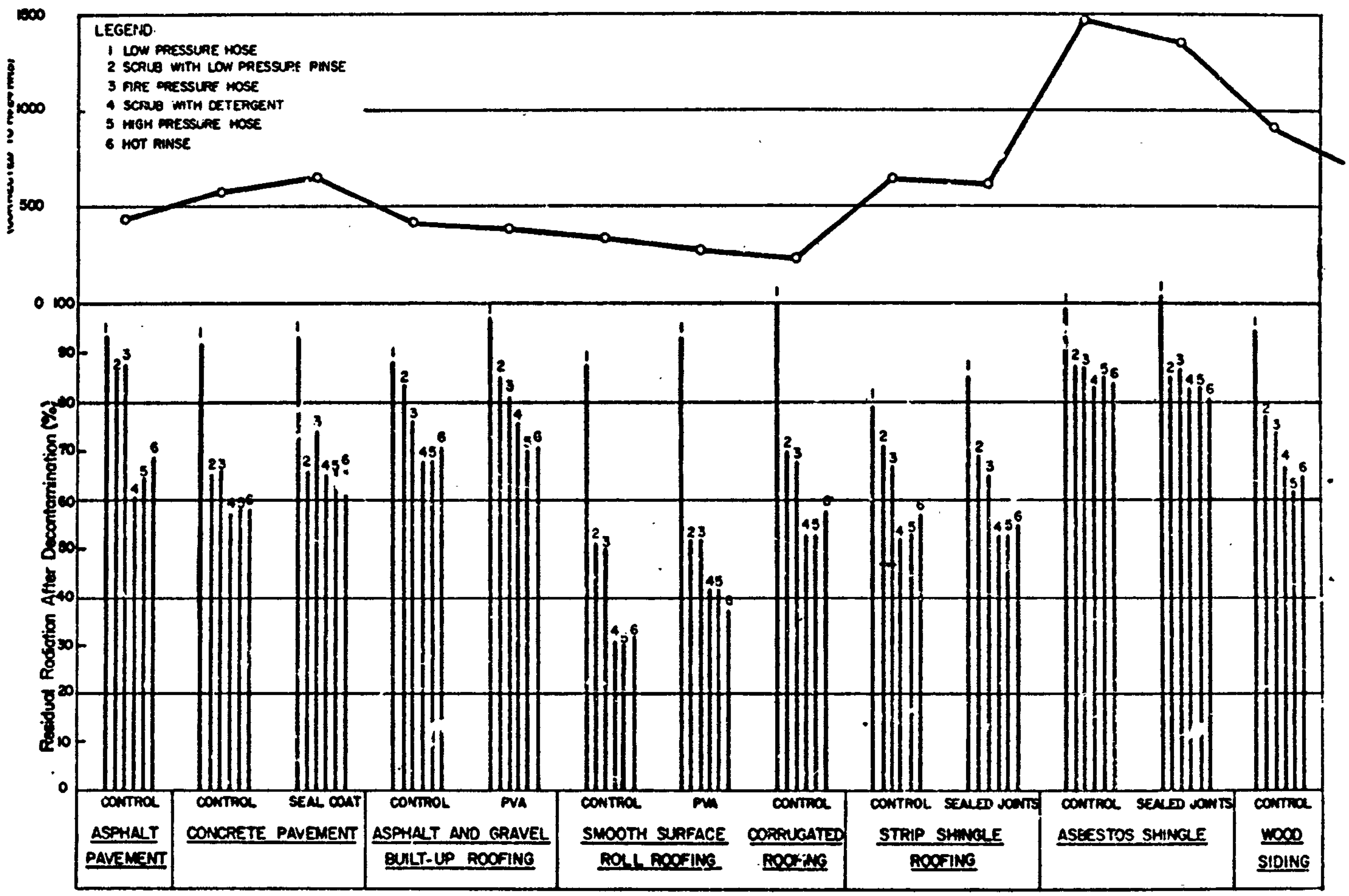

Fig. 4.4 Shot 4 Initial Gamma Contamination and Residual Percentages After Decontamination Operations

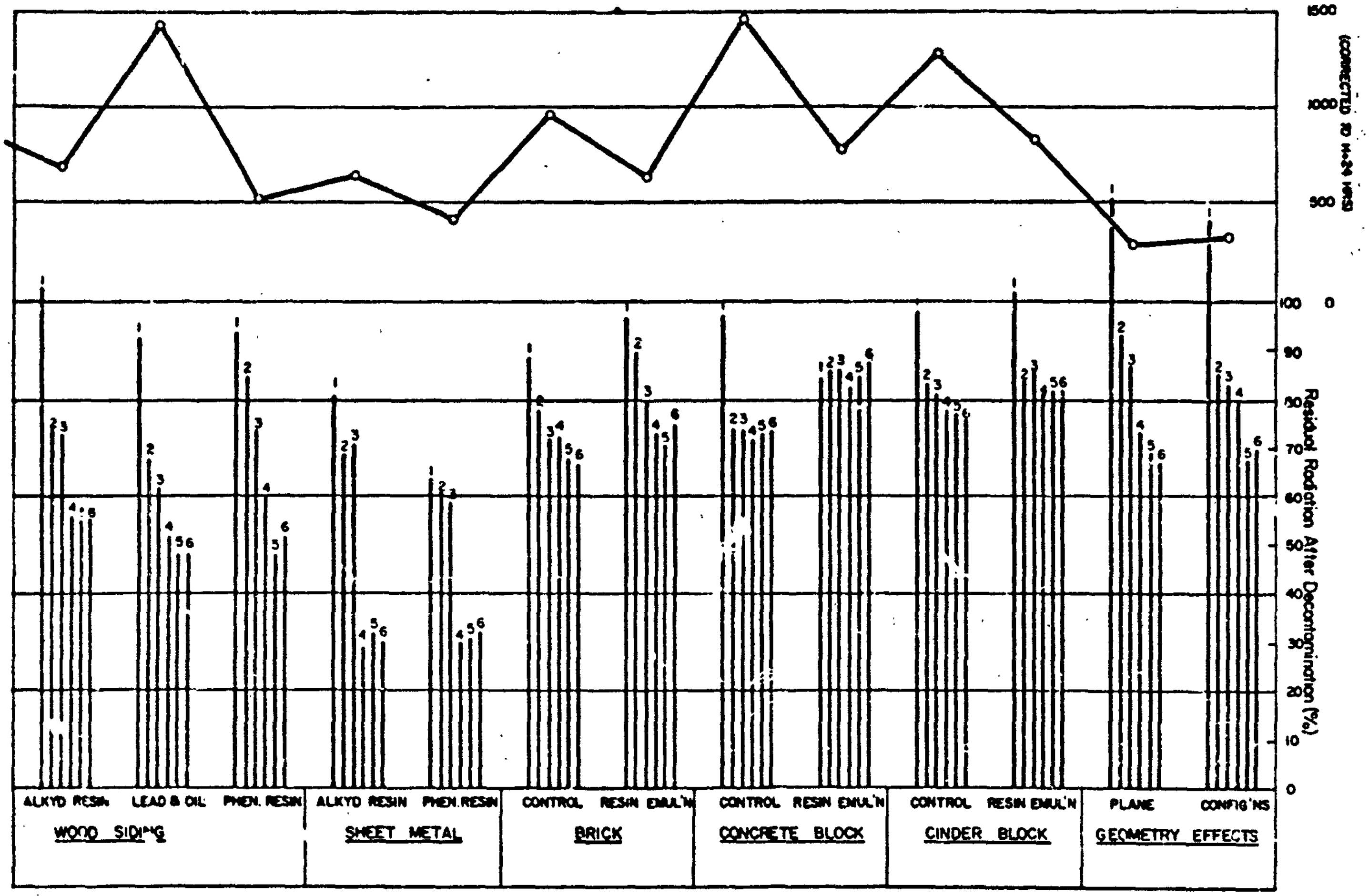

Fig. 4.4 (Contd) Shot 4 Initial Gamma Contamination and Residual Percentages After Decontamination Operations

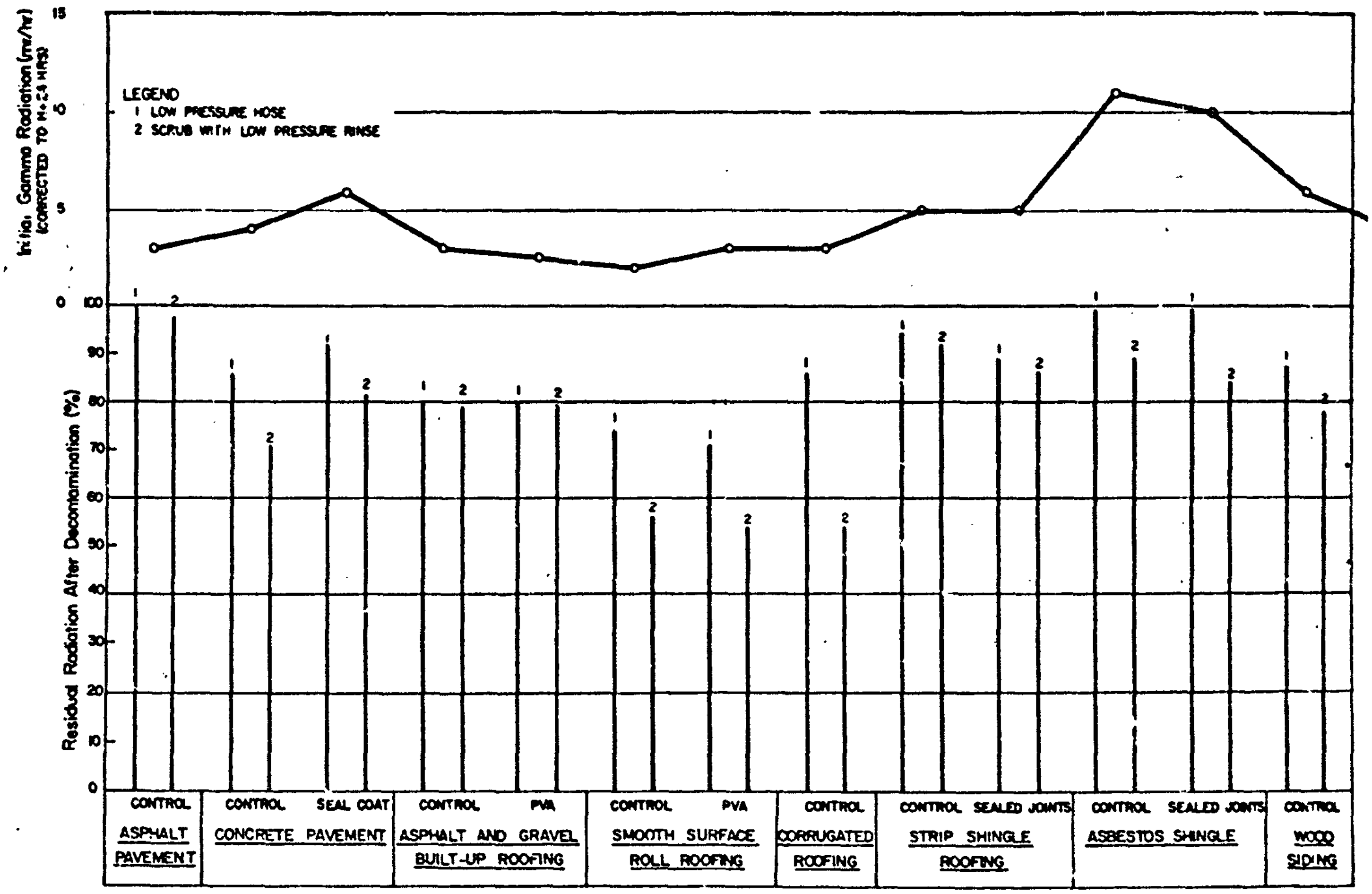

Fig. 4.5 Shot 6 Initial Gamma Contamination and Residual Percentages After Decontamination Operations

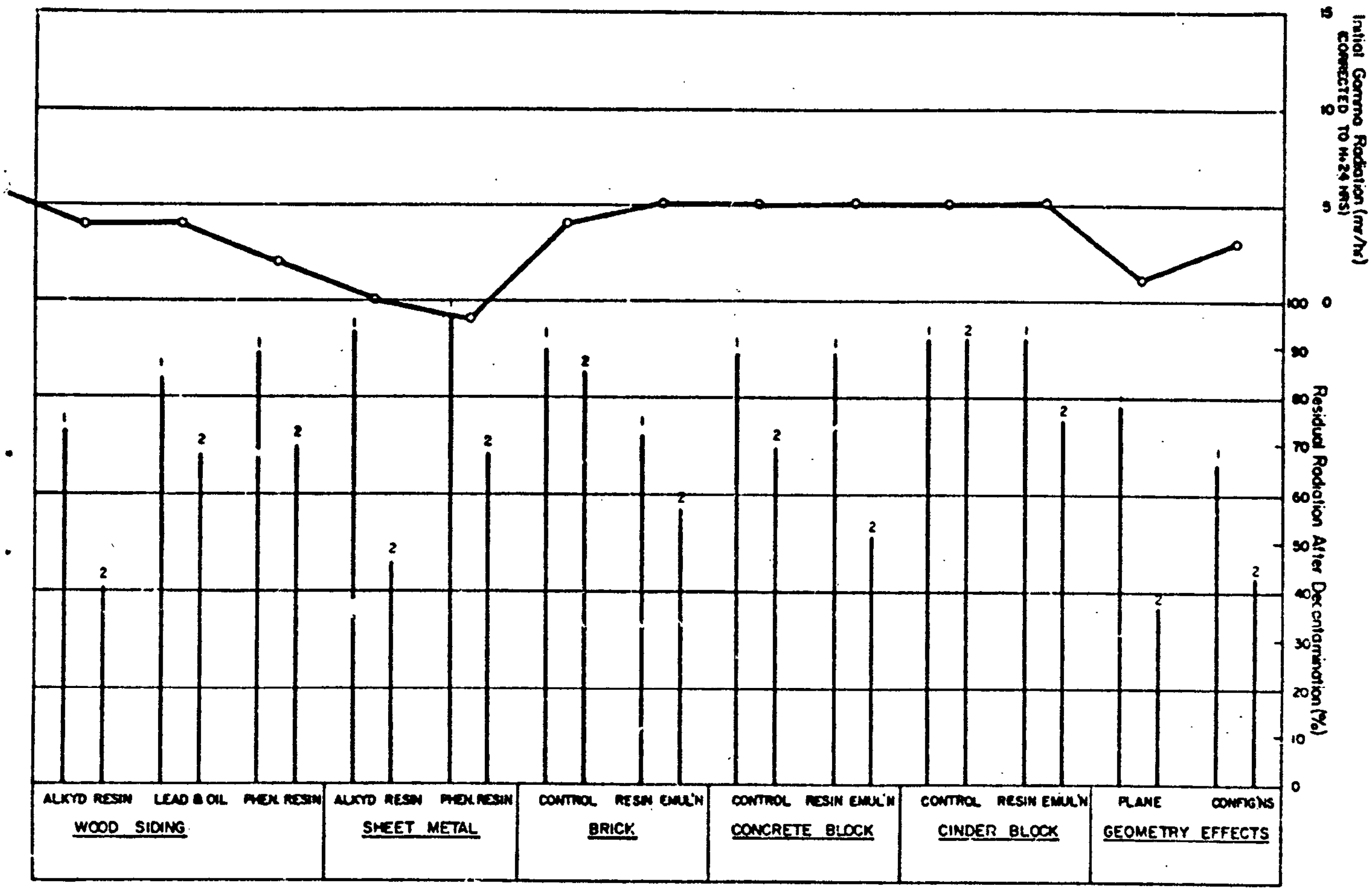

Fig. 4.5 (Contd) Shot 6 Initial Gamma Contamination and Residual Percentages After Decontamination Operations

CHAPTER 5

DISCUSSION

5.1 RESULTS

Subject to certain technical limitations, participation in CASTLE has produced information suitable for direct application to a military situation involving the detonation of thermonuclear weapons in harbors and in relatively shallow coastal waters contiguous to strategically important shore installations. The information obtained is also expected to be applicable, by suitable extrapolation, to surface and shallow water detonations of moderate yield fission type weapons.

One of the technical limitations to unreserved acceptance of CASTLE data lies in the atypical, calcareous nature of the contaminant residues.

The contaminant resulting from Shots 2, 4, and 6 was very tenacious and on most surfaces resisted hosing and scrubbing decontamination efforts which were effective at JANGLE. This difference seems to be largely a function of the nature of the contaminant which in this case was predominantly liquid. It is believed that the adherence characteristics observed resulted from adsorption of the fission product ions found in this liquid. The following is experimental evidence to support the above theory:

1. Radioautographs showed a smear of contamination with a more or less uniform distribution of diffused "hot spots". No particulates were found to be associated with these "hot spots".
2. The application of carriers such as strontium, cerium, and iron effectively decontaminated these surfaces. This is the result of ion exchange.
3. A complexing agent for a similar reason (in this case 3 per cent "Versene") was also effective in decontamination.
4. Contaminant penetration into the surfaces of painted and unpainted wood was approximately the same. This is characteristic of ion exchange but would not apply to particulates.

The explanation presented in reference[14] relative to the tenacious nature of the contaminant found on the rafts in IVY appears doubtful in view of the above evidence. This reference indicates that the fallout particles originated as calcium carbonate (coral) which was converted to calcium oxide by the heat of the detonation. This rapidly changed to calcium hydroxide with the formation of a very thin layer of calcium carbonate on the outer surfaces. Particles were influenced by a sea water environment which caused the formation of an insoluble shell of magnesium hydroxide, surrounded by calcium carbonate. On the interior of the shell, well-developed hydrated calcium sulfate crystals (gypsum) were formed. This leaching effect, by causing partial solution and reprecipitation of the soluble calcium compounds, was felt to account for the adherence of the particles. As indicated above, experimental evidence supports the view that ion exchange is primarily responsible for the adherence of the contamination at CASTLE. However, the role of ion exchange in the wet contamination-decontamination behavior of materials will require further exploration before its implications are fully understood.

Appreciable differences in initial contamination levels existed among the various panel surfaces with no evident correlation to surface properties. Vertical surfaces facing upwind became equally or more highly contaminated than pitched or horizontal surfaces, probably due to the combined action of wind currents and tenacious contaminant.

A possible explanation for this phenomenon is that deposition of wet contaminant was influenced by wind currents which tended to impact the contaminant onto surfaces normal to the wind. Although this effect was most pronounced on shipboard contaminated panels following Shots 2 and 4 where ship speed into the wind and ship structural geometries may increase the impact, the contamination of panels on the stationary barge following Shot 6 exhibited similar relationships. The effect of slope panels used during Shot 6 were all of the same material and had similar contamination characteristics. The construction material panels were placed at the same mounting slopes as practiced in building construction. No direct comparison of identical surfaces at different slopes can be made with these panels, but it is important to compare the contamination of materials at the slopes as they are encountered in actual buildings.

The experimental decontamination work was done in a sequence of operations and only qualitative comparisons between decontamination methods can be made. If a less efficient method were applied after a more efficient one, it is believed that only negligible removal would result. The selection of the sequence of the different decontamination methods was predicated on laboratory tests as suggested in reference[6].

The basic physical parameters which appear to affect resistance to wet or slurry forms of contamination and/or ease of decontamination are impermeability to moisture, non-absorptivity, and hardness. Results illustrating the effects of these parameters are presented as part of Table 4.6. Smoothness of surface did not appear to be as important for wet and slurry forms of contaminant as it was for the dry form found at JANGLE.

Scrubbing followed by flushing seems to have been the most effective and economical of the reclamation techniques employed. Furthermore, the addition of a detergent increased the effectiveness of scrubbing, especially on Shot 4 panels. Hot liquid and high pressure hosing techniques did not seem to be as effective. That high pressure hosing was less effective was further confirmed by employing this method initially on Shot 6 panels.

Repetition of hosing, either low or high pressure, does not seem to be profitable; however, repetition of scrubbing did yield somewhat lower residual percentages in some cases. This is believed to be simply the result of mechanical abrasion of the surface.

Subsequent tests were conducted at the Army Chemical Center. Samples one inch square were cut from the Shot 4 alkyd resin painted wood geometry panel and decontaminated by brushing with various solutions. Results are presented in Table 5.1. "Versene", and "Tide" and "Cheer" (household detergents) removed over 90 per cent of the five month old contamination which remained after operations at Eniwetok. These tests were extended by scrubbing one foot square areas of available panels with brushes and solutions. Results are presented in Table 5.2 and show that although the reductions are not as large as those obtained with the inch square samples, the use of detergents is beneficial.

It was noted that intrinsically impermeable surfaces such as asphalt and tar would derive little or no benefit from protective coatings insofar as contaminability and decontaminability were concerned. However, absorptive, permeable, and porous materials such as wood, concrete, and asbestos cement were benefited to some extent by the use of coatings or sealing of joints. Of the several coatings employed, the phenolic and alkyd formulations were the most satisfactory and showed sufficient merit to justify further experimentation in the laboratory. It is a matter of interest to note that the phenolic coating was selected initially because of its satisfactory resistance to chemical agents and their highly corrosive decontaminants.

It was observed that the decontamination operations contributed materially to the failure of some of the coatings, notably the polyvinyl alcohol applied to the roll roofing panels and the lead and oil paint applied to wood panels. Also, the addition of "Versene" to the scrubbing operation resulted in a visible run-off of asphaltic material from roof surfaces tested which would contribute toward a shorter service life of these materials. Further evidence of coating failure was indicated in several instances by chemical analysis at Army Chemical Center. For example, the top coating of the Shot 4 alkyd resin wood panel was deteriorated to such extent that only the primer coating ingredients could be identified. However, it is recognized that the use of strong acids will be even more destructive.

The usual sequence formerly prescribed for reclamation by scrubbing called for a preliminary hosing to reduce the field, followed by the application of the detergent, scrubbing, and a final flushing. In view of the greater effectiveness of scrubbing as compared to hosing, and in view of the limits normally placed on available water at many shore installations, it is believed that serious consideration should be given to eliminating the preliminary hosing and substituting the sluicing on of a limited quantity of water

TABLE 5.1 Effectiveness of Brushing With Cleaning Agents On Decontamination of One-Inch Square Samples of Alkyd Resin Painted Wood

CLEANING AGENT	RESIDUAL PERCENTAGE *
Water	99
10% Citric Acid	40
1% Versene	2
1% Tide	6
1% Cheer	10

* Percentages are based on final levels compared with contamination levels as received at Army Chemical Center five months after operations at Eniwetok.

TABLE 5.2 Effectiveness of Cleaning Agents On Decontamination Of One-Foot Square Areas Of Selected Materials

		RESIDUAL PERCENTAGES *			
		Cleaning Agents			
MATERIAL	SURFACE	Water	1% Tide	1/2% Versene	1% Tide + 1/2% Versene
Concrete Pavement	Control	100	67	67	81
Asphalt and Gravel	Control	80	85	82	83
Built-up Roofing	PVA **	100	67	50	60
Corrugated Roof	Control	83	55	27	10
Strip Shingle Roof	Control	92	92	79	74
	Sealed Joints	79	93	79	67
Wood Siding	Control	89	84	85	74
	Alkyd Resin	85	67	55	34
	Lead and Oil	86	69	63	62
	Phenolic Resin	100	60	56	42
Brick	Control	100	89	70	88
Concrete Block	Control	100	80	85	83
Cinder Block	Control	92	91	82	88
Geometry Effects	Plane	82	35	63	24

* Percentages are based on final levels compared with contamination levels as received at Army Chemical Center five months after operations at Eniwetok.

** Polyvinyl Alcohol

containing a detergent and a complexing agent. This is immediately followed by scrubbing and then flushing. The additional dose received by workers during this scrubbing operation, because of the higher field present during the operation, may well be compensated for by the fact that only two operations are required instead of three (scrub, flush, instead of hose, scrub, flush). As indicated elsewhere in this report, it is felt that consideration should also be given to the use of detergent systems without water.

The washdown countermeasure operation conducted on the YAG 39 panels was more effective in minimizing final contamination levels than post-attack decontamination operations on unprotected panels. However the practicability of exterior water sprays on fixed structures with surface irregularities cannot be ascertained at this time.

Residual percentages obtained from beta activity measurements deviated significantly from percentages obtained from gamma measurements. This deviation generally indicated lower residuals, sometimes by as much as a factor of two on very rough and porous surfaces. (See Tables B.2 and B.3) It is believed that the decontamination operations which were conducted tended to drive the contaminant into the surface, which had the effect of masking the beta activity. In view of this condition, the results based on the beta activity are considered to be grossly misleading and are included in this report for informational purposes only.

While the tabulated results show some evidence of "saturation effects" - which theory postulates that the higher the initial contaminant activity, the lower the residual percentage that can be obtained - the levels recorded were not high enough to justify a firm conclusion. If the saturation effect theory is valid, it would mean that under contaminated conditions of real military interest (thousands of roentgens per hour at H + 1 hour) lower residual percentages than were obtained in this operation would be achieved by use of the same decontamination methods.

5.2 PHYSICAL AND CHEMICAL INVESTIGATIONS OF SURFACES

In continuation of investigations initiated at the test site, several test surfaces were radioautographed and examined microscopically at the Army Chemical Center to determine residual particle size and contamination distribution. In every case investigated, there appeared to be a smear of contamination with a more or less uniform distribution of "hot spots". (See Fig. 5.1 and 5.2) However, these investigations failed to detect any particulates associated with this activity. By slicing off surface layers of bare wood and the alkyd resin coating with a microtome, it was determined that the contaminant had penetrated into the surface. In both cases, removal of 200 microns effected complete decontamination. Figures 5.3 and 5.4 show the radioautographs of the alkyd resin coating initially, after 100 microns had been sliced off, and after a total of 200 microns had been removed. Figure 5.5 illustrates the effect of slicing off successive surface layers in contaminant removal.

Fig. 5.1 Radioautograph of Brick Panel Surface

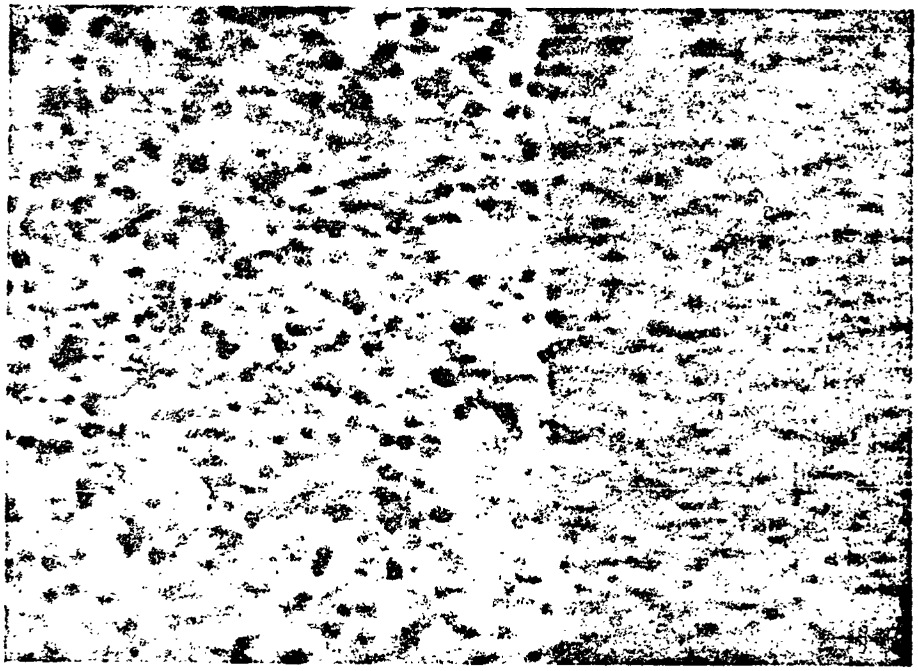

Fig. 5.2 Radioautograph of Wood Panel Surface (Left Side Unpainted, Right Side Alkyd Resin)

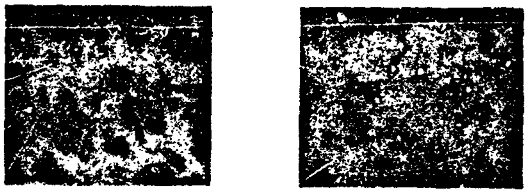

Fig. 5.3 Radioautographs of Alkyd Resin Coated Wood Before Surface Removal

Fig. 5.4 Radioautographs of Fig. 5.3 Surfaces After Removal of 100 Microns (Left) and 200 Microns (Right)

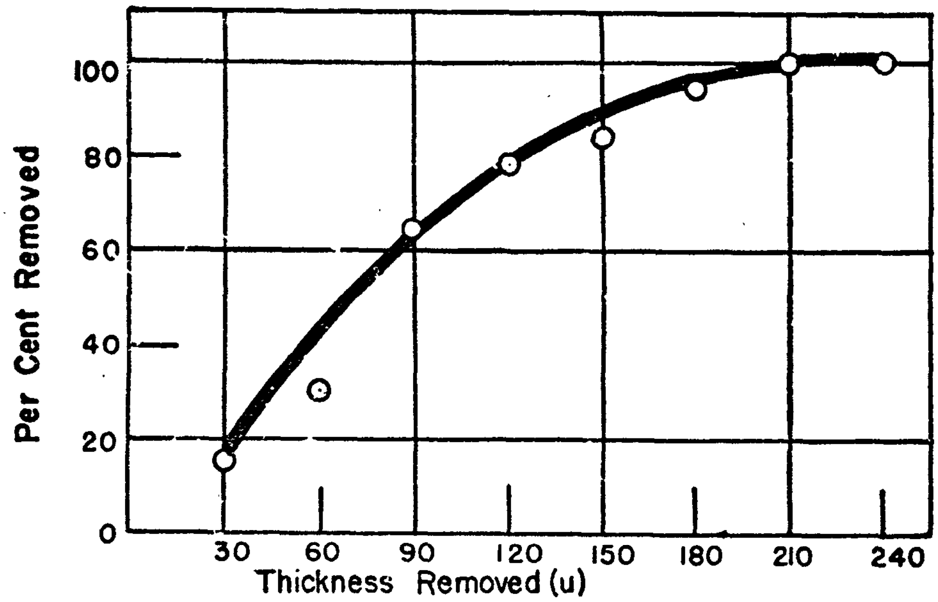

Fig. 5.5 Effect of Surface Removal in Decontamination of Alkyd Resin Painted Wood

Since the contaminant appeared to be ionic, some ion exchange tests were made. Strontium, cerium, and iron carriers were applied to small surface areas of unpainted and painted wood. About 60 per cent decontamination was achieved on painted surfaces by this method with two hour contact. However, as previously indicated, further studies of the effects of ion exchange should be conducted.

5.3 DOSE RATE INSIDE BUILDINGS

Since vertical surfaces became contaminated, on the windward side at least, to an equal or greater extent than roofs and horizontal surfaces, it was felt that previously calculated and experimental building dose rates may be in error as no wall contamination was assumed.[15] Accordingly, as an illustrative example, the relative dose rates at the center of the standard 20 ft × 100 ft Army Theatre of Operations unlined frame building, TM 5-280, have been calculated for three conditions:

1. Unit contamination on roof and ground, no wall contamination.
2. Unit contamination on roof, ground, and one long wall.
3. Unit contamination on roof and ground, and three times unit contamination on one long wall (as suggested by Shot 2 data, Fig. 4.1).

The dose rates for these three conditions, normalized to the first condition, vary as factors of 1, 1.02, and 1.05 for the order given above, at a distance 10 ft from the contaminated long wall. Corresponding factors for dosage at 2 ft from the contaminated wall are 1, 1.26, and 1.79 respectively. These calculations were made using methods and equations suggested in reference[15]. Similar calculations relating to other type buildings are considered beyond the scope of this report, but very worthy of further investigation.

5.4 OTHER DECONTAMINATION METHODS

Dry sweeping as a method of decontamination was attempted on the smooth painted wood back of one panel that had light contamination. The method was completely without merit. Wet scrubbing methods on other lightly contaminated panel backs of the same material were many times as effective.

The effectiveness of reclamation of unpaved ground areas is apparently independent of the nature of the contaminant. This is based on the effectiveness of the crude scraping performed on the porous coral surface underneath the experimental panels. This porous coral soil became contaminated by wash liquids. Physical removal of the top 3 to 4 inches of soil gave the same effective decontamination as similar operations in Nevada where the area was contaminated by dry fallout.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

1. Contamination of shore facilities after detonation of a thermonuclear weapon in a harbor would present severe decontamination problems in areas considerably beyond the range of blast and thermal damage.

2. Hosing and dry sweeping decontamination techniques are relatively ineffective in reducing residual contamination levels on structures exposed to wet or slurry forms of contamination.

3. Scrubbing operations utilizing the proper combinations of detergents and complexing agents are the best practical methods in reducing contamination levels on most construction materials; especially on those having impermeable surfaces.

4. While the use of some of the protective coatings employed was of slight value, phenolic and alkyd formulations showed sufficient merit to justify further experimentation in the laboratory.

5. The differences in initial contamination level of the panels appear to be more a function of orientation of the panels than of the characteristics of the panel surfaces themselves. Vertical surfaces facing upwind were found to be equally or more highly contaminated than pitched or horizontal surfaces. This may significantly increase dosage rates on the inside of structures.

6. The use of unpaved buffer zones around structures is preferable to paved areas, particularly if adequate mechanized dirt moving machinery is available.

7. Residual contamination percentages on surfaces appear to decrease with increasing initial contamination levels.

8. The submicron size and ionic nature of the contaminant might be the reason for the tenaciousness of the contaminant encountered.

9. Washdown countermeasures are effective in minimizing initial contamination of panels of construction materials surfaces. However, the practicability of exterior water sprays on fixed structures with surface irregularities cannot be ascertained at this time.

10. Beta detection instruments are not suitable for measuring

decontamination effectiveness. They may be of value however in locating high intensity areas in a contaminated field where buildings or abrupt changes in surface contours may cause non-uniform settling of fallout.

6.2 RECOMMENDATIONS

1. The residual percentages given in the literature for the various decontamination operations should be reviewed in the light of the results of this operation, and reclamation planning of target complexes should be adjusted accordingly.

2. In view of the added effectiveness of detergents for decontamination; and the probability of serious water shortages on contaminated installations, the development of effective low cost detergent systems may be advisable.

3. The effect on construction material surfaces of the forms of contamination resulting from typical harbor bottom materials should be determined on a comparison basis with the calcareous bottom materials found at CASTLE.

4. The implications of increased dose rates in building interiors caused by wall contamination should be investigated.

5. The influence of high intensity-level contamination on residual percentages following decontamination operations should be determined for comparison with relatively low-level contamination.

6. Investigations concerned with the development of easily removable protective coatings having weather resistant qualities should be accelerated.

7. The effectiveness and practicability of exterior water sprays should be evaluated on fixed structures where immovability and surface irregularities may seriously reduce the effectiveness compared to test results with maneuvering ships.

APPENDIX A

CONSTRUCTION MATERIAL PANEL PHOTOGRAPHS

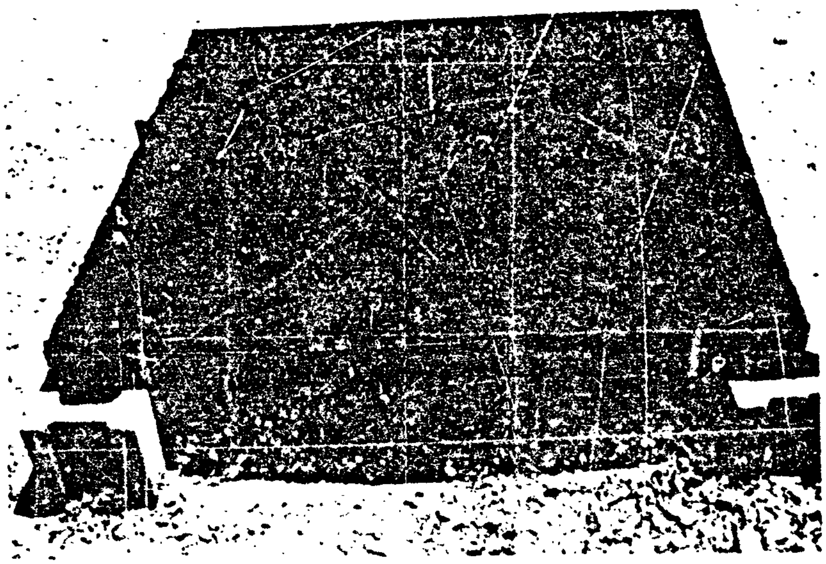

Fig. A.1 Panel No. 1 Asphalt Pavement

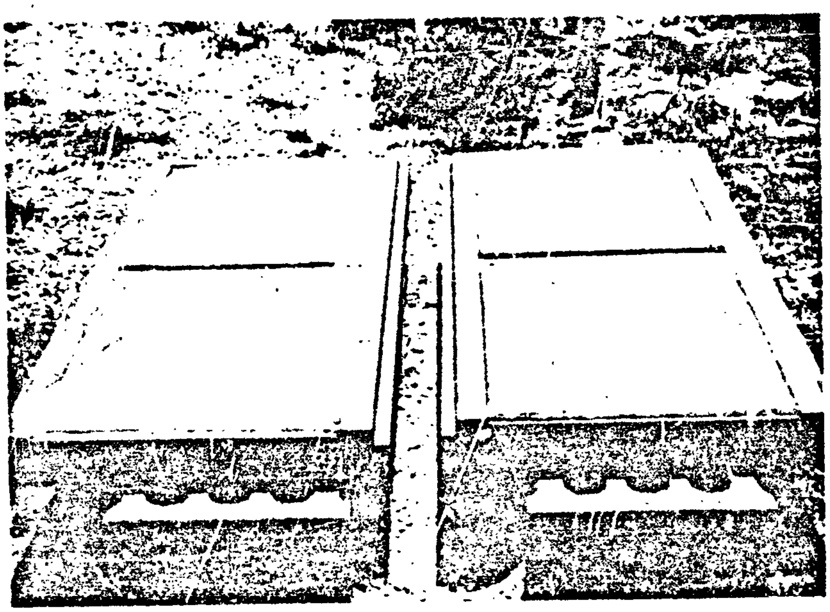

Fig. A.2 Panel No. 2 Concrete Pavement

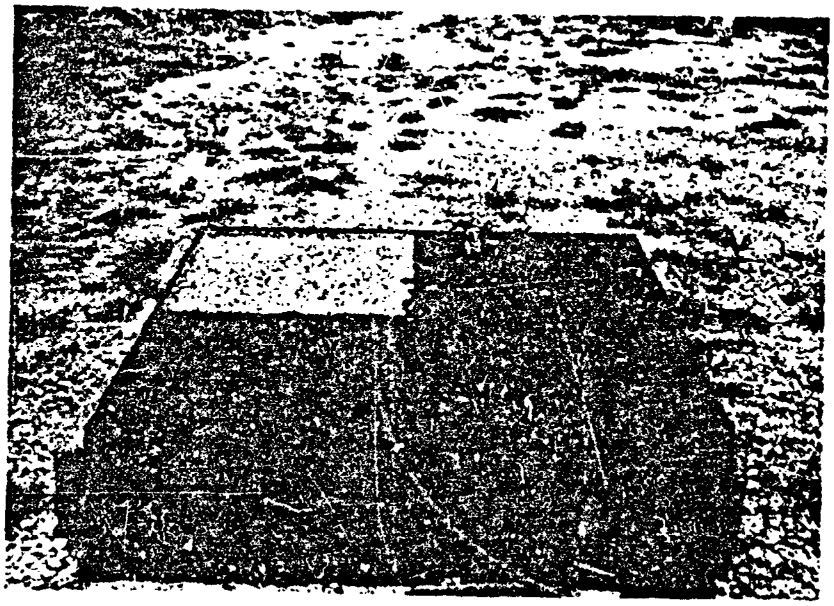

Fig. A.3 Panel No. 3 Asphalt and Gravel Built-Up Roofing

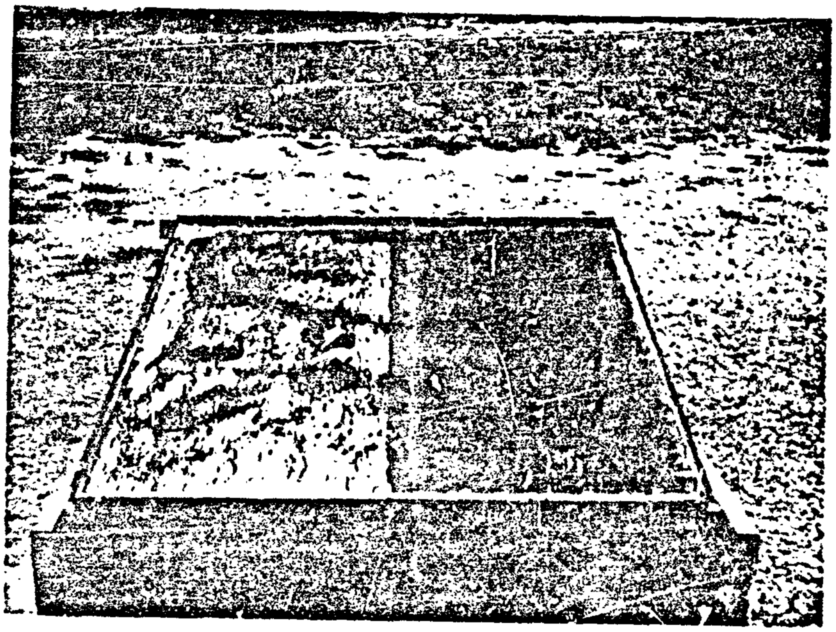

Fig. A.4 Panel No. 4 Smooth Surface Roll Roofing

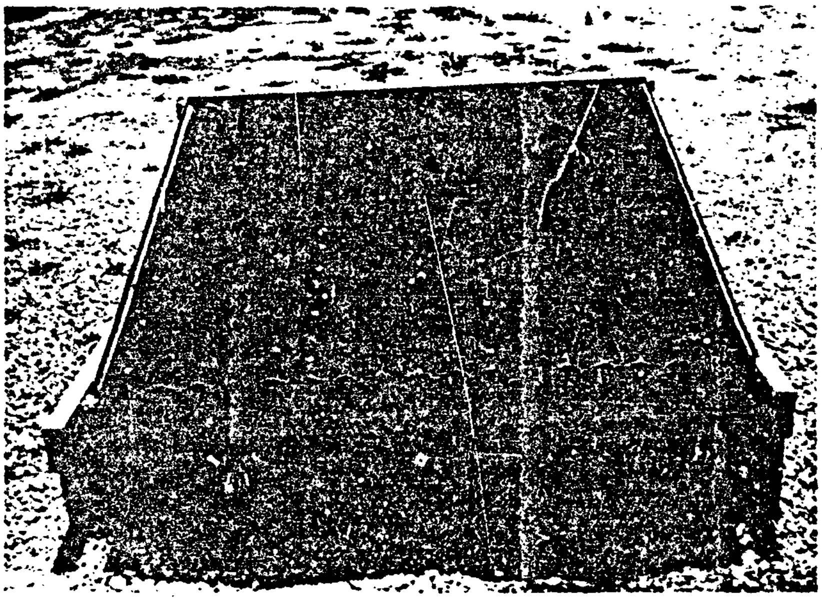

Fig. A.5 Panel Nc. 5 Asphalt Protected Corrugated Metal Roofing

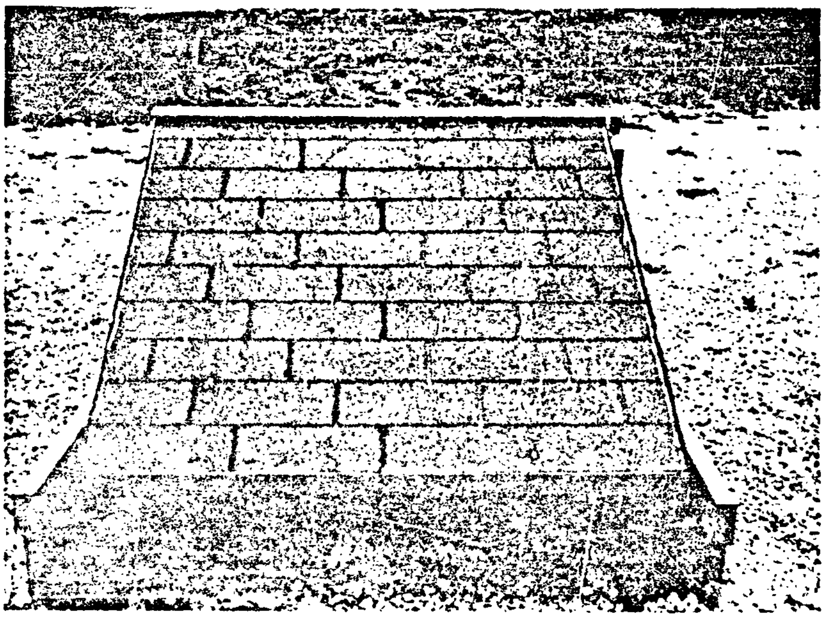

Fig. A.6 Panel No. 6 Mineral Surface Strip Shingle Roofing

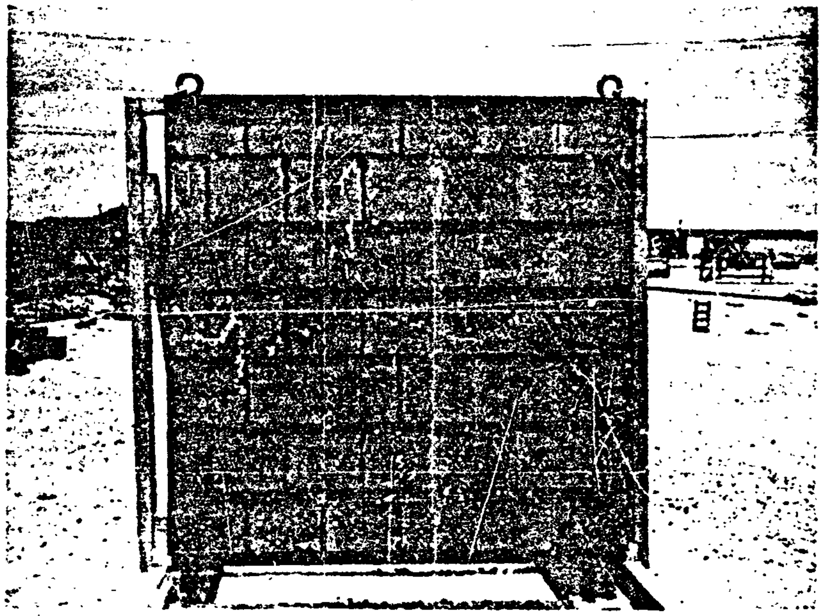

Fig. A.7 Panel No. 7 Asbestos Cement Shingles

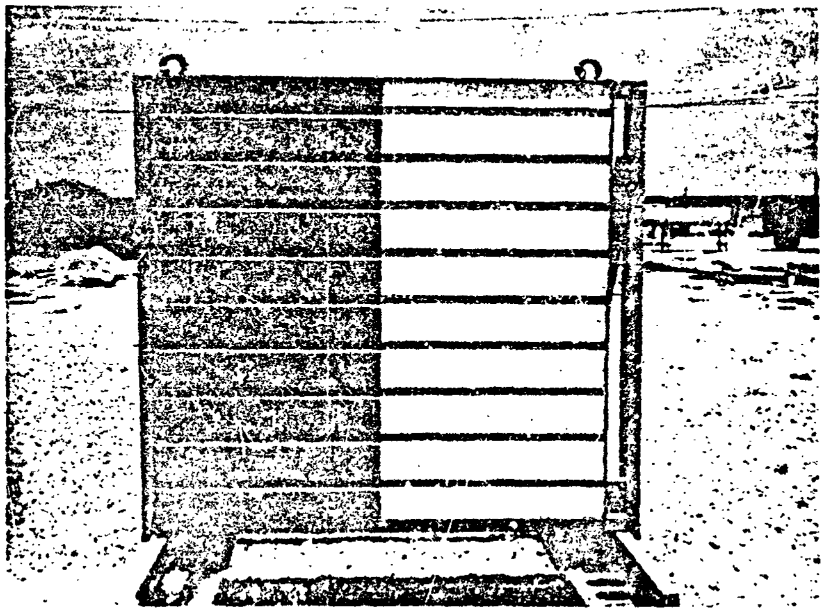

Fig. A.8 Panel No. 8 Wood Siding

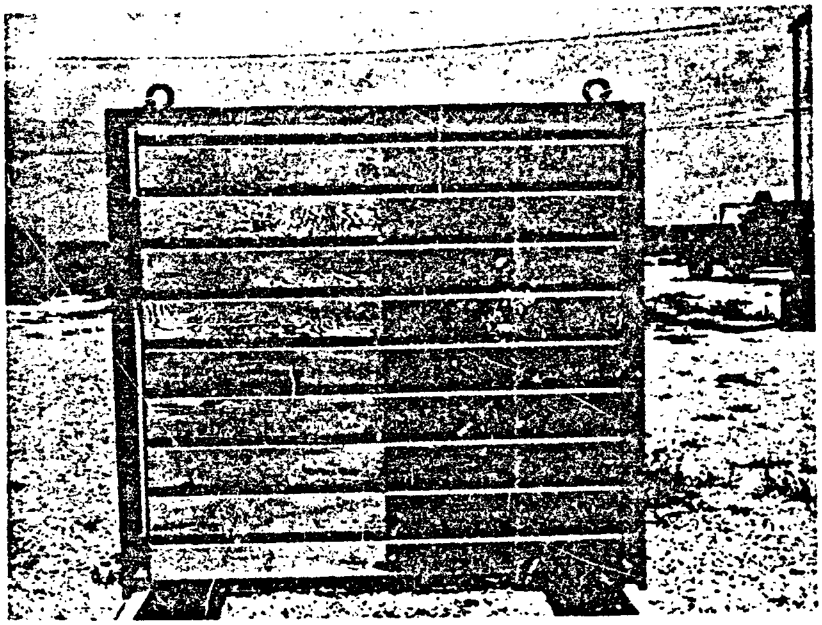

Fig. A.9 Panel No. 9 Wood Siding

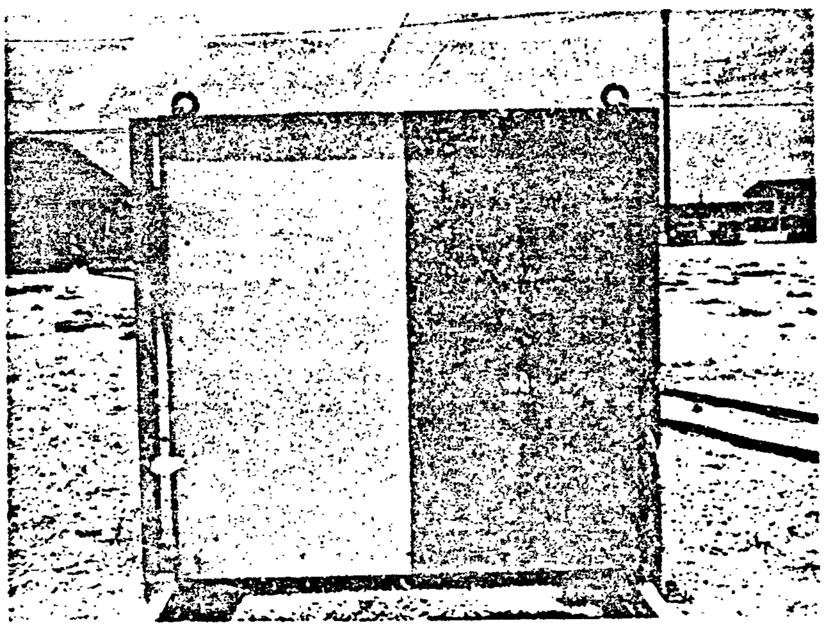

Fig. A.10 Panel No. 10 Sheet Metal

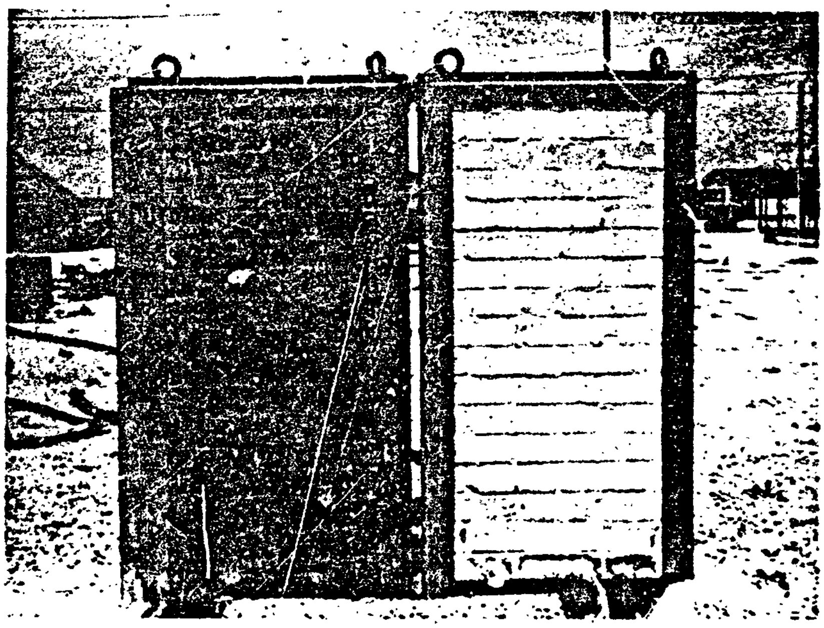

Fig. A.11 Panel No. 11 Brick-Medium Density

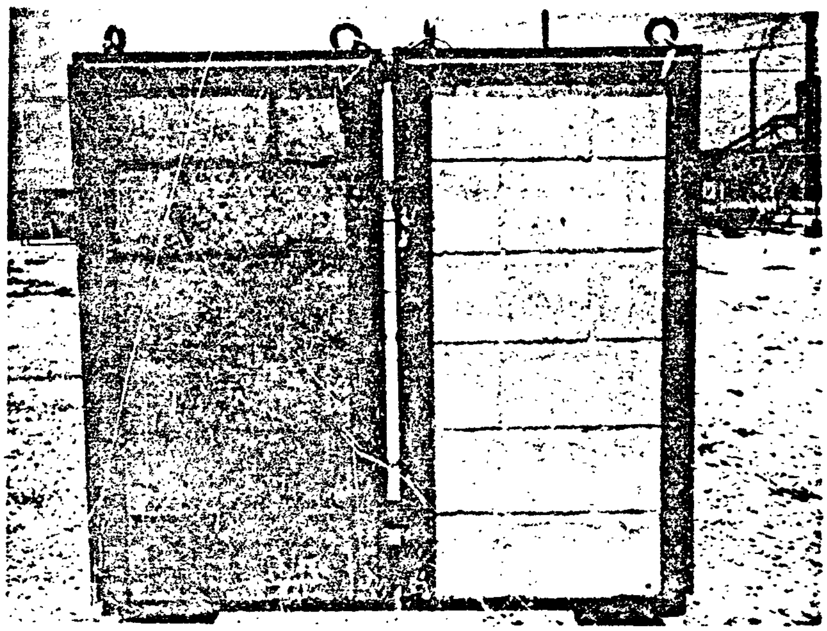

Fig. A.12 Panel No. 12 Concrete Block

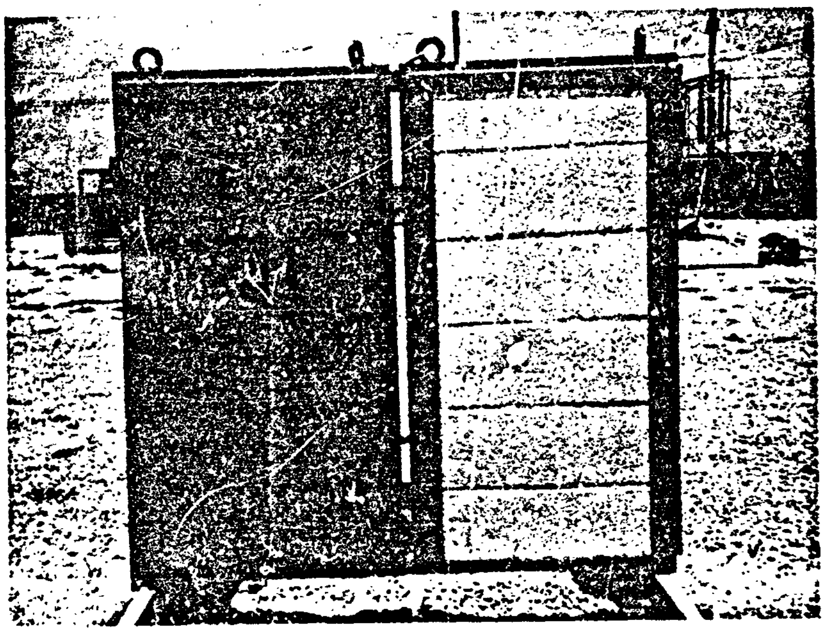

Fig. A.13 Panel No. 13 Cinder Block

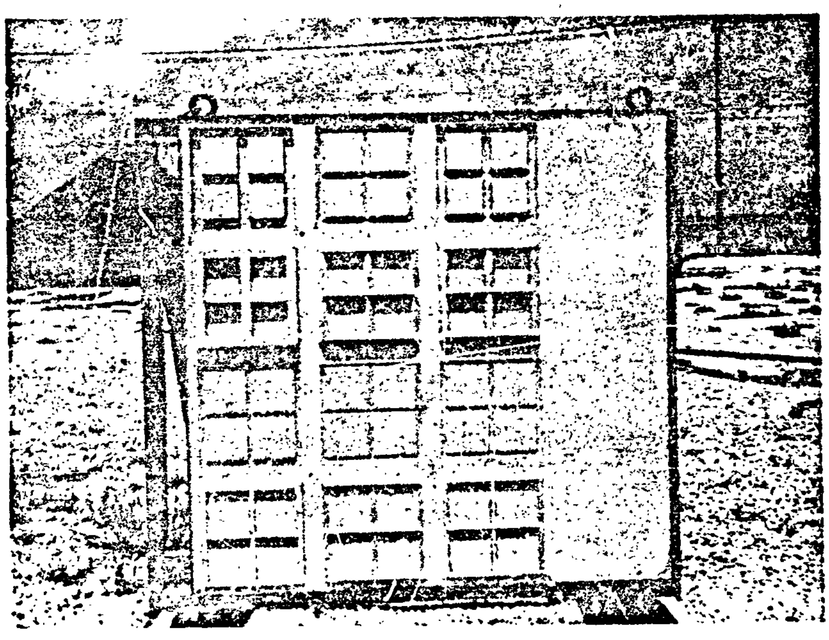

Fig. A.14 Panel No. 14 Geometry Effects

APPENDIX B

DATA BASED ON BETA MEASUREMENTS

TABLE B.1 Average Beta Initial Contamination Per Panel

		INITIAL CONTAMINATION (Corrected to H + 24 hr) uc			
		Shot #2		Shot #4	Shot #6
MATERIAL	SURFACE	YAG 39	YAG 40	YAG 40	STA.650
Asphalt Pavement	Control	670	22510	630	8.7
Concrete Pavement	Control	1220	53700	2330	17.1
	Seal Coat	725	35900	2450	19.2
Asphalt and Gravel Built-up Roofing	Control	670	10370	505	8.7* 11.7*
	PVA **	945	6030	760	12.7* 12.3*
Smooth Surface Roll Roofing	Control	840	52380	1050	22.0
	PVA **	1390	57560	795	27.1
Corrugated Roof	Control	670	43150	960	19.7
Strip Shingle Roof	Control	1170	22900	805	18.0
	Sealed Joints	1060	23560	775	16.0
Asbestos Shingle	Control	3790	84980	3990	30.1
	Sealed Joints	2790	75560	3540	32.6
Wood Siding	Control	1620	92140	3270	26.2
	Alkyd Resin	3790	111730	3110	31.1
	Lead and Oil	2960	129540	5670	18.6
	Phenolic Resin	1120	97320	735	13.9
Sheet Metal	Alkyd Resin	2340	92610	2650	17.7
	Phenolic Resin	945	90260	705	13.7
Brick	Control	395	88090	3480	15.5
	Resin Emulsion	330	165810	2590	25.2
Concrete Block	Control	725	103350	5850	25.2
	Resin Emulsion	500	61430	3260	30.1
Cinder Block	Control	500	52470	3950	18.5
	Resin Emulsion	395	74620	3530	20.4
Geometry Effects	Plane	1060	15070	1930	24.0
	Configurations	945	12820	1530	23.0

* Two identical panels were exposed.
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TABLE B.2 Shot 2-Residual Percentages After Decontamination - β

MATERIAL	SURFACE	Shot 2 RESIDUAL PERCENTAGES (Corrected for Decay and Background): Before Decontamination	Low Pressure Hose	Scrub With Low Pressure Rinse	Fire Pressure Hose	Scrub With Detergent	High Pressure Hose	Hot Rinse
Asphalt Pavement	Control	100	54-39*	26-25*	25	23	23	17
Concrete Pavement	Control	100	75-71	41-36	35	34	34	32
	Seal Coat	100	76-73	48-44	43	38	40	38
Asphalt and Gravel Built-up Roofing	Control	100	78-69	50-49	42	37	35	35
	PVA **	100	73-69	49-43	38	37	37	34
Smooth Surface Roll Roofing	Control	100	88-73	34-30	27	17-11*	12	11
	PVA **	100	88-84	45-43	40	36-32	31	11
Corrugated Roof	Control	100	90-85	57-49	43	33-25	23	24
Strip Shingle Roof	Control	100	76-66	56-50	45	42	39	36
	Sealed Joints	100	80-68	56-50	47	44	44	37
Asbestos Shingle	Control	100	47-49	40-35	34	34	29	27
	Sealed Joints	100	42-51	39-35	38	36	32	30
Wood Siding	Control	100	70-60	44-45	46	38-33*	32	30
	Alkyd Resin	100	93-89	45-43	44	33-24	26	25
	Lead and Oil	100	61-46	31-27	24	18-13	12	12
	Phenolic Resin	100	51-43	20-17	15	5-3	3	3
Sheet Metal	Alkyd Resin	100	63-60	26-26	26	6-3	3	3
	Phenolic Resin	100	45-42	17-16	14	3-2	2	2
Brick	Control	100	70-63	36-35	39	33	32	33
	Resin Emulsion	100	67-64	41-37	40	36	32	34
Concrete Block	Control	100	56-56	37-35	34	33	30	29
	Resin Emulsion	100	65-64	43-40	39	36	36	35
Cinder Block	Control	100	57-41	35-34	32	32	30	30
	Resin Emulsion	100	57-49	34-32	33	32	31	30
Geometry Effects	Plane	100	91-89	52-42	42	34	33	35
	Configuration	100	78-82	48-41	41	32	30	31

* When two (2) percentages are listed in the same column, the second percentage represents the result of repeating the operation

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TABLE B.3 Shot 4-Residual Percentages After Decontamination - β

MATERIAL	SURFACE	Before Decontamination	Low Pressure Hose	Scrub With Low Pressure Rinse	Fire Pressure Hose	Scrub With Detergent	High Pressure Hose	Hot Rinse
		Shot 4 RESIDUAL PERCENTAGES (Corrected for Decay and Background)						
Asphalt Pavement	Control	100	97	77	81	44	45	35
Concrete Pavement	Control	100	100	72	71	71	67	62
	Seal Coat	100	98	67	67	66	57	62
Asphalt and Gravel Built-up Roofing	Control	100	92	84	78	66	64	59
	PVA **	100	100	72	66	58	56	48
Smooth Surface Roll Roofing	Control	100	105	59	58	23	21	23
	PVA **	100	99	65	62	54	51	38
Corrugated Roof	Control	100	101	70	72	44	48	47
Strip Shingle Roof	Control	100	108	91	88	59	61	58
	Sealed Joints	100	113	95	89	60	62	60
Asbestos Shingle	Control	100	99	86	86	80	87	72
	Sealed Joints	100	102	90	87	84	88	76
Wood Siding	Control	100	98	83	84	65	68	56
	Alkyd Resin	100	102	71	71	60	62	56
	Lead and Oil	100	98	71	71	54	55	50
	Phenolic Resin	100	97	81	89	38	35	43
Sheet Metal	Alkyd Resin	100	107	91	89	32	33	32
	Phenolic Resin	100	103	70	80	30	29	26
Brick	Control	100	98	75	79	69	71	66
	Resin Emulsion	100	105	84	90	80	81	79
Concrete Block	Control	100	100	82	81	78	75	75
	Resin Emulsion	100	104	95	96	91	88	91
Cinder Block	Control	100	101	79	81	74	70	72
	Resin Emulsion	100	102	83	82	76	77	72
Geometry Effects	Plane	100	103	71	75	55	63	60
	Configurations	100	102	74	79	61	64	65

* When two (2) percentages are listed in the same column, the second percentage represents the result of repeating the operation.
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TABLE B.4 Shot 2--Beta/Gamma Ratio

MATERIAL	SURFACE	Shot 2 Beta/Gamma Ratios (uc/mr)						
		Before Decon-tamination	Low Pressure Hose	Scrub With Low Pressure Rinse	Fire Pressure Hose	Scrub With Detergent	High Pressure Hose	Hot Rinse
Asphalt Pavement	Control	2.72	2.00-1.48*	1.08-1.02*	1.07	1.05	1.0	0.82
Concrete Pavement	Control	4.70	4.94-4.45	4.12-3.57	3.54	3.47	3.28	3.12
	Seal Coat	4.62	5.57-4.68	4.78-4.0	4.0	3.65	3.54	3.46
Asphalt and Gravel Built-up Roofing	Control	1.92	1.73-1.74	1.54-1.35	1.36	1.14	1.0	1.07
	PVA **	1.64	1.52-1.54	1.43-1.07	1.15	0.99	0.93	0.83
Smooth Surface Roll Roofing	Control	3.29	3.60-3.43	2.88-2.78	2.81	2.23-1.45*	1.63	1.73
	PVA **	4.29	4.68-4.75	4.22-4.30	4.48	4.24-3.39	3.56	2.0
Corrugated Roof	Control	4.17	3.83-4.25	3.68-3.30	2.95	2.50-2.23	2.16	2.3
Strip Shingle Roof	Control	1.92	1.58-1.76	1.66-1.78	1.65	1.48	1.33	1.19
	Sealed Joints	2.02	1.90-1.95	1.84-1.73	1.77	1.71	1.45	1.33
Asbestos Shingle	Control	3.28	2.25-2.68	2.32-1.91	2.36	2.27	1.77	1.98
	Sealed Joints	3.47	2.08-2.90	2.37-1.87	2.64	2.39	2.02	2.35
Wood Siding	Control	3.40	3.90-3.54	3.0-3.4	3.98	3.71-3.18*	2.97	2.95
	Alkyd Resin	4.28	5.53-5.57	4.58-4.86	5.88	5.58-3.96	4.15	4.3[illegible]
	Lead and Oil	3.95	4.11-3.42	3.6-3.78	4.23	3.58-3.11	2.91	2.92
	Phenolic Resin	3.63	3.34-2.85	2.16-2.03	2.54	1.19-0.83	0.84	0.80
Sheet Metal	Alkyd Resin	4.36	5.67-4.95	4.97-3.92	4.97	2.68-1.47	1.72	1.71
	Phenolic Resin	3.83	3.81-3.61	3.06-2.33	2.5	1.11-0.80	0.78	0.78
Brick	Control	3.70	3.46-3.36	2.58-2.48	3.36	2.82	2.18	2.65
	Resin Emulsion	4.23	4.25-4.39	3.33-3.40	4.10	3.87	2.80	3.18
Concrete Block	Control	3.86	3.44-3.39	3.74-3.07	3.31	3.06	2.64	2.50
	Resin Emulsion	3.52	3.53-3.13	3.99-3.47	3.43	3.17	2.95	2.91
Cinder Block	Control	3.02	2.50-2.17	2.67-2.11	2.18	1.91	2.06	2.09
	Resin Emulsion	3.90	3.22-3.29	3.66-3.06	3.30	2.81	2.93	3.24
Geometry Effects	Plane	5.25	5.72-5.59	5.85-5.89	9.0	6.0	5.52	5.82
	Configuration	4.33	4.25-4.47	4.68-4.89	7.45	5.25	4.33	4.0

* When two (2) ratios are listed in the same column, the second ratio represents the result of repeating the operation.

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TABLE B.5 Shot 4 Beta/Gamma Ratios

MATERIAL	SURFACE	Shot 4 Beta/Gamma Ratios (uc/mr) Before Decontamination	Low Pressure Hose	Scrub With Low Pressure Rinse	Fire Pressure Hose	Scrub With Detergent	High Pressure Hose	Hot Rinse
Asphalt Pavement	Control	1.31	1.36	1.11	1.12	0.92	0.86	0.60
Concrete Pavement	Control	3.63	3.92	3.76	3.66	4.25	3.85	3.49
	Seal Coat	3.34	3.50	3.14	2.81	3.17	3.13	2.82
Asphalt and Gravel Built-up Roofing	Control	1.11	1.16	1.05	1.06	1.02	0.97	0.83
	PVA **	1.80	1.83	1.41	1.36	1.31	1.32	1.08
Smooth Surface Roll Roofing	Control	2.80	3.34	3.0	3.0	2.0	1.78	1.76
	PVA **	2.64	2.83	3.09	2.94	3.19	3.0	2.40
Corrugated Roof	Control	3.72	3.81	3.51	3.68	2.93	3.22	2.77
Strip Shingle Roof	Control	1.11	1.35	1.32	1.36	1.18	1.17	1.01
	Sealed Joints	1.14	1.51	1.45	1.45	1.23	1.20	1.11
Asbestos Shingle	Control	2.39	2.38	2.20	2.22	2.18	2.25	1.86
	Sealed Joints	2.30	2.29	2.28	2.14	2.20	2.26	1.94
Wood Siding	Control	3.15	3.22	3.17	3.28	2.90	3.19	2.46
	Alkyd Resin	4.0	3.91	3.60	3.59	4.01	4.20	3.62
	Lead and Oil	3.48	3.66	3.39	3.72	3.35	3.70	3.24
	Phenolic Resin	1.27	1.29	1.12	1.42	0.76	0.87	0.94
Sheet Metal	Alkyd Resin	3.66	4.77	4.52	4.27	3.89	3.52	3.52
	Phenolic Resin	1.50	2.41	1.66	1.91	1.38	1.31	1.08
Brick	Control	3.20	3.50	2.89	3.23	2.84	3.08	2.84
	Resin Emulsion	3.58	3.84	3.12	3.76	3.70	3.74	3.37
Concrete Block	Control	3.52	3.63	3.65	3.58	3.58	3.32	3.20
	Resin Emulsion	3.77	4.58	3.90	3.90	3.92	3.62	3.50
Cinder Block	Control	2.72	2.79	2.42	2.54	2.42	2.27	2.32
	Resin Emulsion	3.82	3.79	3.52	3.39	3.46	3.34	3.01
Geometry Effects	Plane	5.16	5.18	4.37	4.88	4.36	5.13	4.95
	Configurations	4.25	3.72	3.48	3.78	3.08	3.75	3.54

* When two (2) ratios are listed in the same column, the second ratio represents the result of repeating the operation.

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