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WT–1322

OPERATION REDWING—PROJECT 2.8

SHIPBOARD RADIOLOGICAL-COUNTERMEASURE METHODS

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FOREWORD

This report presents the preliminary results of one of the projects participating in the military-effect programs of Operation Redwing. Overall information about this and the other military-effect projects can be obtained from WT-1344, the "Summary Report of the Commander, Task Unit 3." This technical summary includes: (1) tables listing each detonation with its yield, type, environment, meteorological conditions, etc.; (2) maps showing shot locations; (3) discussions of results by programs; (4) summaries of objectives, procedures, results, etc., for all projects; and (5) a listing of project reports for the military-effect programs.

ABSTRACT

Various test surfaces and specimens were exposed on YAG-39 and YAG-40 to fallout from Shots Zuni, Flathead and Tewa. Contaminability-decontaminability (C-D) studies were conducted when the ships returned to Eniwetok Lagoon.

Three days after Zuni the average reading in the nonwashdown area of the YAG-40 was approximately 350 mr/hr and in the washdown area approximately 90 mr/hr. When the decontamination studies were initiated, the average levels after Flathead were lower than those after Zuni by a factor of 10. The average nonwashdown reading was 35 mr/hr and the washdown reading, 10 mr/hr.

The removal of the removable radiological protective coating (RRPC) after Zuni in the nonwashdown area removed all but 0.5 to 8.0 percent of the contaminant, while firehosing alone left a residual of 6 to 28 percent. Firehosing plus removal of the RRPC removed all but 0.2 to 3.0 percent of the activity. In the washdown area, the RRPC removal left 6 to 9 percent residual contamination as compared to 16 to 40 percent after decontamination of an uncoated area, with a hot-liquid jet cleaning unit. After Flathead, the removal of the RRPC from a nonwashdown area left a residual of only 3 percent as compared to 18 percent residual after firehosing and hand scrubbing. Removal of the coating in the washdown area showed only 20 percent reduction of the original contaminant, but the initial level was actually too low to give reliable instrument readings.

Mechanical scrubbing of surfaces exposed at either Zuni or Flathead was slightly inferior to manual brushing, but operators felt no fatigue and stated that long scrubbing times could easily have been endured.

Wire ropes and manila lines 1 inch or more in diameter will create a long-term radiation source. Protective coatings on canvas and canvas substitutes show promise in reducing the hazard from this material. Firehose exposed to fallout when coiled will create a more severe long-term radiation hazard than when stored uncoiled.

Surface roughness of wood decking was a major factor in determining the initial contamination level. Penetration of the fallout contamination into the wood beyond the rough surface layer was negligible, but decontamination to a residual of 2 percent would have required removal of approximately 2 mm of the surface layer because of the roughness. The payed joints between the wooden planks presented no additional problem, as long as the joints were free of fissures and pockets.

Soap plus water and ammoniacal petroleum-based waterless cleaner were equally effective in removing the fission product contamination from the hands.

Beta measurements provided the best assessment of surface decontamination effectiveness, and 3-foot gamma measurements provided the best data in determining the overall ship decontamination effectiveness.

The basic C-D studies showed that it was more difficult to remove the Zuni contaminant than that of Flathead, confirming the results of other studies that showed this difficulty was mainly due to the difference in mass involved. These studies also showed that EDTA and Orvus solution were far superior decontamination agents than C-7907 or water alone. Allowing the activity to remain on the surface for two weeks made it more difficult to remove

than if decontamination was performed one day after the surface was contaminated.

Radiological warfare may require new standards of cleanliness for naval ships. Wood decking should be maintained as smooth as possible with no raw wood exposed. All payed joints should be free of fissures and pockets. Nothing, including wire ropes, manila lines, and firehoses not required during attack, should be stored on the main deck. After contamination, any materials that cannot be destroyed should be stored uncoiled to minimize the radiation field, or stored in an unfrequented location.

CONTENTS

FOREWORD ---------- 4

ABSTRACT ---------- 5

CHAPTER 1 INTRODUCTION ---------- 11

CHAPTER 2 REMOVABLE RADIOLOGICAL PROTECTIVE COATINGS AND CHEMICAL PAINT STRIPPING ---------- 15

2.1 Objectives ---------- 15
2.2 Background ---------- 15
2.3 Procedures ---------- 15
2.3.1 Preshot Preparations ---------- 15
2.3.2 Decontamination Operation ---------- 17
2.4 Equipment and Materials ---------- 17
2.5 Results and Discussion ---------- 18
2.5.1 Zuni Decontamination ---------- 20
2.5.2 Flathead Decontamination ---------- 20
2.6 Conclusions ---------- 20

CHAPTER 3 MECHANICAL SCRUBBING METHODS ---------- 22

3.1 Objectives ---------- 22
3.2 Experimental Details ---------- 22
3.3 Results and Discussion ---------- 23
3.4 Conclusions ---------- 25

CHAPTER 4 PROTECTION OF MISCELLANEOUS SHIPBOARD MATERIALS AND EQUIPMENT ---------- 26

4.1 Objectives ---------- 26
4.2 Procedure ---------- 26
4.2.1 Materials and Equipment Tested ---------- 26
4.2.2 Exposure and Analysis of Samples ---------- 26
4.3 Results and Discussion ---------- 29
4.3.1 Wire Ropes and Manila Lines ---------- 29
4.3.2 Canvas Samples ---------- 32
4.3.3 Firehoses ---------- 34
4.4 Conclusions ---------- 36

CHAPTER 5 CONTAMINATION AND DECONTAMINATION OF SHIPBOARD WOODEN DECKING ---------- 37

5.1 Objective ---------- 37
5.2 Procedure ---------- 37
5.2.1 Test Specimens ---------- 37
5.2.2 Specimen Stations and Exposure ---------- 38
5.2.3 Specimen Processing and Measurements ---------- 39
5.3 Results and Discussion ---------- 40

5.3.1 Distribution and Form of Contaminant as Related to Wooden Decking ---------- 40
5.3.2 Effect of Washdown ---------- 41
5.3.3 Decontamination of Wooden Decking ---------- 43
5.3.4 Paying Studies ---------- 45
5.3.5 Penetration of Fallout Fission Products into Wood ---------- 45
5.4 Conclusions ---------- 48
5.5 Recommendations ---------- 48

CHAPTER 6 SKIN DECONTAMINATION AND PROTECTION METHODS ---------- 49

6.1 Objectives ---------- 49
6.2 Procedures ---------- 49
6.3 Results and Discussion ---------- 50
6.4 Conclusions ---------- 53

CHAPTER 7 MONITORING AND HAZARD ASSESSMENT METHODS ---------- 54

7.1 Objectives ---------- 54
7.2 Operations ---------- 54
7.3 Discussion of Results ---------- 55
7.3.1 Measurements from the Decontamination Studies ---------- 55
7.3.2 Wipe-Sample Results ---------- 57
7.3.3 Film-Badge Dosimetry ---------- 60
7.3.4 Application of Combined Measurements ---------- 69
7.4 Conclusions ---------- 72

CHAPTER 8 BASIC CONTAMINATION-DECONTAMINATION STUDIES ---------- 73

8.1 Objectives ---------- 73
8.2 Procedures ---------- 73
8.2.1 Specimen Exposure ---------- 73
8.2.2 Decontamination Operations ---------- 74
8.2.3 Equipment and Instrumentation ---------- 74
8.3 Results and Discussion ---------- 74
8.3.1 Contamination ---------- 74
8.3.2 Decontamination ---------- 77
8.4 Conclusions ---------- 82

REFERENCES ---------- 83

TABLES

2.1 Summary of Zuni Decontamination Studies ---------- 19
2.2 Summary of Flathead Beta Surveys ---------- 19
3.1 Brush Test Results ---------- 23
4.1 Materials and Equipment Tested ---------- 27
4.2 Decontamination Results for Wire Rope and Manila Lines Exposed at Zuni ---------- 31
4.3 Decontamination Results for Wire Rope and Manila Line Samples Exposed at Flathead and Analyzed at NRDL ---------- 32
4.4 Decontamination Results of Canvas Samples Exposed at Zuni ---------- 35
4.5 Canvas Samples Exposed at Flathead and Analyzed at NRDL ---------- 35

4.6 Decontamination Results for Firehose Samples ---------------------- 36
5.1 Comparison of Contamination Ratios of Teak and Fir after
Fallout and Weathering ---------------------------------- 41
5.2 Relative Effect of Washdown on the Various Fallouts ---------------- 43
5.3 Decontamination of Decking Specimens------------------------------ 43
6.1 Geometric Means of Hand Contamination of Personnel
Aboard Test Ships, Program 2---------------------------- 50
7.1 Decontamination Effects for Area Between the Flight Deck
and the Main Mast, Section 2 ---------------------------- 56
7.2 Decontamination Effects for Flight Decks-------------------------- 57
7.3 Measured Hazard Ratios of Washdown Effects---------------------- 69
7.4 Washdown Effects, Hazard Component Ratios, Calculated------------ 71
8.1 Average Fraction Remaining on Duplicate Zuni Samples
after Decontamination with Different Decontaminating
Agents and Methods ------------------------------------ 77
8.2 Average Fraction Remaining on Duplicate Flathead Samples
after Decontamination with Different Decontaminating
Agents and Methods ------------------------------------ 78
8.3 Analysis of Variance of Logarithms of Fraction Remaining
on Different Surfaces Exposed at Shot Zuni------------------ 78
8.4 Analysis of Variance of Logarithms of Fraction Remaining
on Different Surfaces Exposed at Shot Flathead --------------- 80
8.5 Effectiveness Ratios of Decontamination Methods
(Compared to Plain Water)------------------------------- 80
8.6 Effectiveness Ratios of Method-Agent Combinations
(Compared to Cold Spray with Water)---------------------- 80

FIGURES

1.1 Track made by YAG-40 during Shot Zuni participation -------------- 12
1.2 A nonwashdown section of the YAG-40 after Shot Zuni
showing the white powder contaminant ----------------------- 13
1.3 Washdown sections of YAG-40 after Shot Zuni-------------------- 13
1.4 Tracks made by YAG-39 and YAG-40 during Shot Flathead
participation --------------------------------------- 14
2.1 Application and removal of RRPC ------------------------------ 16
2.2 Two-man lance fitted with different nozzles ---------------------- 18
2.3 Premature lifting of RRPC film ------------------------------- 20
3.1 Mechanical scrub brush------------------------------------- 24
3.2 Comparison of manual and power brushing results----------------- 24
4.1 Wire ropes and manila line ---------------------------------- 28
4.2 Front view of sample rack on flight deck for Shot Zuni,
looking aft-- 29
4.3 Front view of sample rack on flight deck for Shot Flathead,
looking aft-- 30
4.4 Isodose contour around 5/16-inch standard wire rope exposed
at Shot Zuni-- 30
4.5 Autoradiograph of a canvas sample exposed at Shot Zuni -------------- 33
5.1 Relative fallout distribution as determined by beta radiation
detectors at H + 48 ------------------------------------- 40

5.2 Concentration of coral powder in the decking depressions after Shot Zuni ---------- 41
5.3 Radioautograph of Flathead fallout on uncoated fir decking section with marine-glue paying ---------- 42
5.4 Radioautograph of Zuni fallout on decking sections of uncoated fir (lower) and fir coated with navy-gray paint (upper) after decontamination ---------- 44
5.5 Radioautograph, payed joint of uncoated teak decking ---------- 46
5.6 Gamma activity distribution in fir and teak exposed in washdown and nonwashdown areas ---------- 47
5.7 Gamma activity distribution in samples wetted after being contaminated ---------- 47
6.1 Mixed fission products on palms of both hands (μc) ---------- 51
6.2 Comparison of two methods of cleaning hands contaminated with fission product fallout from Shot Zuni ---------- 52
6.3 Comparison of two methods of cleaning hands contaminated with fission product fallout from Shot Navajo ---------- 52
7.1 Relative residual radiation levels aboard YAG-40 at H+56 hours after Shot Zuni ---------- 58
7.2 Relative residual radiation levels aboard YAG-40 at H+56 hours after Shot Flathead ---------- 58
7.3 Relative residual radiation levels aboard YAG-39 at H+56 hours after Shot Navajo ---------- 59
7.4 Relative residual radiation levels aboard YAG-40 at H+56 hours after Shot Tewa ---------- 59
7.5 Relative residual radiation levels aboard YAG-39 at H+75 hours after Shot Tewa ---------- 60
7.6 Dose distribution aboard the YAG-39 for Shot Zuni (as determined by film badges) ---------- 61
7.7 Dose distribution aboard the YAG-40 for Shot Zuni (as determined by film badges) ---------- 62
7.8 Dose distribution aboard the YAG-39 for Shot Flathead (as determined by film badges) ---------- 63
7.9 Dose distribution aboard the YAG-40 for Shot Flathead (as determined by film badges) ---------- 64
7.10 Dose distribution aboard the YAG-39 for Shot Navajo (as determined by film badges) ---------- 65
7.11 Dose distribution aboard the YAG-40 for Shot Navajo (as determined by film badges) ---------- 66
7.12 Dose distribution aboard the YAG-39 for Shot Tewa (as determined by film badges) ---------- 67
7.13 Dose distribution aboard the YAG-40 for Shot Tewa (as determined by film badges) ---------- 68
8.1 Activity on Zuni samples of navy-gray paint before and after decontamination ---------- 75
8.2 Activity on Flathead samples of navy-gray paint before and after decontamination ---------- 76
8.3 Fraction of Zuni activity on navy-gray paint samples after decontamination ---------- 79
8.4 Fraction of Flathead activity on navy-gray paint samples after decontamination ---------- 81

Chapter 1

INTRODUCTION

The need for the development of new or improved methods of shipboard protection and decontamination was realized during Operation Castle. Consequently, a laboratory program was organized to develop countermeasure methods that would meet shipboard requirements. This project, which consisted of eight studies, was initiated to evaluate in the field several of the laboratory methods under development since Castle and to obtain information for improving countermeasures.

Two studies, determination of the removability and decontamination effectiveness of the latest removable radiological-protective coating (RRPC) and determination of the effectiveness of chemical paint stripping as a decontamination method, are reported in Chapter 2. These two studies were designed to obtain improved decontamination effectiveness and to reduce time of recovery.

Chapter 3 covers the evaluation of a mechanical scrub brush in comparison to manual scrubbing. This study was initiated to determine the feasibility of improving the scrubbing method of decontamination through use of a power brush.

Chapter 4 describes a study of the contaminability and decontaminability of miscellaneous shipboard materials such as wire ropes, manila lines, canvas, and firehoses.

Chapter 5 covers a basic study of the contaminability-decontaminability characteristics of wooden decking.

Chapter 6 reports an evaluation of a waterless hand cleaner as a skin decontamination method and the use of a skin barrier cream to minimize contaminability of the hands.

Chapter 7 covers a study of methods of assessing a radiological situation. The assessment of the radiological situation is not only of value in determining the hazard but also in measuring the effectiveness of decontamination methods.

Chapter 8 covers a study of basic contaminability-decontaminability characteristics of a typical shipboard surface that will lead to the development of a more-realistic radioactive-fallout simulant for use in the laboratory.

The test materials and samples were placed and the protective coating applied on the YAG-40 prior to its participation in Shot Cherokee. A study of contaminability-decontaminability of a typical shipboard surface was carried out on the YAG-39 with equipment that had been used in the laboratory on fallout simulants. The study of a skin protection and decontamination method was carried out at the Rad-Safe Center at Site Elmer.

Test areas and test samples were located on two sections of the YAG-40, one where the washdown was inoperative.

The YAG-40 intercepted the fallout on Shot Zuni at about H + 3 hours and a maximum reading of 8 r/hr was reached at approximately H + 7 hours. Course of the YAG-40 is shown in Figure 1.1. The YAG-39 intercepted the fallout at H + 10 hours and a maximum of 35 to 40 mr/hr was reached at approximately H + 20 hours. Sample recovery from the YAG-40 was carried out on D + 2, upon its return to the Eniwetok Lagoon. By this time, the average level in the nonwashdown area was from 700 to 1,200 mr/hr. Decontamination operations and analysis of samples were initiated on D + 3.

The Zuni contaminant arrived on the YAG-40 as a fallout of powdery coral. All of the horizontal surfaces forward of the superstructure, the nonwashdown area, were very uniformly covered with this white powder, as shown in Figure 1.2. The powder that remained was apparently very tenacious, because the ship went through a very heavy rainfall several hours after encountering the fallout. It was observed in this area that more material appeared to be collected in low spots where readings as high as 5 r/hr on D + 3 were observed.

In the section aft of the superstructure where the washdown operated during the fallout, most of the white powder was washed to low spots and collected, as shown in Figure 1.3

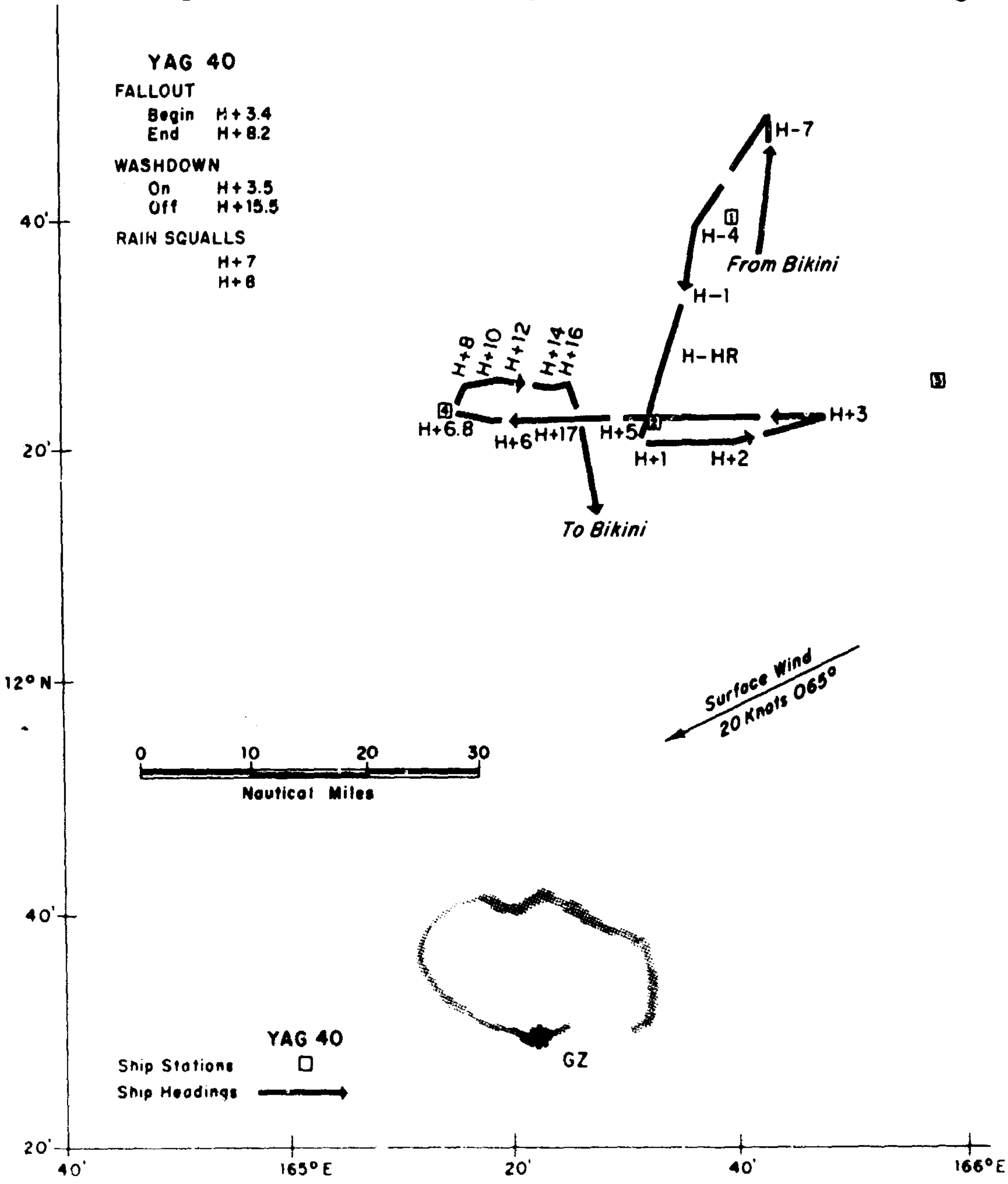

Figure 1.1 Track made by YAG-40 during Shot Zuni participation.

The surfaces appeared to be clean except in these spots. The white powder proved to be a very good indicator of progress of the decontamination operations. In most cases, if the surface looked clean, survey instruments showed it to be clean.

Prior to the ships' participation in Shot Flathead, test areas were again prepared and

Figure 1.2 A nonwashdown section of the YAG-40 after Shot Zuni showing the white powder contaminant.

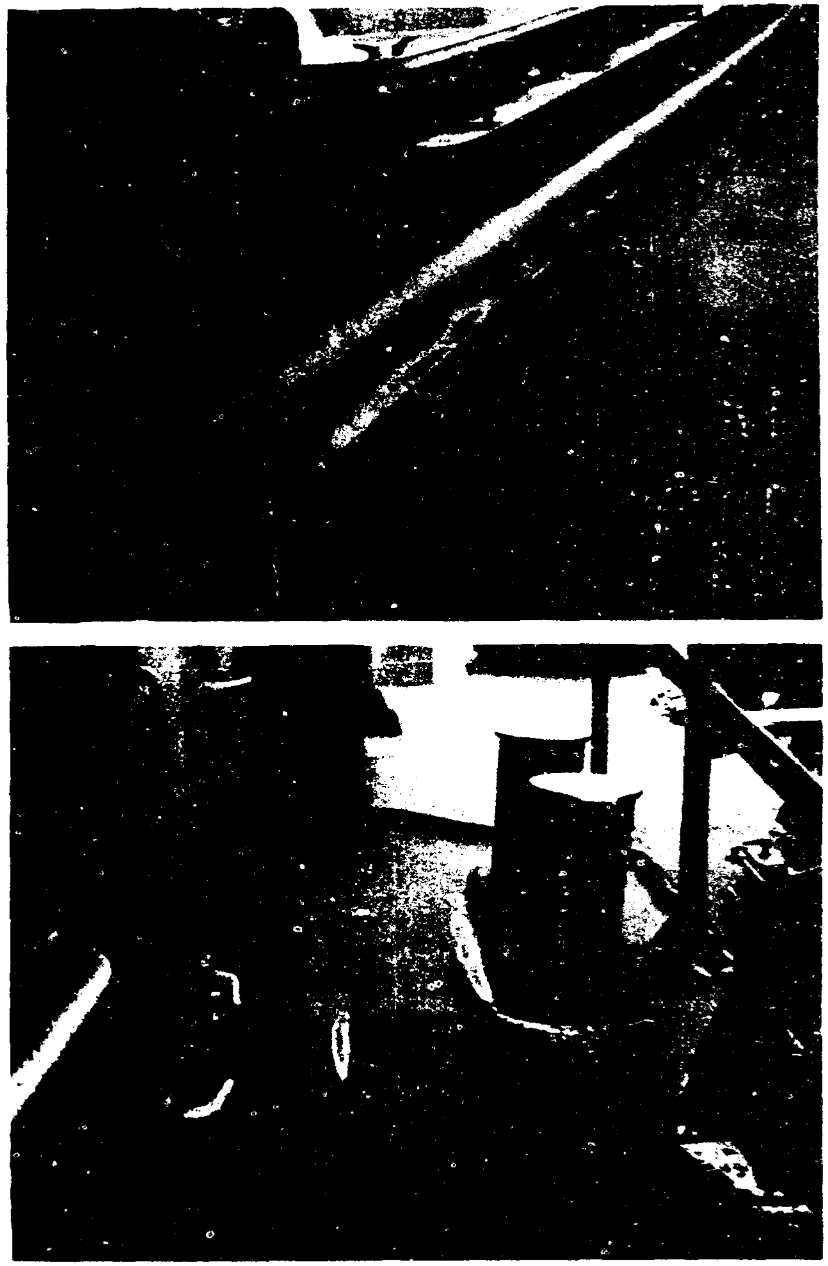

Figure 1.3 Washdown sections of YAG-40 after Shot Zuni.

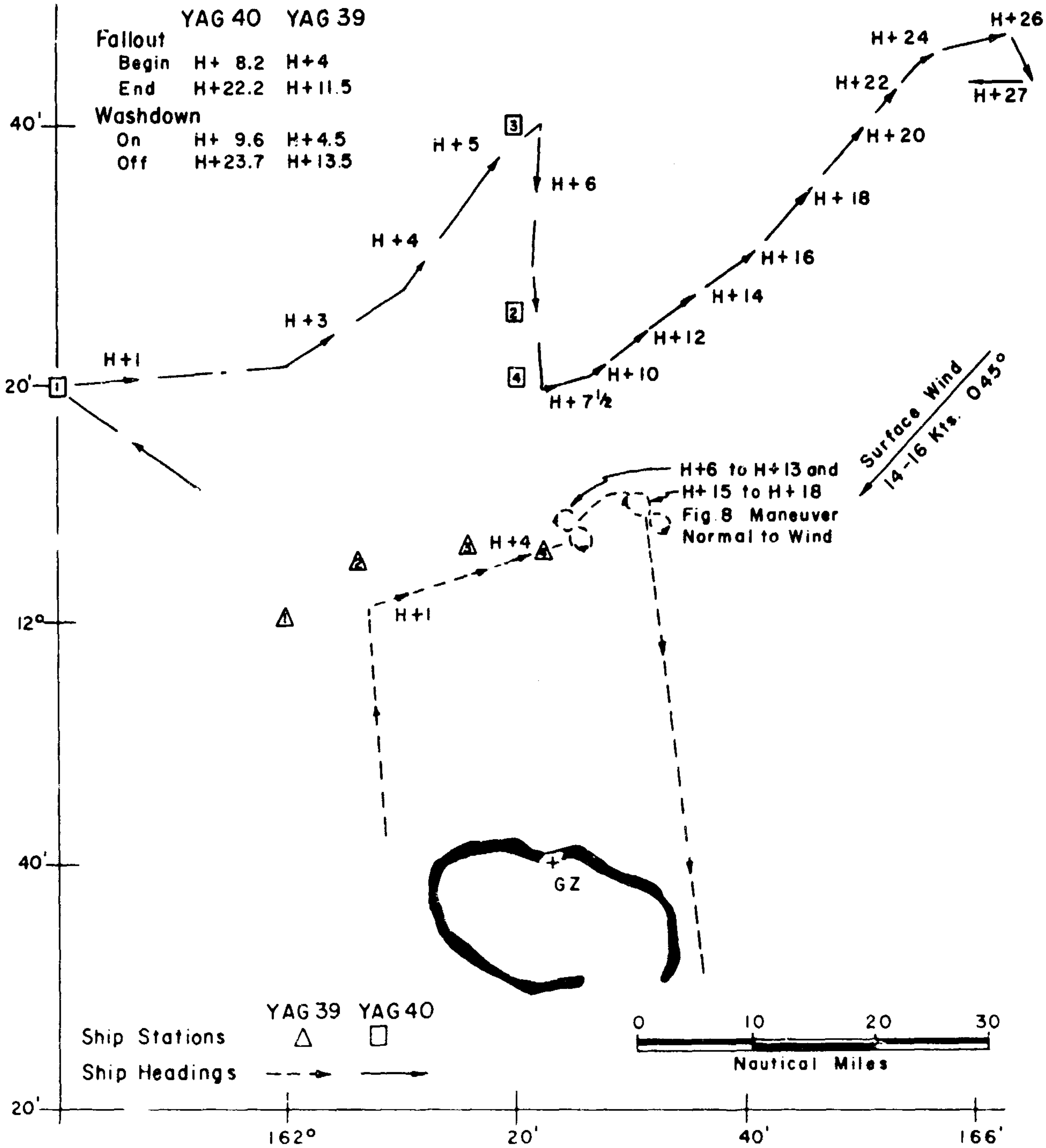

Figure 1.4 Tracks made by YAG-39 and YAG-40 during Shot Flathead participation.

new test samples placed on stations. Limited tests were also conducted on Shot Tewa.

The courses of the YAG-39 and YAG-40 during Shot Flathead are shown in Figure 1.4. The fallout from this shot was not particulate and the ships' weather surfaces showed no visual evidence of being contaminated. Tewa contaminant deposited on the test ships was similar to that from Zuni.

Chapter 2

REMOVABLE RADIOLOGICAL PROTECTIVE COATINGS AND CHEMICAL PAINT STRIPPING

2.1 OBJECTIVES

The objectives of this investigation of removable radiological protective coatings (RRPC) and chemical paint stripping were three-fold: to investigate the removability and decontaminability of the latest formulation of a hot-water-sensitive RRPC, to determine the feasibility and effectiveness of chemical paint stripping as a tactical decontamination procedure, and to determine the feasibility and effectiveness of a step-wise paint removal process as a decontamination procedure.

The latter two objectives concerning chemical paint stripping were not realized because of the low levels of activity remaining after removal of the RRPC and the procedures were deleted from the operation.

2.2 BACKGROUND

Non-tenacious contamination can be readily removed from painted steel surfaces by water flushing or firehosing; however, much of the contaminant from nuclear or thermonuclear weapons is very tenacious and requires more vigorous removal procedures such as scrubbing or surface abrading. Since these procedures are slow and costly, a coating that could be applied over standard Navy paints and readily removed by a high-pressure stream of hot water was sought as a solution of the shipboard decontamination problem.

The removal of radioactive contamination from ships by removing a hot-water-sensitive paint was first tested at Operation Castle. Although the results were inconclusive, these tests demonstrated the feasibility of the procedure. When the test ships returned to San Francisco Naval Shipyard (SFNS) the chemical paint removal procedure was successfully prooftested during industrial decontamination operations there. Data from these decontamination operations (unpublished SFNS report) indicated that 75 to 90 percent of the contaminant was removed by the removal of a layer of paint. Most of the contaminant remaining resulted apparently from recontamination, since the same percentages were obtained when the surface was stripped to bare metal.

2.3 PROCEDURES

The original plan of attack required that the RRPC be applied to the areas immediately before the weapons test; however, preliminary applications showed that the experimental coating was not satisfactory unless a rigidly controlled application procedure was followed. As a result of these preliminary tests, the application procedure for applying the RRPC was modified.

2.3.1 Preshot Preparations. Salt deposits were removed by washing down with a small stream of fresh water. Special care was taken to conserve water. Excess moisture was removed by dry mopping the test surfaces or by wiping them dry with rags. Two coats of

RRPC, approximately 1 mil thick, were sprayed on the clean surfaces. This spraying was done early in the morning or after sundown when the surfaces were cool.

Approximately two weeks before Zuni, the following areas on the YAG-40 were coated with RRPC (Figure 2.1A):

In the washdown area, a strip from the port to the starboard bulwark the width of No. 5 hatch (not including the vertical surfaces of the entrance cubicles on top of the hatch).

In the nonwashdown area, the bulkheads abaft the flight deck, a strip from the port to

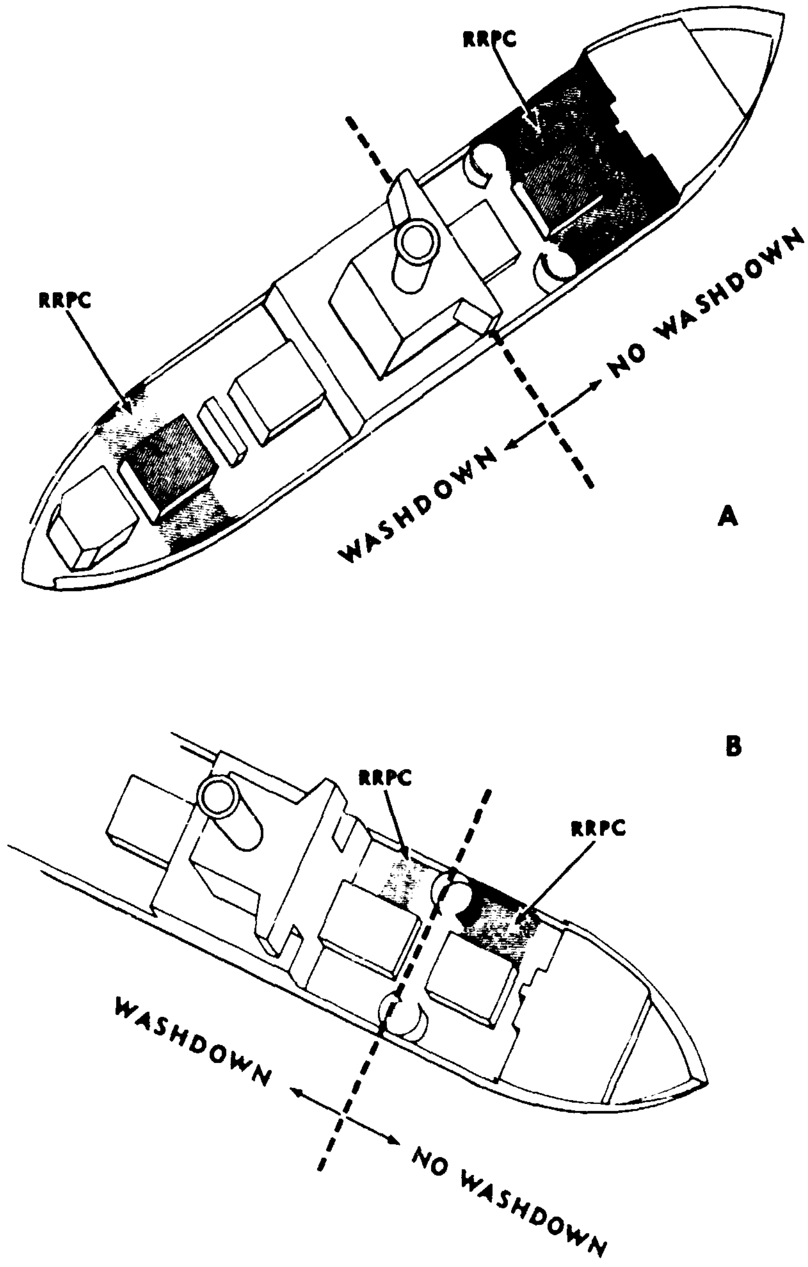

Figure 2.1 Application and removal of RRPC.

the starboard bulwark the width of No. 2 hatch, and the port gun and guntub and the starboard guntub.

Seven days before Flathead, the following areas on the YAG-40 were coated with RRPC (Figure 2.1B):

In the washdown area, a 15-foot length of the main deck on the port side of No. 3 deckhouse from the rivet strip to about 12 inches from the port bulwark.

In the nonwashdown area, the port deck opposite No. 2 hatch from the rivet strip to the port bulwark, the inner surface of the port bulwark opposite No. 2 hatch and the forward face of the port guntub.

2.3.2 Decontamination Operation. After each contaminating event, an initial beta survey was made in the areas coated with RRPC. After this survey, the RRPC was removed either with a 1,250-gph or 6,000-gph hot-liquid-jet unit operating at 150 to 190 F and 150 to 200 psi. The decks were cooled with running water before removal of the RRPC to reduce its adhesion to the standard Navy paint which softened in the hot water.

Surveys of the test areas after removal of the RRPC showed contamination levels to be too low to obtain any useful data on the effectiveness of chemical paint stripping. Therefore, this phase of the operation was deleted.

Zuni. The initial survey of the test areas was made on D + 3 before starting decontamination operations after Zuni. When the survey was completed, a team of six men, using a 6,000-gph hot-liquid-jet unit equipped with a 2-man lance and a $1\frac{1}{4}$-inch nozzle, removed the RRPC from No. 5 hatch. Simultaneously, another team of three men, using a $1\frac{1}{2}$-inch firehose, washed down the starboard half of the flight-deck bulkhead and No. 2 hatch, the starboard deck opposite No. 2 hatch and starboard rail and guntub. A second survey of the test areas was made when the decontamination operations were completed.

On D + 4 another survey was made of the nonwashdown test areas shown in Figure 2.1. Two teams of four men, using two 1,250-gph hot-liquid-jet units, removed the RRPC from the flight-deck bulkhead and the top of No. 2 hatch. On D + 5, a team of six men, using the 6,000-gph hot-liquid-jet unit equipped with a Y-gate and two 2-man lances, completed the removal of RRPC from the test areas. A team of three men flushed the waste from the ship with the streams from $1\frac{1}{2}$-inch firehoses.

A final survey of the residual contamination was made on D + 6.

Flathead. The initial survey was made on the afternoon of D + 2 for Flathead. Although the activity level was low, the surveys indicated that some decontaminability data could be obtained for RRPC. Hence, on the morning of D + 3, the coated test areas were resurveyed. A team of six men, using a 6,000-gph hot-liquid-jet unit equipped with two 2-man lances, removed the RRPC. Upon completion of this removal operation, a final survey was made.

2.4 EQUIPMENT AND MATERIALS

The RRPC[1] used in these tests was produced under Bureau of Ships sponsorship by the Mare Island Naval Shipyard Paint Laboratory in accordance with U.S. Naval Radiological Defense Laboratory (NRDL) specifications.

Standard paint-spraying equipment was used to apply the test formulation. This equipment consisted of a 10-gallon paint pressure pot, the necessary air and paint lines and a standard spray gun.[2]

The equipment used for the removal of RRPC consisted of two 1,250-gph hot-liquid-jet units which combine steam and salt water to produce a stream of hot water at 180 to 200 psi and 140 to 190 F. This stream is discharged through a flat-spray nozzle.[3] A 6,000-gph

[1] Designated as Formula 3J327-67C, presently under patent consideration as Patent Application, Navy Case No. 20553.

[2] Binks, Model 18 equipped with a 66 fluid nozzle and a 66SF air nozzle, manufactured by Binks Manufacturing Company, Chicago 12, Illinois.

[3] The $\frac{1}{2}$ P 1580 manufactured by Spraying Systems Company, 3201 Randolph Street, Bellwood, Illinois.

hot-liquid-jet unit was also used at the same temperature and pressure. This unit was equipped with a $1\frac{1}{4}$-inch play-pipe type nozzle on a lance with two outboard handles (Figure 2.2A). In addition, a special nozzle was fabricated in the field to give a flat-spray pattern with the 2-man lance (Figure 2.2B).

Surveys were made with an NRDL beta survey meter. This instrument measured the relative contamination levels and gave readings in microamperes. Reference 6 describes the beta survey meter.

2.5 RESULTS AND DISCUSSION

The decontamination results for Zuni are summarized in Table 2.1. Removal rates for the RRPC were approximately 75 ft^2/man hour with the 1,250-gph jet unit and 200 ft^2/man hour with the 6,000-gph unit.

The decontamination results for Flathead are summarized in Table 2.2. Removal rates of the RRPC in this test using a 6,000-gph unit was approximately 50 ft^2/man hour.

Considerable difficulty was encountered in the initial attempts to apply RRPC to the ship surfaces. In the first attempt the film failed within 24 hours. It pulled away from weld beads and inside corners (see Figure 2.3) to such an extent that the wind blew pieces

Figure 2.2 Two-man lance fitted with different nozzles: A, $1\frac{1}{4}$-inch play pipe; B, special flat spray.

of the film away. Subsequent shore tests indicated that four factors had to be considered: surface temperature during application and removal, moisture on the surface, salt deposits on the surface, and thickness of the dry film.

When the coating was applied to a hot surface, the film dried so quickly that it bonded weakly with the underlying paint layers. Moisture accelerated lifting the film as did salt deposits on the surface. If the coating was applied in films less than 1 mil thick, removal was difficult; furthermore, if it was applied as heavy as 3 mils it did not adhere. Accordingly, to get the necessary decontamination data, application conditions were rigidly observed, although it was apparent that this coating was not physically suited for the test. The actual application conditions were as follows: surfaces were cool to the touch; salt deposits were washed off with fresh water; all surfaces were dry mopped or wiped dry with rags; and coating was applied in two or three layers until a dry film thickness of 1.5 to 2 mils was obtained. The thickness of the final film was determined, after application, by cutting a small section, peeling the film off and measuring its thickness with a micrometer. The exposed spot was then recoated.

Surface temperature was very important during the removal operation as well as dur-

TABLE 2.1 SUMMARY OF ZUNI DECONTAMINATION STUDIES

Area	Decontamination Operation	Average Contamination Level Before Decontamination	Percent Remaining	
			After Each Decontamination	After Final Decontamination
		μa *		
Nonwashdown:				
Starboard half of flight deck bulkhead	Firehose	485	19.0	—
	RRPC removal †	70	17.6	3.3
Starboard half of No. 2 hatch	Firehose	8,830	10.4	—
	RRPC removal †	530	1.5	0.2
Starboard deck opposite No. 2 hatch	Firehose	14,100	6.1	—
	RRPC removal †	480	5.3	0.3
Starboard guntub	Firehose	595	28.0	—
	RRPC removal †	70	10.0	2.6
Port half of flight deck bulkhead	RRPC removal	165	6.3	6.3
Port half of No. 2 hatch	RRPC removal	1,515	0.5	0.5
Port deck opposite No. 2 hatch	RRPC removal	500	2.0	2.0
Port guntub	RRPC removal	145	8.1	8.1
Starboard deck opposite No. 3 deckhouse	Scrubbing	327	13.4	13.4
Port deck opposite No. 3 deckhouse	Scrubbing	171	17.9	17.9
Washdown:				
No. 5 hatch	RRPC removal	494	8.3	8.3
Port deck opposite No. 5 hatch	RRPC removal	268	6.4	6.4
Starboard deck opposite No. 5 hatch	RRPC removal	308	8.6	8.6
No. 4 hatch	Hot-liquid jet with detergent	1,500	15.8	15.8
Starboard deck opposite No. 4 hatch	Hot-liquid jet with detergent	488	28.2	28.2
Port deck opposite No. 4 hatch	Hot-liquid jet with detergent	298	39.6	39.6

* Microamperes measured with USNRDL Model RBI-13 Beta Survey Meter.
† The removal of the RRPC was accomplished after initial firehosing.

TABLE 2.2 SUMMARY OF FLATHEAD BETA SURVEYS

Area	Decontamination Operation	Average Contamination Level Before Decontamination	Percent Remaining
		μa *	
Nonwashdown:			
Port deck opposite No. 2 hatch	RRPC removal	632	3.3
Port bulwark	RRPC removal	127	4.7
Port guntub bulkhead	RRPC removal	783	0.9
Starboard deck opposite No. 2 hatch	Scrubbing	703	17.6
Washdown:			
Port deck opposite No. [illegible] deckhouse	RRPC removal	30	80.0
Starboard deck opposite No. 3 deckhouse	Hot-liquid jet with detergent	17	152.0

* Microamperes as measured with USNRDL Model RBI-13 Beta Survey Meter.

ing application. If the base coat was hot to the touch, it became soft and sticky and made the removal of the RRPC more difficult.

2.5.1 Zuni Decontamination. On the basis of beta surveys in the nonwashdown area after Zuni, firehosing reduced the contaminant to a range of 6 to 28 percent of the original level. Further removal of the RRPC reduced the remaining level to a range of 2 to 18 percent of the level after firehosing and resulted in an overall (firehosing plus RRPC removal) removal of all the contaminant except 0.2 to 3.3 percent of the original level. Without prior firehosing, removal of the RRPC left a residue of 0.5 to 8 percent of the original contaminant. Hand and mechanical scrubbing in an uncoated area left a residue of 13 to 18 percent.

In the washdown area, RRPC removal left 6 to 9 percent residual contamination as compared to 16 to 40 percent residual from a hot-liquid-jet and detergent procedure.

The contamination from this shot was definitely particulate and was plainly visible. During decontamination operations, its removal could actually be observed.

2.5.2 Flathead Decontamination. Activity levels from Flathead were much lower than from Zuni. The contaminant was not visible and appeared much more tenacious.

In the washdown area a residue of 80 percent of the contaminant remained after removal of the RRPC. When the starboard side of No. 3 deckhouse was decontaminated with a hot-

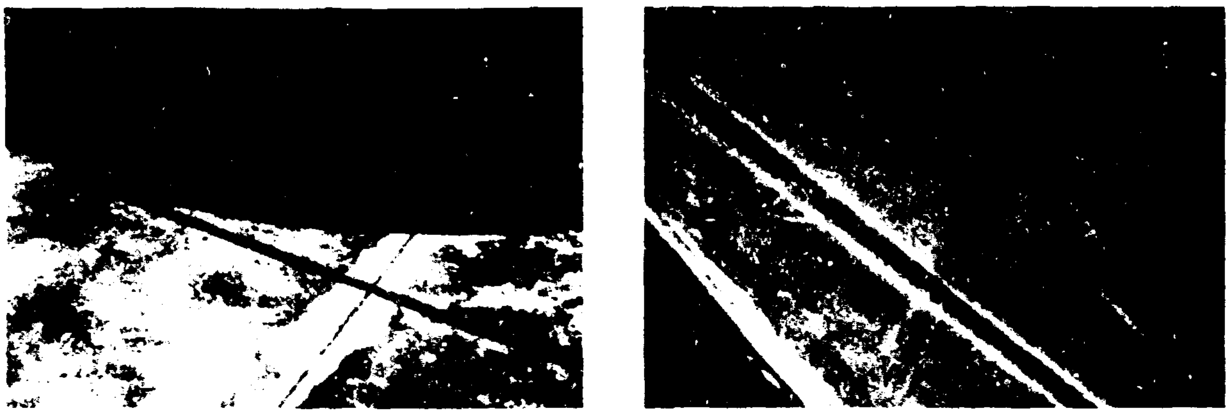

Figure 2.3 Premature lifting of RRPC film; A, at weld beads; B, at an inside corner.

liquid-jet unit plus detergent, it showed an apparent increase in activity. This condition was undoubtedly the result of merely moving the contamination from one place to another.

In the nonwashdown area, removal of the RRPC left 1 to 5 percent of the original contaminant as compared to 18 percent from the hand and mechanical scrubbing studies on the opposite side of the hatch.

2.6 CONCLUSIONS

It is concluded that the physical characteristics of the RRPC used during this operation were unsatisfactory for shipboard use. Manpower requirements for removal of this particular test coating exceed those for standard firehosing and scrubbing operations. The principle of using a removable paint film as a decontamination procedure, however, has been established. Additional development work is necessary to improve the physical characteristics of the coating and to minimize the difficulties experienced in its application and removal.

With Zuni contaminant, RRPC removal in the washdown area gave a threefold greater reduction in the residual contamination than hot-liquid-jet cleaning. In the nonwashdown area, RRPC removal gave a fourfold greater reduction in the residual activity than firehosing and scrubbing.

With Flathead contaminant, RRPC removal in the washdown area gave a 20-percent-greater reduction of activity than the hot-liquid-jet unit. In the nonwashdown area, the RRPC removal gave a 3- to 15-fold greater reduction than hand and mechanical scrubbing.

Chapter 3

MECHANICAL SCRUBBING METHODS

Laboratory tests on painted surfaces have shown effective decontamination by prolonged vigorous scrubbing with brushes and cleaning solutions; however, brush decontamination during Operation Castle did not produce corresponding results. Since it was felt that brushing with long-handle scrub brushes during Operation Castle was an unsatisfactory scrubbing technique that lacked vigor and coverage, a mechanical scrub brush was designed to correct these conditions without unduly taxing the operator's endurance.

3.1 OBJECTIVES

The objectives of this part of Project 2.8 were to investigate the advantages and disadvantages of mechanical brush decontamination methods and to determine the advisability of recommending mechanical scrubbing as a standard recovery method. The work involved comparisons between manually and mechanically operated scrub brushes in relation to rates, efficiency, effort required, and personnel fatigue.

3.2 EXPERIMENTAL DETAILS

The tests were conducted on the painted metal surfaces at the ventilation deckhouse area on the main deck of the YAG-40. The port and starboard bulkheads and the weather decks adjoining them and extending to the port and starboard railings were divided equally into sixteen sections, eight on each side. Alternate sections were designated manual or mechanical scrub areas.

One requisite of the test was that the area be free of washdown and the contamination be left undisturbed. The entire area was thoroughly firehosed prior to the scrub tests and immediately after them.

The test personnel were as follows: 2 scrubbers (manual); 2 operators (mechanical brush); 1 tender for scrubbing solution and firehose; and 1 supervisor. The manual and mechanical scrubbing teams worked simultaneously on adjacent test sections, and the duties of the teams were exchanged as each section was finished. Scrubbing each section was timed for prespecified intervals as controlled by voice count of the brush strokes.

Six predesignated locations were measured within each of the sixteen test sections for beta radiation after the first firehosing and again after the brush test and final flushing.

The men were observed during the tests and interrogated after the test. Information on personnel fatigue, individual preferences and morale were recorded.

The mechanical brush consisted of a 1-hp air motor coupled to a flexible shaft to which was attached a 10-inch-diameter scrub brush. The motor was mounted on a pack rack which was carried on the operator's back. The flexible shaft was 10-feet long and its lower end was encased by a rigid 5-foot length of 2-inch aluminum tubing which served as a handle by which the operator manipulated the brush. This tubing also held the brush in place and prevented it from wobbling as it rotated. See Figure 3.1.

A salt water detergent solution (C-120) was injected into the annular center of the brush from a pressure pot through a rubber tube and a 1/4-inch copper tubing attached along the length of the brush handle.

The ship's compressors supplied the air motors with 40 cubic feet of air per minute under a pressure of 90 psi.

Comparative decontamination data were obtained with the NRDL RBI-13 Beta Survey Instrument.

3.3 RESULTS AND DISCUSSION

The test results are shown in Table 3.1 and Figure 3.2. The table compares mechanical and manual decontamination effectiveness for two of the scrub rates from Shot Zuni and the single scrub rate tested at Shot Flathead.

The scrubbing test data from Shot Zuni were very erratic. There was a wide difference of decontamination effectiveness within each test section which had undergone a single uniform brush decontamination operation. Therefore a brush test was extended to include a single brushing rate upon a small area during Shot Flathead.

TABLE 3.1 BRUSH TEST RESULTS

Tests	Contamination Level Before Decontamination	Percent Remaining	
		Mechanical Brush	Manual Brush
	mr/hr	pct	pct
Fast scrub rate, Zuni, 50 ft^2/min	17	62.5	40
Slow scrub rate, Zuni, 7 ft^2/min	50	15.0	14.0
Only rate tested, Flathead, 10 ft^2/min	70	15.0	17.9

The Zuni tests were hampered by heavy rains; it was also unfortunate that exigencies prompted shipboard personnel to decontaminate the starboard test area partially during the return trip to the Eniwetok Lagoon; finally the test areas could not be isolated from other decontamination activities aboard the ship and were subjected to runoff from other areas. Nevertheless, results were not materially altered by these disturbing occurrences since they were borne out by results from Shot Flathead.

This test demanded very vigorous manual scrubbing and after a few minutes the men were completely exhausted. Men using the mechanical brush, on the other hand, felt no fatigue, and stated that longer scrubbing times could easily have been endured. This fact was a decided advantage; however, 40 cubic feet of air per minute under a pressure of 90 psi were required to power each mechanical brush. If several of these brushes were used simultaneously, large air compressors would be needed to furnish this power. Consequently, it was felt that mechanical brushes had to be far superior to manual methods in decontaminability before they could be considered as a standard recovery method. On the other hand, brushes electrically powered or of a different design not requiring large auxiliary equipment may well lessen this requisite for great improvement in decontaminability.

The first scrub rate (Table 3.1) of 50 ft^2/min was too fast and the surfaces were covered too quickly for thorough scrubbing. The second scrub rate of 7 ft^2/min was sufficiently

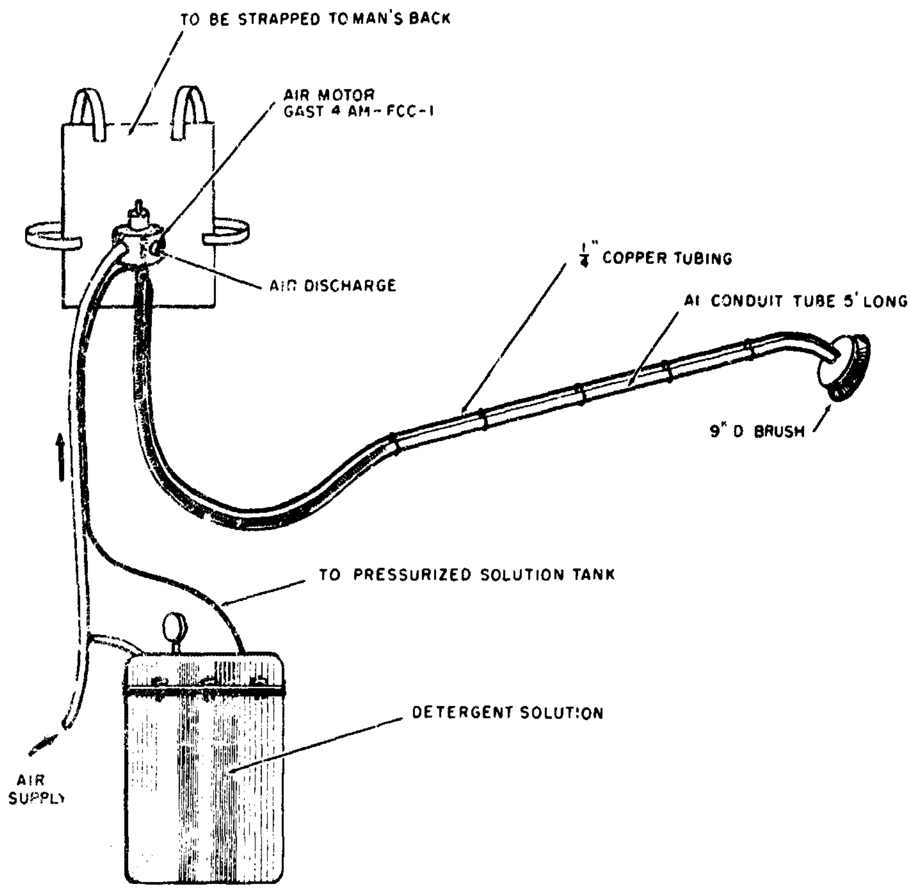

Figure 3.1 Mechanical scrub brush.

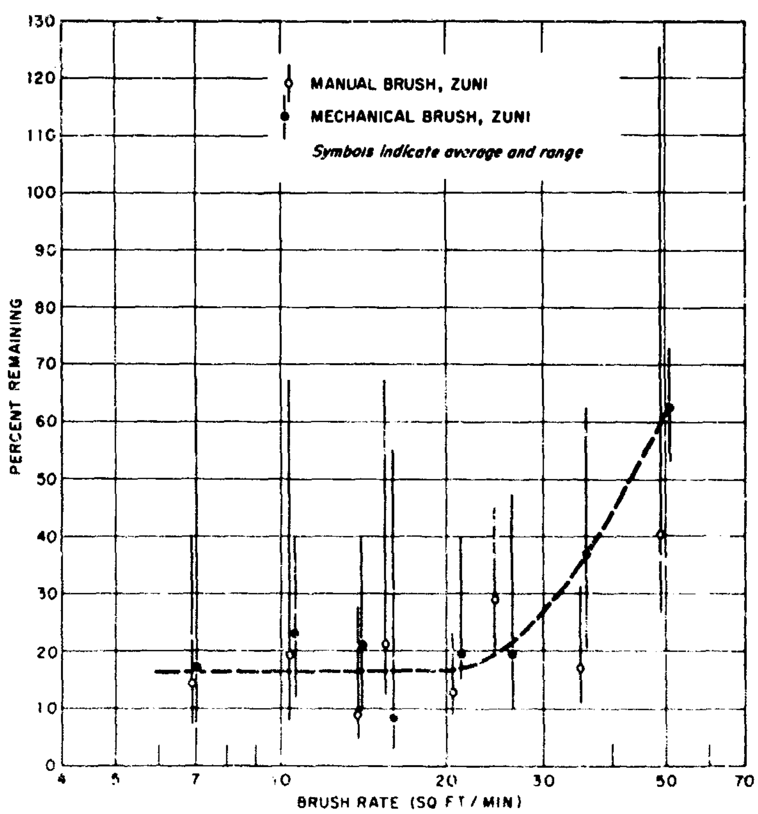

Figure 3.2 Comparison of manual and power brushing results.

slow that extending the time further did not produce a measurable improved effectiveness.

The decontamination effectiveness of mechanical brushing was very similar to manual brushing.

Aside from the beta data used to compare the decontamination effects, visual evidence of more thorough cleaning by manual means was noted in the test. The test results proved that the light mechanical brushing equipment was unsuitable for use in decontamination recovery work.

3.4 CONCLUSIONS

The low requirement of physical effort is an advantage of light mechanical scrubbing methods. The heavy auxiliary equipment that is required is a disadvantage of the light mechanical scrubbing method tested. This method is inadvisable as a standard recovery procedure.

The effectiveness of the mechanical brush does not appear to be sufficiently superior to the manual brush method to justify continuation of its development.

Chapter 4

PROTECTION OF MISCELLANEOUS SHIPBOARD MATERIALS AND EQUIPMENT

Miscellaneous shipboard materials and equipment, such as life rafts (canvas wrapped), wire cables, canvas, tarpaulins, ropes, and firehoses became highly contaminated during Operation Castle and were believed to contribute greatly to the general radiation field on board a ship that was inadvertently exposed to fallout. Most of these materials were essentially untouched during normal ship-decontamination operations, because the general procedure was ineffective. This part of Project 2.8 was planned to obtain information on the contaminability and decontaminability of various protected and unprotected materials.

4.1 OBJECTIVES

The objectives of this investigation were to determine (1) the extent of the radiation hazard created by miscellaneous shipboard materials, such as wire ropes, manila lines, canvas, and firehoses and (2) whether a protective coating will minimize the contaminability or improve the decontaminability of such materials.

4.2 PROCEDURE

4.2.1 Materials and Equipment Tested. The materials and equipment tested aboard the YAG-40 are listed in Table 4.1 together with some descriptive details. The canvas duck materials were coated with commercial synthetic sealers and resins to improve their decontaminability.

4.2.2 Exposure and Analysis of Samples. The samples were exposed aboard the YAG-40 for Shots Zuni and Flathead. Some samples were also exposed on Barge No. 29 for Shot Flathead. One set of samples was studied aboard the YAG-40 after Zuni and a similar set was studied ashore. No such studies were attempted after Flathead since these samples were sent directly to NRDL for analysis. Their analyses were performed at NRDL on D + 48 and D + 49.

Wire Ropes and Manila Lines. A set consisting of each wire rope and manila line listed in Table 4.1 was suspended running fore and aft on top of the YAG-40's No. 3 deckhouse for Shot Zuni. An identical set was suspended adjacent to the first set but running athwartship. The sequence of suspension was: (1) Wirelon, (2) Pacoat, (3) polycord, (4) standard wire rope, and (5) manila line (see Figure 4.1). For Flathead, the Wirelon and polycord-coated wire ropes were replaced with $^{3}/_{4}$-inch and 1-inch manila lines, respectively. In addition, a 6-inch manila line was also suspended from the same stanchions. Each sample was suspended with necessary hardware to maintain the topes and lines taut.

After Shot Zuni, the five samples running fore and aft of the ship were studied in place as part of the deckhouse. Beta meter readings from an NRDL RBI-13 instrument were taken on the samples before and after the deckhouse was decontaminated. The decontam-

TABLE 4.1 MATERIALS AND EQUIPMENT TESTED

Item	Description	Coatings
Shot Zuni:		
Standard wire rope	3/8-inch	None
	3/8-inch	Pacoat* 3/32-inch thick
	3/16-inch	Wirelon† 1/16-inch thick
	3/32-inch	Polycord† 3/64-inch thick
Manila line	5/16-inch	None
Canvas duck	No. 4, white	1/2 with Phil-O-Seal‡
	No. 4, deck blue (2)	1/2 with Epoxy Resin§
	No. 8, white	1/2 with Silicone Sealer¶
	No. 8, deck blue	1/2 with Phil-O-Seal
	No. 8, deck blue	1/2 with Armor Silinite
Leatherette	Upholstery quality	None
Firehose	1 1/2-inch linen lined 50-foot length	None
Shot Flathead:		
Standard wire rope	3/8-inch	None
	3/8-inch	Pacoat 3/32-inch thick
Manila line	5/16-inch	None
	3/4-inch	None
	1-inch	None
	6-inch	None
Canvas duck	No. 10, white (2)	Epoxy Resin
	No. 10, white	None
	No. 10, white (2)	Silicone Sealer
	No. 10, white	RRPC**
Leatherette	Upholstery quality	None
Firehose	1 1/2-inch linen lined 50-foot length	None

* Polyvinylchloride coating manufactured by Pacific Wire Rope Company, San Francisco, California.

† Coated wire rope, manufactured by Rochester Ropes, Inc., Culpepper, Va.

‡ Canvas sealer, manufactured by Phil-O-Seal, Inc., Los Angeles, Calif.

§ Amine cured Epoxy Resin coating.

¶ Armor Silinite, silicone sealer, manufactured by Armor Laboratories, Los Angeles, California.

** Radiological Removable Protective Coating, described in Chapter 2.

ination consisted only of firehosing.

The four wire ropes, three protected and one unprotected, and one manila line that ran athwartship on top of the No. 3 deckhouse, were recovered on D + 2 and analyzed ashore. No loose particles were visible on the samples and there was no detectable change in the contamination level by transporting to the shore. Each sample was stretched horizontally, approximately 5 feet above the ground in an area of low background and contact gamma readings were made with a portable radiac at random points along the sample, as well as around its circumference at locations of any high readings. Then these samples were washed with rags saturated with fresh water and detergent (Tide) at a rate of 1.5 ft/min. Gamma readings were again taken after the washing. Upon completion of the first decontamination, the samples were completely immersed in fresh water that was intermittently agitated over a 42-hour period.

After the 42-hour immersion, the samples were removed and resurveyed. The studies were confined only to the wire portions of the samples; accessories such as turnbuckles, eyes, hooks, and clamps were neglected.

The shipboard study was not done after Shot Flathead. All manila lines and wire ropes exposed to Shot Flathead were shipped to NRDL for laboratory studies. These samples were surveyed for gamma and beta activity with appropriate portable radiacs before and after each decontamination operation. Decontamination consisted of scrubbing with detergent and fresh water for 2 minutes, then rinsing with a hot-fresh-water jet at 200 psi and 180 F. Subsequent decontamination operations were essentially similar except for varying time intervals for scrubbing, and varying concentrations of detergent.

Canvas Samples. All canvas materials and leatherette samples were stapled onto eight 24-inch by 24-inch by $^3/_4$-inch sealer-treated plywood panels mounted on a rack located just aft of the flight deck of YAG-40. Figure 4.2 shows which of the canvas ducks

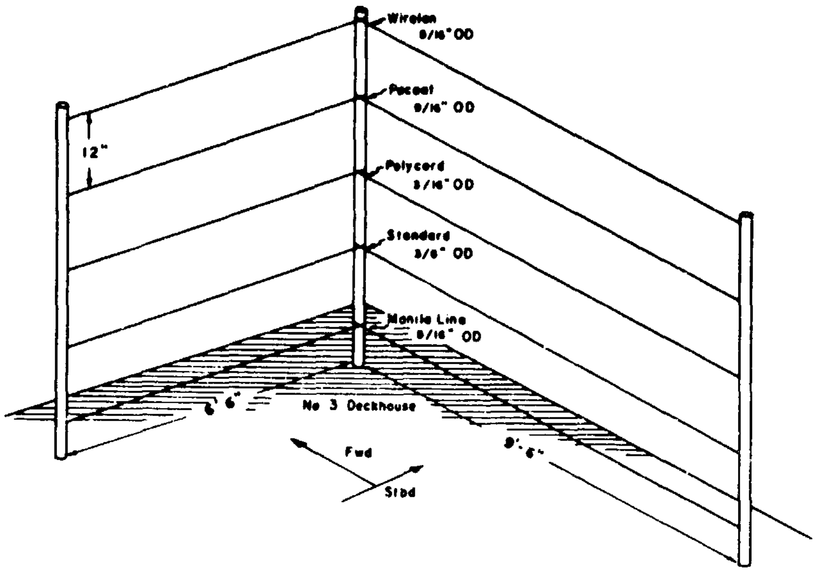

Figure 4.1 Wire ropes and manila line.

were coated for the Zuni test; Figure 4.3 shows those coated for the Flathead test. One half of each canvas sample was treated with the synthetic sealer or resin. All samples were exposed to the fallout from Zuni; the four lower panels were left in place and treated as part of the flight deck area during decontamination operations performed by Project 2.9. Beta survey and wipe samples were taken on these samples before and after the decontamination. The decontamination procedure consisted of firehosing, hand scrubbing, and firehosing.

The canvas samples from Zuni were analyzed ashore on the plywood panels. Radioautograph, wipe samples, and contact gamma surveys were taken before and after each decontamination operation. The decontamination consisted of scrubbing with a stiff brush, detergent (Tide), and water followed by rinsing with fresh water.

For Shot Flathead, canvas samples were stapled on eight 24-inch by 12-inch by $^1/_2$-inch sealer-treated plywood panels. These panels were mounted on the same rack used for Zuni. By using the smaller samples, each could be analyzed separately without being affected by others nearby. After contamination, all the samples were removed on D + 2, boxed, and shipped to NRDL for analysis. Similar canvas samples were located on the Barge No. 29 and shipped to NRDL for analysis. No analysis of canvas samples were performed on the YAG-40 for Flathead.

All canvas samples from Flathead were analyzed at NRDL. There was no loose activity visible on the samples at time of packing for shipment and there was no evidence of contaminant being loosened from the samples in transit. The canvas was carefully removed from the plywood panels to minimize the flaking of loose contaminant. Beta and gamma surveys were made before and after decontamination. In addition, a gamma log rate meter (Model USNRDL-LRM 1) was used to determine the gamma radiation intensity produced by the canvas samples exposed at Flathead. All canvas samples were thoroughly scrubbed for 2 minutes with a stiff brush, using detergent and fresh water and then rinsed with a hot-fresh-water jet at 200 psi and 180 F. This decontamination procedure was repeated twice on each sample.

Firehose. Two 50-foot lengths of $1\frac{1}{2}$-inch standard firehoses were suspended around the No. 3 deckhouse and connected as part of the temporary emergency washdown system aboard the YAG-40 during Zuni. The two lengths used as the test samples ex-

Deck Blue No. 8 Armor Silinite Coated | Unprotected	Leatherette Unprotected	Deck Blue No. 8 Phil-O-Seal Coated | Uncoated	Deck Blue No. 4 Epon 1001 Coated | Uncoated
Leatherette	White No. 8 Armor Silinite Coated | Uncoated	White No. 4 Phil-O-Seal Coated | Uncoated	Deck Blue No. 4 Epon 1001 Coated | Uncoated

← Starboard Port →

Figure 4.2 Front view of sample rack on flight deck for Shot Zuni, looking aft.

tended from under the port side passageway, main deck, along the front of the superstructure and then along the port side of the deckhouse. On D + 2, one of the test samples was disconnected, coiled and removed from the ship for shore analysis. The remaining test firehose was considered part of the ship and treated as part of the port side of the No. 3 area. Gamma and beta surveys and wipe samples were taken on this test sample before and after decontamination. Firehosing was the only decontamination procedure.

The 50-foot length of firehose, brought ashore after Zuni, was surveyed with a portable gamma radiac both while the firehose was coiled and uncoiled. The 3-foot section which produced the highest intensity was cut from the 50-foot length for further analysis. This section was decontaminated with a brush, fresh water, and detergent (Tide). The scrubbing required 3 minutes. Gamma readings were again taken after decontamination. Two pieces, approximately 24 inches long, were cut from the more radioactive portions of the firehose for radioautographing. These pieces were surveyed for gamma, decontaminated, resurveyed, and re-radioautographed. Several wipe samples were also taken before and after decontamination.

The 50-foot firehose which had been removed for shore analysis was replaced with a new sample for Flathead. This length and the one placed on the barge, after contamination, were recovered and shipped to NRDL for laboratory analysis. No shipboard tests were conducted on firehoses for Flathead. Analysis of the firehose which had readable contamination consisted of hand scrubbing with water saturated with a detergent and firehose rinsing with the addition of hot-liquid-jet cleaning of the samples.

None of the firehoses used in the tests was coated.

4.3 RESULTS AND DISCUSSION

4.3.1 Wire Ropes and Manila Lines. Results obtained from the wire rope and manila line samples studied after Zuni are shown in Table 4.2. Table 4.3 shows the results obtained from samples exposed at Flathead.

The most radioactive portion of the standard wire rope exposed during Zuni was used

Canvas No. 10	Canvas No. 10	Canvas No. 10	Canvas No. 10	Canvas No. 10	Canvas No. 10	Leatherette	
Coated with Epon 1001	Uncoated	Coated with Armor Silinite	Uncoated	Coated with Phil-O-Seal	Coated with Epon 1001	Uncoated	
Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8

← Starboard Port →

Figure 4.3 Front view of sample rack on flight deck for Shot Flathead, looking aft.

to obtain an isodose contour around one point of the rope, (Figure 4.4) Contours for other ropes and lines exposed at both shots could not be obtained because of low readings.

Results of gamma and beta surveys showed that all standard unprotected wire ropes had higher amounts of initial activity than protected wire ropes. The higher reading is probably attributed to the surface roughness and absorption capabilities. No quantitative contributions were attempted but a qualitative estimate of the improvement in the contaminability of a coating over a standard wire rope may be had by comparing a $^5/_{16}$-inch standard wire rope coated with Pacoat ($^9/_{16}$-inch overall diameter) with the standard $^5/_{16}$-inch diameter uncoated wire rope. Initial readings of the standard wire rope which has

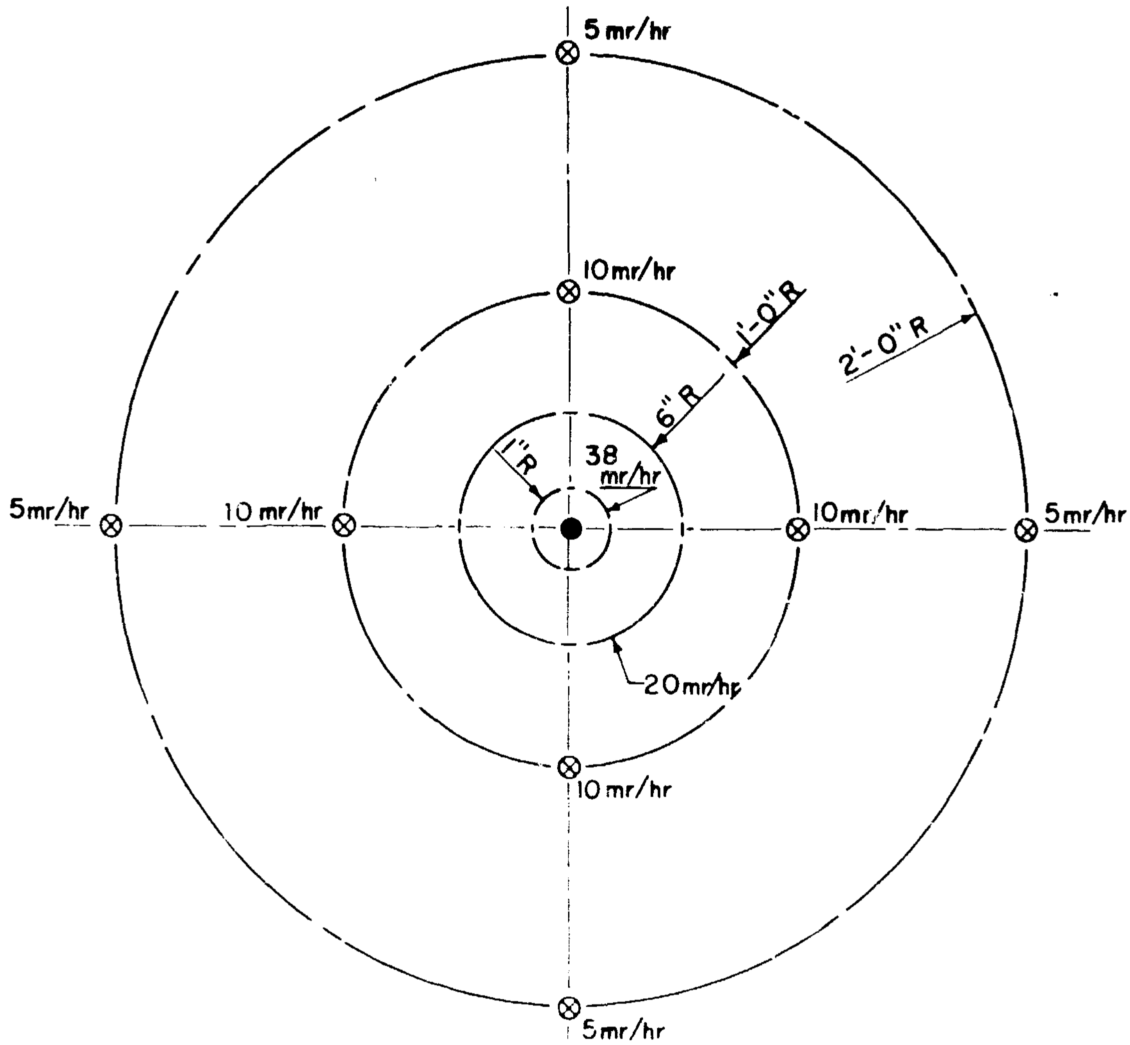

Figure 4.4 Isodose contour around $^5/_{16}$-inch standard wire rope exposed at Shot Zuni. (H + 57.5 hr.)

a smaller collecting area than the coated wire rope was 4.5 times higher. Hence it may be inferred that a coating over standard wire rope lowers the initial contamination level per unit area because of its smoother surface, less absorbability and adsorbability.

A manila line sample had a slightly lower initial contamination level than the same size standard wire rope.

Beta surveys (Table 4.2) taken on manila line and wire ropes indicated that 80 to 93.2 percent of the activity was removed by firehosing alone. Gamma surveys on Zuni samples (Table 4.2) show that a 1-ft/min washing action with rags saturated with water and detergent removed 8 to 73 percent of the activity from wire ropes and manila lines, the higher amounts of activity being removed from the coated wire ropes. Flathead wire rope and

TABLE 4.2 DECONTAMINATION RESULTS FOR WIRE ROPE AND MANILA LINES EXPOSED AT ZUNI

Samples	Decontamination Results *							
	Method 1				Method 2		Method 3	
	Beta Survey		Wipe Samples		Gamma Survey		Gamma Survey	
	Initial H + 104	Percent Remaining	Initial Count	Percent Remaining	Initial H + 56	Percent Remaining	Initial H + 99	Percent Remaining
	μa	pct	cpm	pct	mr/hr	pct	mr/hr	pct
Wirelon coated wire rope, 5/16-in overall diameter	380	8.5	5.8×10^5	<1	11	27	1.5	negligible
Manila line unprotected 5/16-in diameter	1,800	8.2	1.02×10^5	2	27	92	12.6	48.0
Pacoat coated wire rope, 5/16-in overall diameter	512	6.8	6.6×10^5	<1	8	63	2.5	8.0
Polycord coated wire rope, 5/16-in overall diameter	440	12.0	6.98×10^5	1	4	50	1.0	negligible
Standard wire rope unprotected 3/8-in overall diam.	1,150	20.0	0.586×10^5	8.5	36	86	16.0	56.0

* Method 1 samples were decontaminated aboard the YAG-40 by standard shipboard recovery methods; Method 2 samples were decontaminated ashore by wiping with rags saturated with water and detergent; Method 3 samples were decontaminated by a 42-hour immersion in fresh water. This method was conducted on the same samples following Method 2.

manila line samples (Table 4.3) again indicated that 19 to 48 percent of the activity was removed by the combined decontamination procedure of hand scrubbing with detergent, firehosing and hot-liquid-jet cleaning.

The coated sample showed the highest amount removed. The results obtained, therefore, must depend on a variable other than the decontamination method. Data obtained indicate that absorption of activity into the strands of the wire rope and the fibers of the manila lines will be one major factor in determining the decontamination effectiveness.

Wipe sample data show that Zuni produced a contaminant on wire ropes and manila lines which was easily removable. This fact confirms the data obtained by beta surveys. Wipe samples from wire ropes or manila lines will not indicate the extent of contaminability or decontaminability, since they only indicate that amount which is at the surface and which is wipable. It cannot indicate how much activity had been absorbed or is located in cracks and crevices. Wipe samples from Flathead samples were not attempted.

The 6-inch manila line exposed at Flathead read 192 mr/hr on D + 48. Considering that only 20 percent could be removed by decontamination, this constitutes a significant hazard. The decontamination process entailed scrubbing with a brush, detergent and warm fresh water plus a firehose rinsing on the 3-foot piece for 2 minutes. Expanding the decontamination procedure for long lengths of manila line found on board all naval vessels will require many man hours of labor to obtain a reduction of only 20 percent. Confinement of such a contaminated rope in a small area by coiling it will present a high level of activity. It is suggested that any manila line or wire rope, suspected to be contaminated, be removed from the ship if not needed. However, if it is essential to keep the contaminated rope aboard, it should be left uncoiled, or coiled and placed in an area where the external gamma radiation will be a minor hazard.

Visual observation of a wire rope with Pacoat revealed that slight flexing action broke the coating from the surface of the wire rope. Exposure to direct sunlight for long periods caused the plastic coating over the wire rope to lose part of its initial smooth surface. Although this type of coated wire rope may decrease the initial levels of contamination

TABLE 4.3 DECONTAMINATION RESULTS FOR WIRE ROPE AND MANILA LINE SAMPLES EXPOSED AT FLATHEAD AND ANALYZED AT NRDL

Decontamination method consisted of scrubbing with detergent and water for 2 minutes followed by a hot-water rinse.

Sample	Initial Gamma Reading D + 49	Percent Remaining
	mr/hr	pct
Standard wire rope 5/8-in unprotected	0.8	81
Pacoat coated wire rope, 9/16-in overall diameter	0.25	52.0
5/16-in galvanized standard wire rope	3.6	69.5
3/4-in manila line unprotected	3.5	71.5
1-in manila line unprotected	9.6	76.0
6-in manila line unprotected	32.1	80.0

when compared to standard wire rope, it will not withstand repeated flexing. This fact eliminates much of its value as a wear-resistant coating.

4.3.2 Canvas Samples. Results obtained from samples studied after Zuni are shown in Table 4.4. Table 4.5 shows the results from Flathead samples studied at NRDL.

All canvas samples exposed during Shot Zuni with and without protective coatings had 2.3 to 13 percent remaining after decontamination as determined by beta surveys. Gamma surveys of decontaminated Zuni samples do not indicate the same decontamination effectiveness (50 to 85 percent remaining). This was primarily expected due to adsorption and absorption of activity into the canvas fibers. It was also expected due to part of the activity penetrating into the wood backing, although the wood was thoroughly treated with sealer. Any activity which was absorbed by the canvas and wood backing could not be touched by any of the decontamination procedures. Therefore, only beta readings were considered representative for Zuni samples. For Flathead, the samples were removed from the wood backing before analysis and both sides of them were then treated equally during all decontamination operations.

All canvas samples used at Shot Zuni were 24 inch by 24 inch; half of one was coated with some type of synthetic sealer and the other half was untouched. No attempt was made in studies after Zuni to separate the two sections; therefore, close proximity may have affected the gamma readings. For Flathead, the samples were half the original size so that each sample could be analyzed separately.

Fairly good decontamination results were obtained by beta surveys from Shot Zuni canvas samples. In this case, canvas and leatherette samples show 87 to 97.7 percent removed although the results do not indicate the extent to which the activity penetrated the fibers. Comparison of unprotected and coated canvas samples does not show any significant difference, hence the coatings cannot be critically evaluated by Zuni samples although one autoradiograph of the canvas sample which was coated with Epoxy resin definitely shows that the coating had improved the decontamination. An autoradiograph (Figure 4.5) of one sample from Zuni which had one half coated with Epoxy resin showed that the coating greatly improved the decontaminability. Although the gamma data do not agree, the

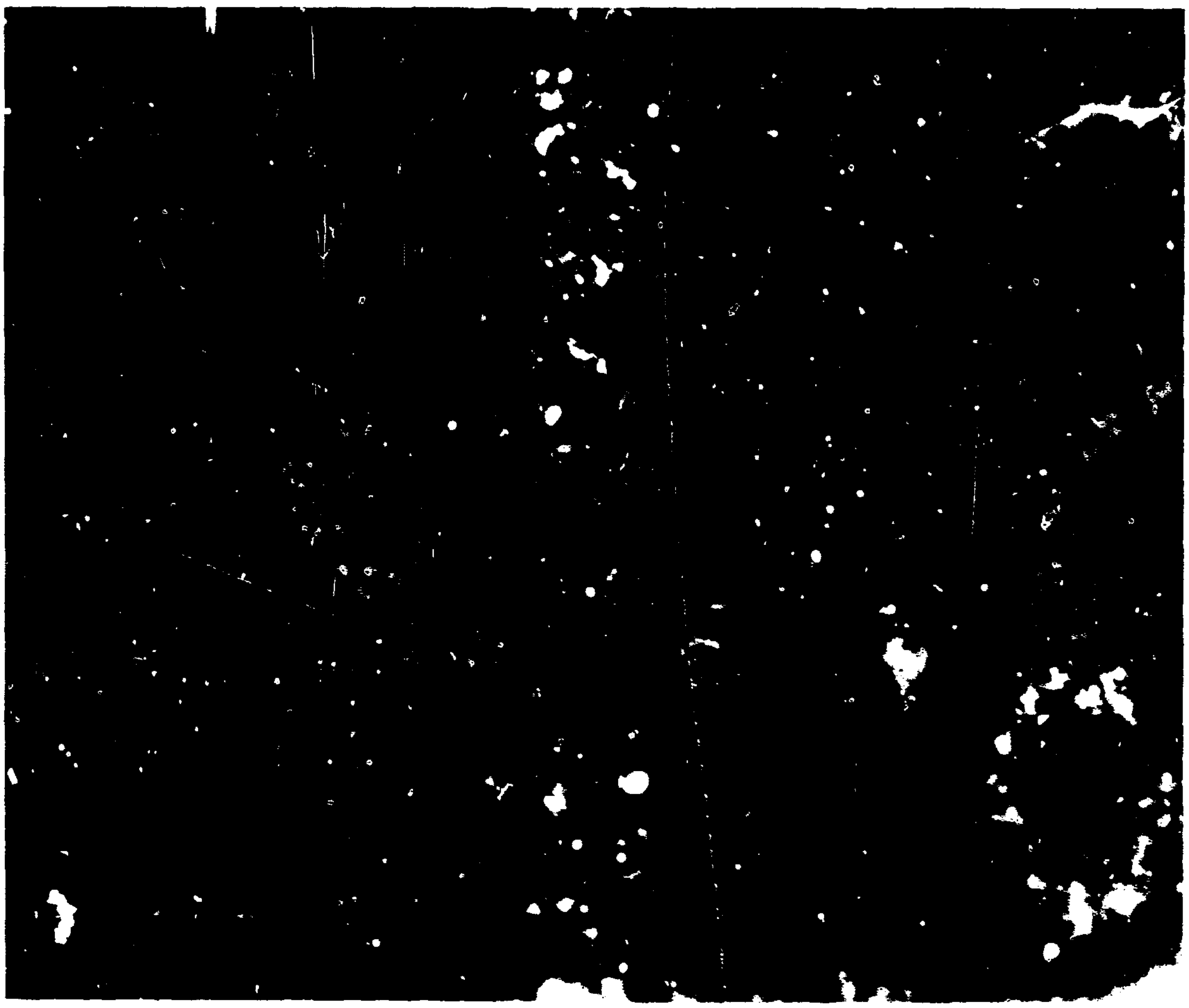

Figure 4.5 Autoradiograph (positive print) of a canvas sample exposed at Shot Zuni. Lighter area was not coated; darker area was coated with Epoxy Resin Sealer.

beta readings indicate good correlation with the autoradiograph. Once again it must be reiterated that absorption of activity into the wood backing caused gamma readings of the canvas samples exposed at Zuni to be uninterpretable. The film definitely shows a demarcation line of the results obtained when the canvas coated with Epoxy resin is compared with the unprotected side. The result shows that the contaminability of standard canvas material had been lowered. The principal disadvantage with Epoxy resin coating on canvas was that the coated canvas became very stiff and brittle.

Samples 1 and 3 from Flathead were decontaminated by using a scrub brush, detergent and fresh water. This was the same procedure used for all Zuni samples analyzed ashore. All other Flathead samples were decontaminated with a hot-liquid jet at 170 F and 200 psi pressure as well as hand scrubbed with detergent in water. No significant differences were observed for the various decontamination methods utilized since all the samples which were studied on D + 48 and D + 49 had fairly low readings. It was noted that the unprotected sample (No. 2) had the highest initial reading; leatherette samples, which presented the smoothest surface had the lowest initial readings as determined by gamma and beta surveys. In general, the samples which had the lower beta or gamma readings had the higher percentage remaining.

Data from Flathead samples indicated that 20 to 59.8 percent gamma activity remained after the decontamination operation for all protected canvas materials whereas only 11.4 percent remained for the smoother-surfaced leatherette samples and 18.5 percent remained on the unprotected canvas samples. Although the unprotected canvas sample had a lower percentage remaining, in several cases the gamma reading after decontamination was higher than the initial gamma readings for the protected samples. Although the data for subsequent decontamination operations are not presented in the tables, continued washing and scrubbing on the unprotected canvas samples did not significantly lower this final reading. The natural decay of activity was the predominant factor in decreasing the readings. This fact indicates that the activity was imbedded into the fibers of the canvas and its removal became progressively more difficult once the loose material was removed. Concentration of many large contaminated canvases which had been cleaned of the loosely held activity presented a radiation hazard which could be reduced only be removing the canvases from the ship.

Beta surveys showed from 6 to 34 percent remaining after decontamination for the protected canvas samples; 55 percent remaining for the leatherette samples, and slightly less than 6 percent remaining for the unprotected canvas samples. It must be noted that the unprotected sample had 1.4 to 1.6 times higher initial reading than the Silicone sealer-coated canvas sample and 7 to 17 times higher initial reading than the canvas samples coated with Epoxy resin. After decontamination, the readings were all fairly low with no large significant differences.

Discussions of all samples were predicated on the assumption that all were exposed to uniform amount of fallout. Since variations were noted in the initial readings obtained on the two samples coated with Epoxy resin as well as on the two coated with Silicone sealer, it was felt that extensive comparisons of the coatings were not warranted.

4.3.3 Firehoses. Results obtained on all firehose samples studied are shown in Table 4.6.

Contaminated standard firehoses that are coiled can cause a definite radiation hazard as compared to those which are extended. This was evidenced by gamma readings taken at the surface of coiled and uncoiled firehoses used as test samples at Zuni and Flathead. The readings taken on a coiled firehose were 8 to 10 times higher than on the extended firehose. For Zuni, 84 and 84.1 percent contamination was removed, as determined by

TABLE 4.4 DECONTAMINATION RESULTS OF CANVAS SAMPLES EXPOSED AT ZUNI

Sample	Decontamination Aboard YAG-40				Decontamination Ashore			
					1st Decontamination		2nd Decontamination	
	Beta Survey		Wipe Samples		Gamma Surveys			
	Initial H+80	Percent Remaining	Initial H+82	Percent Remaining	Initial H+56	Percent Remaining	Initial H+77	Percent Remaining
	μa	pct	c/m	pct	mr/hr	pct	mr/hr	pct
Leatherette	925	13	70,900	6.1	60	88	37	100
Unprotected	950	13	87,300	2.9	65	79	35	100
White canvas, No. 8								
Unprotected	4,500	10.8	11,000	5.3	—	—	—	—
Silicone coated	4,500	5.8	12,000	4.5	—	—	—	—
White canvas, No. 4								
Unprotected	4,750	9.7	55,500	10.0	—	—	—	—
Phil-O-Seal coated	4,250	6.4	8,670	5.7	—	—	—	—
Deck blue, No. 8	—	—	—	—	165	78	87	86
Unprotected	—	—	—	—	210	68	95	100
Silicone coated	—	—	—	—	150	81	85	88
Phil-O-Seal coated	—	—	—	—	235	75	120	100
Deck blue, No. 4								
Unprotected	5,750	2.6	10,800	3.1	150	52	55	81
Epoxy Resin coated	1,075	2.3	9,600	6.3	120	76	60	83

TABLE 4.5 CANVAS SAMPLES EXPOSED AT FLATHEAD AND ANALYZED AT NRDL

Sample	Gamma Portable Radiac Readings		Ratemeter * Readings		Beta Readings	
	Initial D+48	Percent Remaining	Initial D+48	Percent Remaining	Initial Before D+49	Percent Remaining
	mr/hr avg.	pct	c/m	pct	μa	pct
1 Epoxy Resin coated	17.6	33.5	53.7	43.9	290	28.5
2 Unprotected	102	18.5	359	[illegible]	2,050	5.87
3 Silicone sealer coated	68.6	32.7	278	30.5	1,400	17.2
4 Epoxy Resin coated	7.6	59.8	28	51.8	[illegible]	33.7
5 RRPC coated	37.6	35.7	159	33.2	[illegible]	17.2
6 Silicone sealer coated	74.6	20.0	238	21.6	1,240	6.8
7 and 8 Leatherette unprotected	2.20	11.4	9.4	38.3	22.8	55.0

*Gamma log ratemeter, Model NRDL-LRM No. 1.

beta and gamma studies, respectively. For Flathead, only 75.1 and 49.2 percent contamination was removed, as determined by beta and gamma surveys, respectively. The variation in results indicates that the contamination characteristics were different for these two shots. The decontamination procedures used for the test sections were essentially identical. Considering the rough surfaces of the firehose, tests conducted on samples contaminated by Shots Zuni and Flathead indicated better decontamination effects than expected.

4.4 CONCLUSIONS

Small diameter wire ropes probably will not present a serious external gamma hazard; however, wire rope of more than 1-inch diameter will definitely create a long-range gamma hazard because of its inherent absorption characteristics and availability of many tiny crevices. The same applies to manila lines.

Coated ropes tend to improve the situation by making the surfaces smoother, thereby making contaminability slightly less. Further field tests are not warranted, but laboratory scale tests should be made to improve resistance to contamination and decontaminability of larger diameter wires and manila lines.

TABLE 4.6 DECONTAMINATION RESULTS FOR FIREHOSE SAMPLES

Samples exposed at Zuni, analyzed on the YAG-40:	
Beta reading before decontamination H + 79	2,300 μa
Percent remaining, decay corrected, beta survey	20 pct
Wipe samples before decontamination H + 82	24,000 c/m
Percent remaining, decay corrected, wipe samples	26 pct
Samples exposed at Zuni, analyzed ashore:	
Gamma readings 1 inch from surface on coiled hose, H + 122	1.0 r/hr
Average gamma readings on uncoiled hose, 1 inch from surface, H + 122	125 mr/hr
Average count for wipe samples before decontamination, H + 122	22,400 c/m
Average count for wipe samples after decontamination, H + 266.5	1,500 c/m
Percent remaining wipe samples, decay corrected	15.9 pct
Samples exposed at Flathead, analyzed at NRDL:	
Gamma reading at surface of coiled firehose	250 mr/hr
Average contact* gamma readings of uncoiled firehose	24.8 mr/hr
Average initial gamma reading before decontamination, D + 49	24.8 mr/hr
Percent remaining after decontamination, gamma survey	60.8 pct
Initial beta readings before decontamination	1,125 μa
Percent remaining after decontamination, beta survey	24.9 pct

*Instrument was in contact with surface at time reading was taken.

It is recommended that in the event that ropes are contaminated and are considered essential for shipboard use, they should, if possible, be kept in the extended position and should not be concentrated in locations where the external hazard must be kept at a minimum.

Since the limited tests on canvas materials indicated that coatings tend to lower the initial contamination levels, further testing on coatings should be conducted in the laboratory. Further field testing does not seem to be warranted.

Concentration of contaminated canvas materials on board naval vessels should be avoided since complete decontamination of such materials was not possible due to absorption and adsorption. If contaminated firehoses cannot be discarded due to lack of replacement hoses, it should be stored in the uncoiled position, or stored in an unfrequented location.

Chapter 5
CONTAMINATION AND DECONTAMINATION OF SHIPBOARD WOODEN DECKING

At previous operations, wooden decking has presented a more difficult decontamination problem than steel decking. During Operation Castle, a time-consuming surface-removal operation had to be performed on the YAG-40 boat deck to reduce radiation levels to an acceptable limit (Reference 1). Subsequently, repeated chemical decontamination of the bulkheads above this deck resulted in some recontamination of the wood deck. After this ship returned to NRDL, tests showed that only approximately 20 percent of the contamination was in the wood; the remainder was in the pitch (marine-glue paying) between the planks. The marine glue was full of cavities and cracks up to ½ inch deep. These openings had resulted from expansion or contraction of the pitch with temperature changes (see References 12 and 13). It was thought that a temperature-stable paying material that did not bubble or crack under conditions of normal flight-deck heat and wear would give additional contamination protection.

Well-painted wood has been shown to decontaminate more easily than unpainted wood (Reference 13). In the same manner, wood treated with a penetrating or other type waterproofing sealer should be easier to decontaminate than untreated wood.

5.1 OBJECTIVE

The objective of this study was to gain information about means of preventing wood from absorbing radioactive fallout and to determine to what extent wooden decking can be decontaminated without resorting to surface removal.

5.2 PROCEDURE

Specimens of typical ships' wooden decking material were coated, weathered, exposed to fallout from Shots Zuni, Flathead, or Tewa and analyzed. Analysis of the specimens involved radiological surveys, radioautography, sectioning, and various decontamination procedures.

5.2.1 Test Specimens. Three types of specimens were used for the experimental phase of this problem: (1) deck planking, (2) decking sections, and (3) the YAG-40 wooden decking. Deck planking specimens were obtained from the San Francisco Naval Shipyard. The specimens were 12 inches by 6 inches by 1⅜ inch and were made from new material ready for use aboard aircraft carriers. Two materials, both of which complied with Navy specifications, were tested: (1) Douglas fir, and (2) teak laminated onto fir. The Douglas fir was unplaned; the teak was planed. The coatings applied to these specimens were:

Coating	Application
None	
Deck gray	2 spray coats
Epoxy Resin, 60 percent solids	1 brush coat
Epoxy Resin, 40 percent solids	2 brush coats
Monsanto Butvar B-76	2 brush coats
Armor Silinite	2 brush coats

The deck planking specimens furnished data on material and coating comparison and the penetration depth of fission products.

Specimens of decking sections were constructed of standard materials by the San Francisco Naval Shipyard. They were 12 inches by 12 inches by 3 inches and included two payed seams and four plugs. Douglas fir and teak laminated onto fir were used for the planking. Three paying systems that are normally used in shipboard wooden decking were tested: (1) marine glue[1], (2) Produce Research PR-1099, and (3) Minnesota Mining EC-1364. The latter two are thick liquids which, upon the addition of a curing agent, set to a consistency similar to tire rubber. One third of the specimens were given two spray coats of deck-gray paint. The decking sections gave data on payed joints and materials.

The YAG-40 wooden decking was the only available large-area specimen. This decking cannot be considered typical, since it had many coats of deck-gray paint and had not received heavy service. Its wood was Douglas fir; its paying, which in many places contained cracks and crevices, was marine glue. A typical flight deck was simulated on the forward section of the ship and was constructed with planking, gutters with tie-downs, and had arresting gear plates running athwartship. A 4-by-4-foot section of this deck containing these three features was chosen for a detailed radiation survey. The boat deck of the YAG-40 had planking running fore and aft and sloped outboard. A 1-by-4-foot section of it was chosen for a detailed radiation survey. This section lay on the port side of the boat deck. The areas of wooden decking gave data on the distribution of fission products.

5.2.2 Specimen Stations and Exposure. The deck planking and decking sections were assembled into racks 3 feet long that were fastened to specimen stations with quick-release clamps. There were three stations on the YAG-40: Station 1 was located in the after port corner of the flight deck and had no washdown protection during fallout; Station 2 was on top of the after deckhouse and received washdown protection during fallout; Station 3 was an open-close collector in the forward part of the ship. Four deck planking specimens were exposed to fallout in this open-close collector. After the ship left the fallout area, an operator in the shielded control room actuated a mechanism which slid a cover over the specimens in this collector to protect them from rain. Three specimens of each type of deck planking were exposed at Stations 1 and 2. The following decking specimens were exposed:

Paying	Wood	Coating
	Station 1	
Marine glue	Fir	None
Marine glue	Fir	Deck gray
Marine glue	Teak	None

[1] Specification: MIL-G413 Class 2 (Sealing Compound).

Marine glue	Teak	Deck gray
PR-1099	Fir	None
PR-1099	Fir	Deck gray
PR-1099	Teak	None
PR-1099	Teak	Deck gray
EC-1364	Fir	None
EC-1364	Fir	Deck gray
	Station 2	
Marine glue	Fir	None
Marine glue	Teak	None
PR-1099	Fir	None
PR-1099	Teak	None
EC-1364	Fir	None

Specimens were coated and then fastened on station five weeks before exposure to the first fallout to give them natural weathering.

An evaluation of washdown protection during the fallout events was possible from data gathered at Stations 1 and 2. Specimens at both of these stations received rain after the fallout and prior to analysis. Specimens at Station 3 were protected from rain after the fallout in order that a separate study might be made on the effect of water in altering the depth of penetration of the fission products.

5.2.3 Specimen Processing and Measurements. After the deck planking and decking sections from Stations 1 and 2 were exposed to fallout, they were removed to a processing area. Both groups of specimens were surveyed, radioautographed, decontaminated, surveyed, and radioautographed. The surveys were performed with an AN/PDR-T1B gamma survey instrument or an NRDL beta survey instrument Model RBI-13 by making direct contact with the surface. Both instruments were protected against contamination by a plastic film wrapping.

The radioautographs were made with a Type K X-ray film in a grain-inspection film holder. Film was kept in close contact with the surface by a 25-pound sandbag. Films were given 15 mr/exposure, as measured by a T1B.

Decontamination consisted of firehosing at a rate of 10 ft^2/min; detergent hand scrubbing with long-handled palmyra fiber brush at a rate of 5 ft^2/min; and a firehosing rinse at 10 ft^2/min. One specimen of each type was decontaminated.

Cores were removed from the deck planking specimens following radioautography. They were removed by boring with a plug cutter from the clean back of a specimen to the exposed face. The cores were identified and covered with saran wrap to contain the fission product. These cores were gamma counted, sectioned, and the sections gamma counted.

Radiation counting of the cores and sections was done with a gamma scintillation counting apparatus consisting of an AN/CP-79 UD scaler, a preamplifier, and a thallium-activated sodium iodide crystal. Beta and soft gamma were attenuated with 0.25-inch aluminum.

The sectioning of the cores was performed after the initial core radiation count. The saran wrap was removed and retained for counting, then the core was mounted in the sample holder of the microtome sectioning apparatus (Model 820 Microtome manufactured by Spencer Lens Company, Buffalo, New York) with a jig to assure parallel sectioning. The microtome was set to cut a section 2 mils thick. After each section was made, it was removed from the blade with cellophane tape and mounted on a 3-by-5-inch file card with the tape. The material still remaining on the blade was then removed with cellophane tape, which was added to the card. The first intact section was identified as that entire section first observed free from perforations.

Station 3 specimens were removed to the processing area where 10 ml distilled water was applied to one half the face of each in order to study penetration.

The 4-by-4-foot area of the flight deck and the 1-by-4-foot area of the boat deck were surveyed with an AN/PDR-T1B gamma survey instrument and an NRDL beta probe Model RBI-13 before and after the decontamination operations. Radioautographs were made of parts of the sections after the decontamination operations.

5.3 RESULTS AND DISCUSSION

5.3.1 Distribution and Form of Contaminant as Related to Wooden Decking. The radiation levels observed at H + 48 were within the range of 5 mr/hr to 1 r/hr for all shots. The data from the detailed study of the 4-by-4-foot flight deck area indicated that the contaminant was not uniformly distributed. The beta data for Zuni are illustrated as radiation contours in Figure 5.1. The data for the fallout from the other shots show a similar distribution. Visual observation after Shot Zuni showed concentration of coral powder in depressions in the decking (Figure 5.2); coral powder was found radioactive by

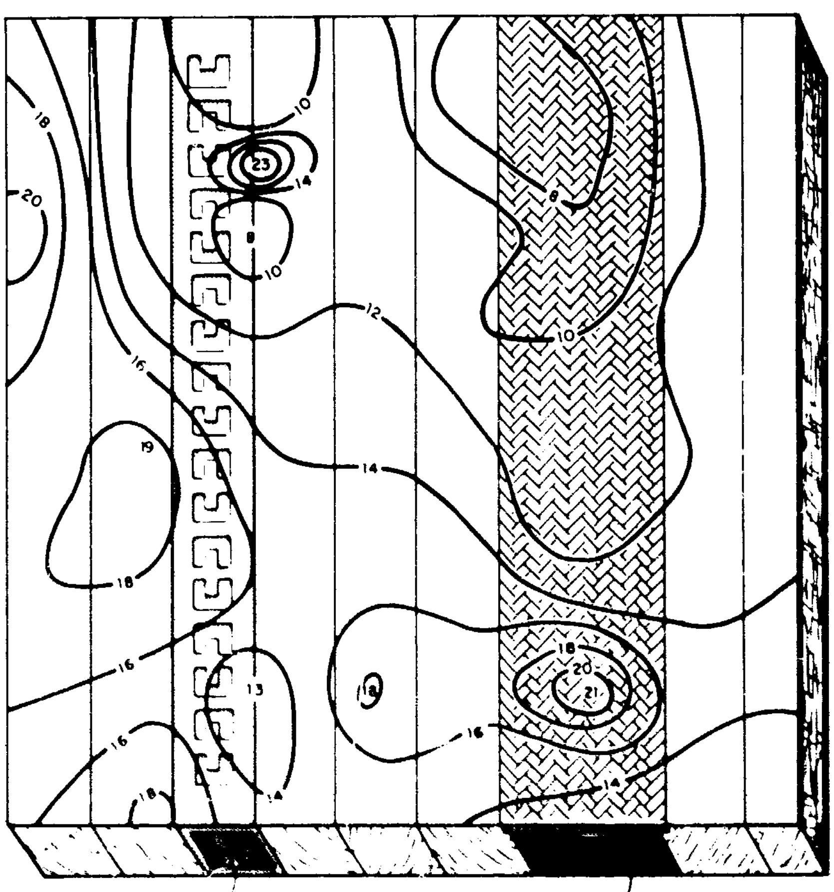

Figure 5.1 Relative fallout distribution as determined by beta radiation detectors at H + 48. (Values given are microampere readings from a USNRDL RBI-13 beta detector.)

autoradiographs and radiation detectors. The irregular distribution of the fallout was probably caused by wind eddies during fallout and by weather after fallout.

The Flathead fallout was invisible, and showed only a slight tendency to concentrate in crevices, however, autoradiographs showed it to be particulate (Figure 5.3). This fallout was wet and contained small amounts of particulate solid.[1]

Tewa fallout at YAG-40 was very fine and almost invisible; it gave a faint hazy cast to paint. No autoradiographs or radiation measurements were made to show concentra-

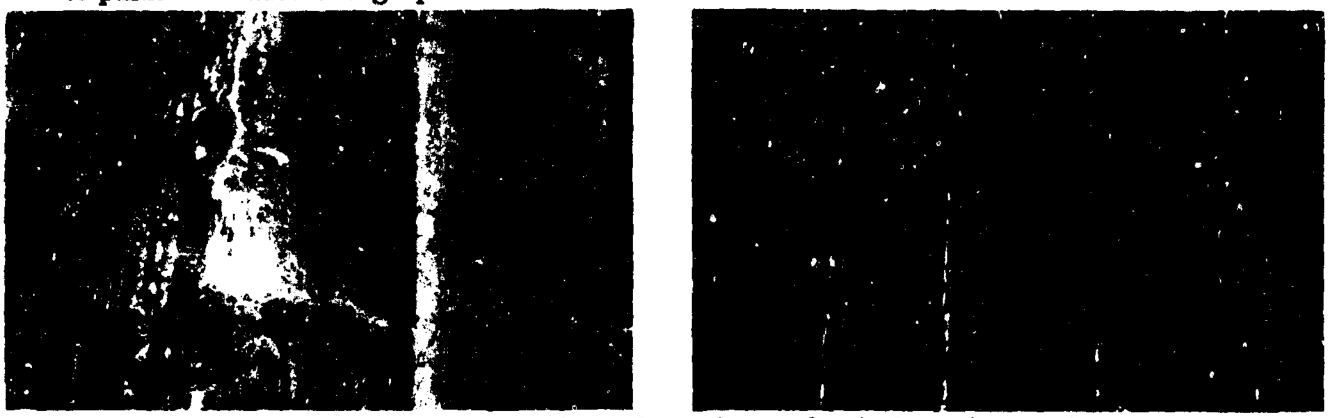

Figure 5.2 Concentration of coral powder in the decking depressions after Shot Zuni. Left picture shows a portion of the flight deck of the YAG-40, right shows a portion of the boat deck.

tion of this fallout in depressions or cracks; but since it appeared intermediate to Flathead and Zuni fallouts in visual characteristics, it is assumed that it migrated to some degree to cracks and depressions.

The teak specimens were contaminated to a lesser degree than the fir specimens from all fallouts (Table 5.1). Surface roughness was probably the determining factor with grain density operating to a lesser degree. The non-ionic portion of the fallout was probably blown or washed from the smooth close-grained surfaces more than from the rough surfaces. The type of coating on these specimens had no effect on the radiation level after 2 days weathering.

5.3.2 Effect of Washdown. Washdown was found approximately equally effective on all specimens. Coating types and surface roughness had no observed effect on washdown re-

TABLE 5.1 COMPARISON* OF CONTAMINATION RATIOS OF TEAK AND FIR AFTER FALLOUT AND WEATHERING

Shot	Specimen	Ratio of Teak to Fir	
		Unprotected	Washdown
Zuni	Deck planking	0.67	0.69
	Core sample	0.15	0.14
Flathead	Deck planking	0.93	0.3[illegible]
	Decking section	0.60	0.46
Tewa	Deck planking	0.30	0.56
	Decking section	0.65	0.35

* Mean radiation level of teak divided by that of fir.

sults. Washdown during Zuni and Tewa was much less effective on the wood specimens than it was during Flathead (Table 5.2). One possible explanation for these results depends upon a difference in the ionic-to-particulate ratio for the various fallouts. Washdown droplets may have intercepted fallout non-ionic particles and driven them through the water

[1] P. D. LaRiviere, private communication.

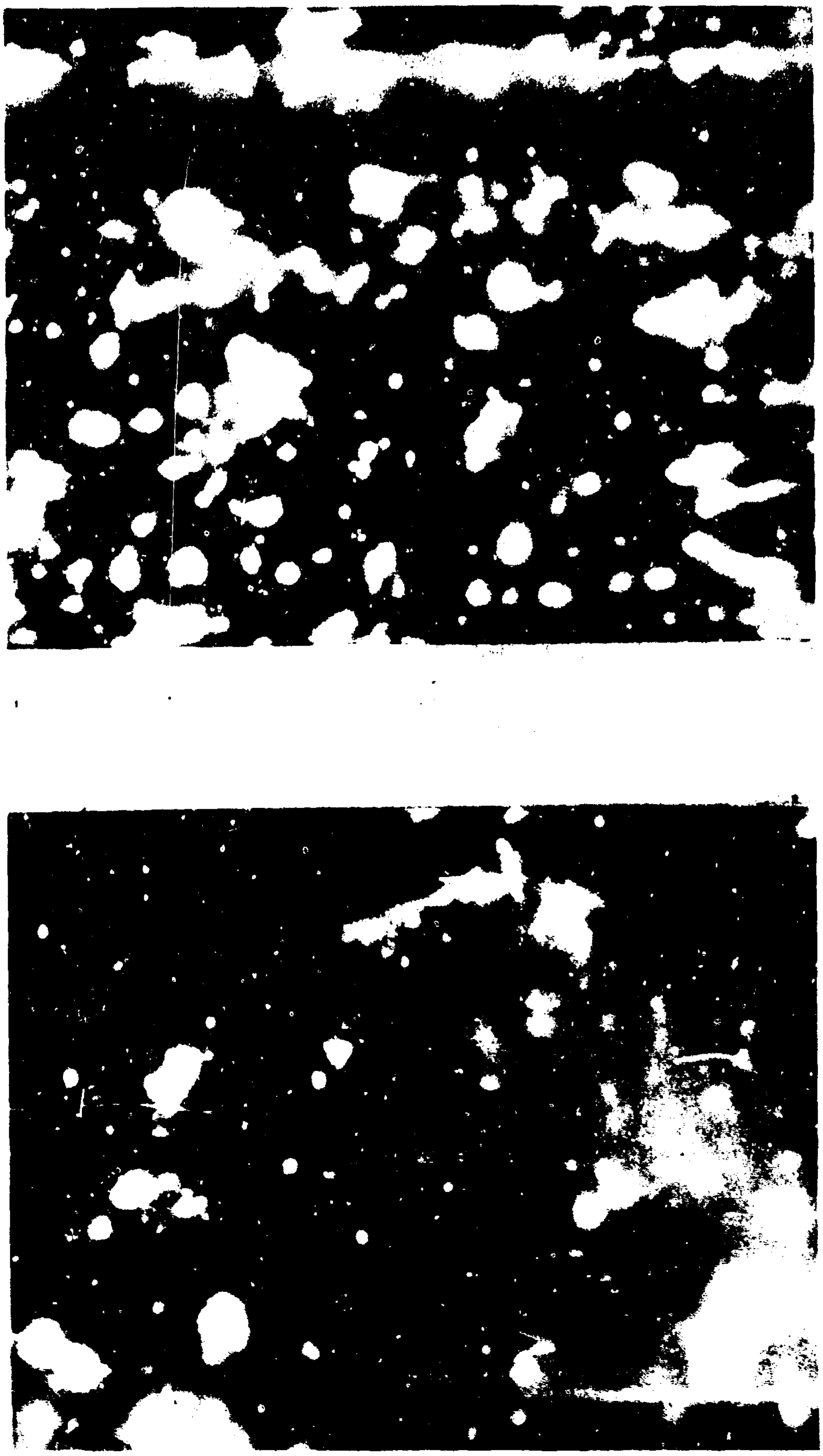

Figure 5.3 Radioautograph of Flathead fallout on uncoated fir decking section with marine-glue paying. Section in upper picture had no washdown protection, lower one had washdown protection.

film onto the surface where they remained, but most ionic material may have been diluted by washdown and then washed away before becoming fixed to the surface.

5.3.3 Decontamination of Wooden Decking. With the given decontamination procedure of firehose, detergent scrub, firehose, the fission product contaminant from Zuni fallout was removable to a lower residual than the contaminant from Flathead and Tewa (Table 5.3). There were no observable decontamination differences among the coatings, nor was any consistent improvement in decontamination attributable to coating the wood rather than leaving it uncoated.

All decontamination data were highly variable; variations of ±100 percent of the mean residual were not uncommon. The Tewa fallout decontamination data for Stations 1 and 2

TABLE 5.2 RELATIVE EFFECT OF WASHDOWN ON THE VARIOUS FALLOUTS

As Stations 1 and 2 may have inherently received differing amounts of fallout due to ship configurations, the washdown effect is described relative to Shot Zuni uring mean radiation levels, thus

$$\frac{\text{washdown}}{\text{unprotected}}\ (\text{Shot X}) \div \frac{\text{washdown}}{\text{unprotected}}\ (\text{Shot Zuni})$$

Shot	Amount Remaining Compared with Zuni
Zuni	1.00
Tewa	0.9
Flathead	0.16

were so scattered they are not presented: there were many specimens which had more than twice the radiation level after decontamination as before, but there were not enough specimens for a useful statistical test. It was noted that the specimens which showed increased radiation had a low initial fission product radiation level. The fission product may have been transferred to them by the scrub brush from the specimens contaminated with considerable fission product.

Probably the Zuni contaminant was more easily removed because most of the fission product was in relatively insoluble particles large enough to be seen and easily subjected to mechanical and detergent scrubbing action. Autoradiographs (Figure 5.4) show the difference between the decontamination of coated and uncoated fir. The residual contaminant on the coated fir is in spots, which are probably depressions in the surface, while that on the uncoated fir appears similar to a staining process. A similar effect was noted for teak (Figure 5.5 lower). The Flathead fallout probably was more tenacious than that from Zuni due to the difficulty in removing the much smaller particles associated with the

TABLE 5.3 DECONTAMINATION OF DECKING SPECIMENS

Decontamination sequence was firehosing, hand scrubbing and firehosing.

Shot	Specimen	Percentage * of Activity Remaining			
		Unprotected		Washdown	
		Fir	Teak	Fir	Teak
		pct	pct	pct	pct
Zuni	Deck planking	14	12	10	11
	Core sample	15	9	14	23
Flathead	Deck planking	45	29	75	94
	Decking sections	29	39	78	50
Tewa	Barge deck planking	42	44	—	—

* Mean of 12 specimens.

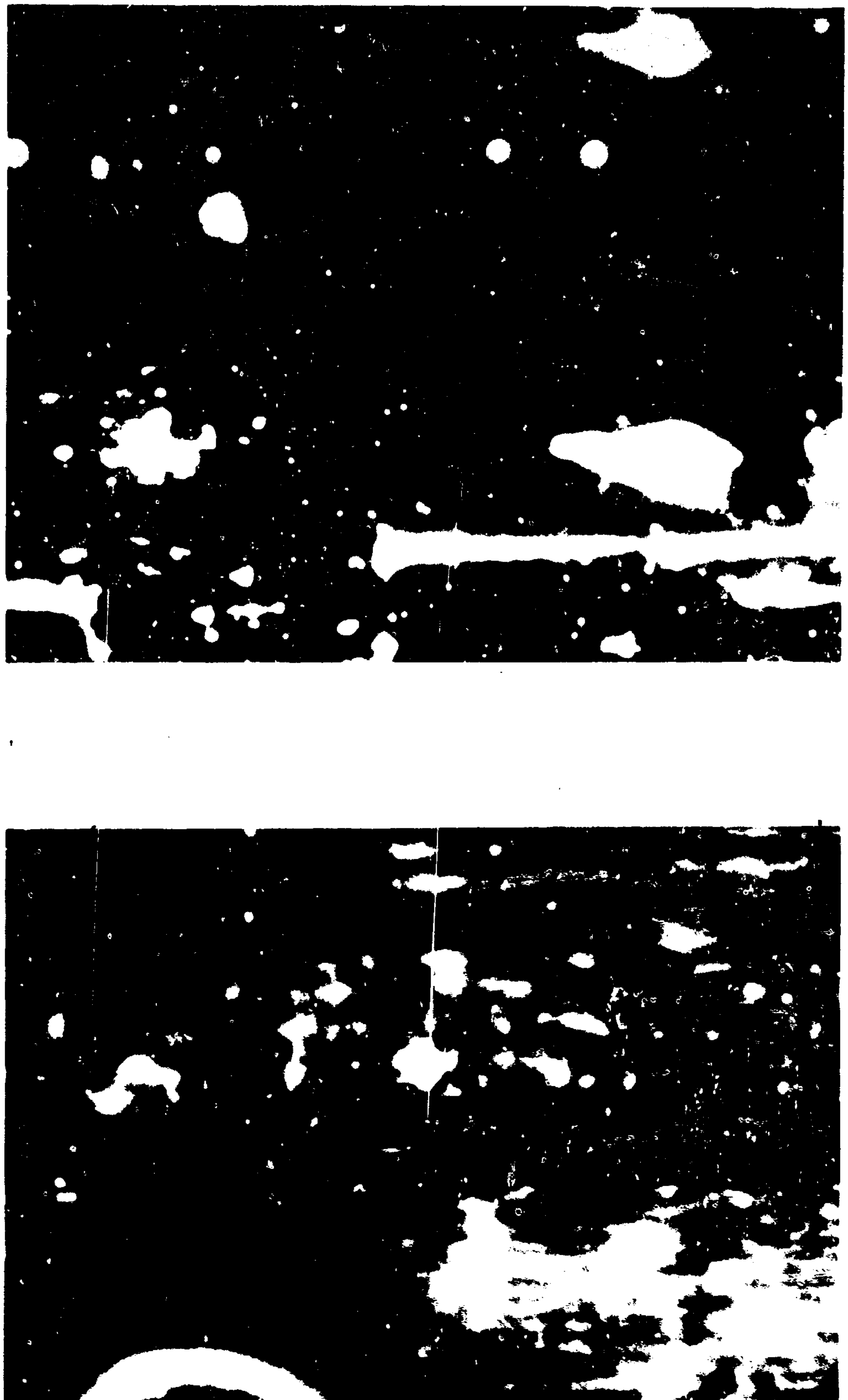

Figure 5.4 Radioautograph of Zuni fallout on decking sections of uncoated fir (lower) and fir coated with navy-gray paint (upper) after decontamination.

wet fallout and the greater percentage of absorbed fission product. The difficulty in removing Tewa fallout as compared with that from Zuni was probably due to the difference in the mean particle size rather than type.

The reason none of the coatings showed better decontamination characteristics than uncoated wood is likely due to the crude decontamination operation used in this experiment rather than coating failure. A mechanical, rather than hand motion would test the importance of coatings in decontamination better.

The degree of success of the firehose, detergent handscrub, firehose decontamination procedures for wood appears to depend directly upon the particle size of the fallout material. Theoretically, it would seem reasonable that the smaller particles would be readily trapped in the surface irregularities of the wood and subject to large adhesive forces because of their high area-to-mass ratio.

The washdown countermeasure apparently influenced the percentage residual contamination; the greater the washdown effect, the less is the decontamination procedure effect. A decontamination procedure generally shows a higher percentage residual contamination if the surface under test has had prior decontamination treatment; washdown may act as such prior treatment.

5.3.4 Paying Studies. The differences in contamination-decontamination of paying materials were expected because of crazing and loss of adhesion to the wood surface. These effects would result from weathering and heavy usage. The 5-week (minimum) weathering during these tests was insufficient to produce a difference in the physical appearance of the payed joints. Payed joints lower than the normal surface were contaminated to a much greater degree than the adjoining wood (Figures 5.2 and 5.5). The payed joints were not more difficult to decontaminate than the adjoining wood. The marine-glue payed joints of the boat deck were severely cracked: autoradiographs made after decontamination showed that the joints were more contaminated than the wood. The sunken payed joints were contaminated highly, due, no doubt, to migration of the contaminant during the washdown or rains.

5.3.5 Penetration of Fallout Fission Products into Wood. Sixty specimens exposed to Zuni fallout were analyzed for depth of penetration. Values for fission product distribution in representative specific samples is presented in Figure 5.6. No differences due to types of coatings were observed. The amount of fission product found below the first intact section was approximately 70 c/s, for both fir and teak, and was apparently independent of initial contamination level and washdown protection. There was about 50 percent less fission product below the first intact section after the decontamination procedure than before decontamination. This decontamination procedure lowered the gross fission product contamination to a residual of about 12 percent. From the standpoint of decontamination operations, it is noted that even after decontamination, the bulk of the fission product was in the rough surface of the wood, and that more than 99 percent of it was less than 2 mm deep.

Wetting wood which had been contaminated with fission product caused the contaminant to move into the wood slightly. These results are presented (Figure 5.7) as the residual radioactivity remaining after removal of a surface layer of given thickness. The specimens treated were smooth and rough fir and smooth teak. The rough fir and smooth teak showed no effect and results are not presented. The fission product migrated into the smooth fir to a slight extent.

There was little penetration of the fission product into wood beyond the rough surface; under the conditions of this test, the effect of coatings was not detected. Increased pene-

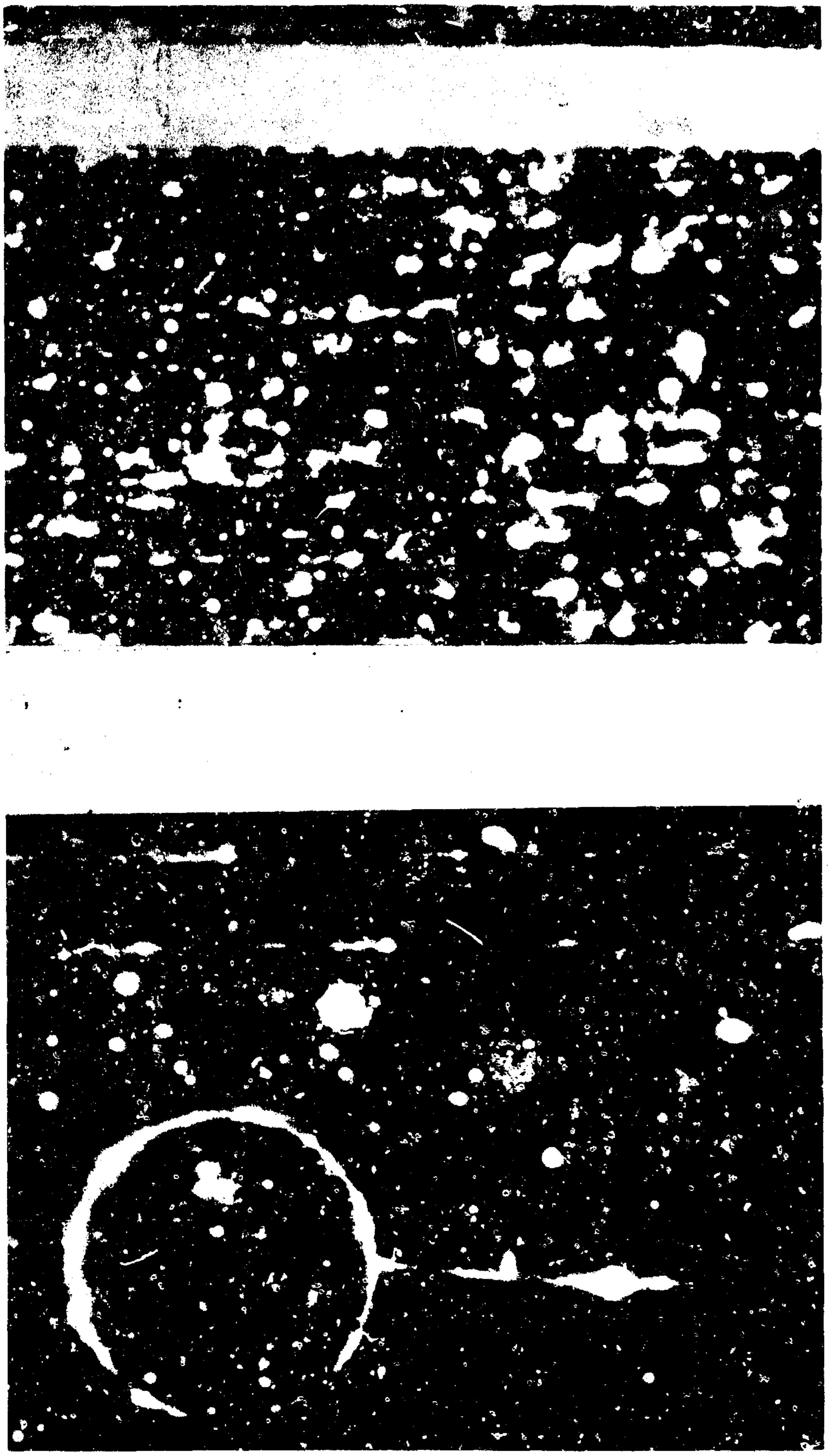

Figure 5.5 Radioautograph, payed joint of uncoated teak decking. Upper figure, before decontamination; lower, after decontamination.

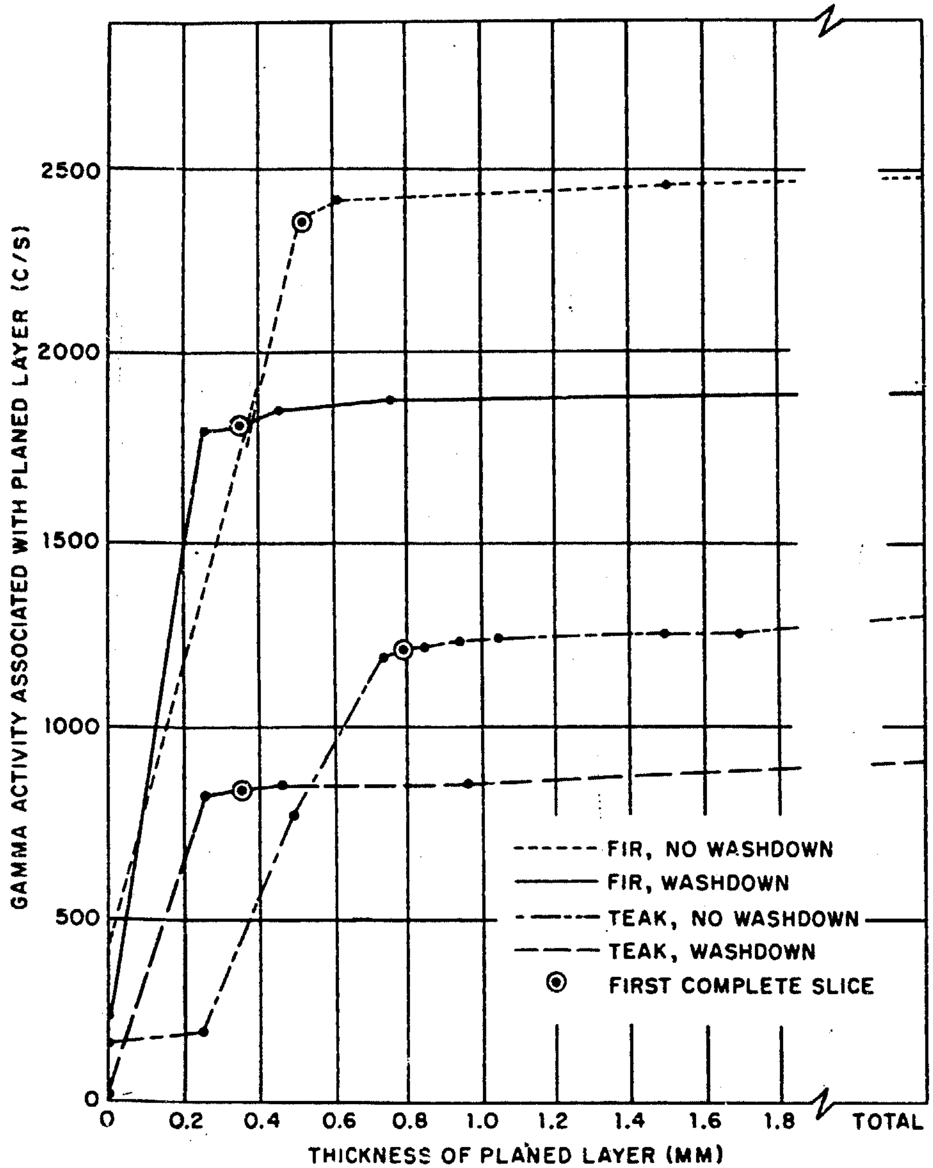

Figure 5.6 Gamma activity distribution in fir and teak exposed in washdown and nonwashdown areas.

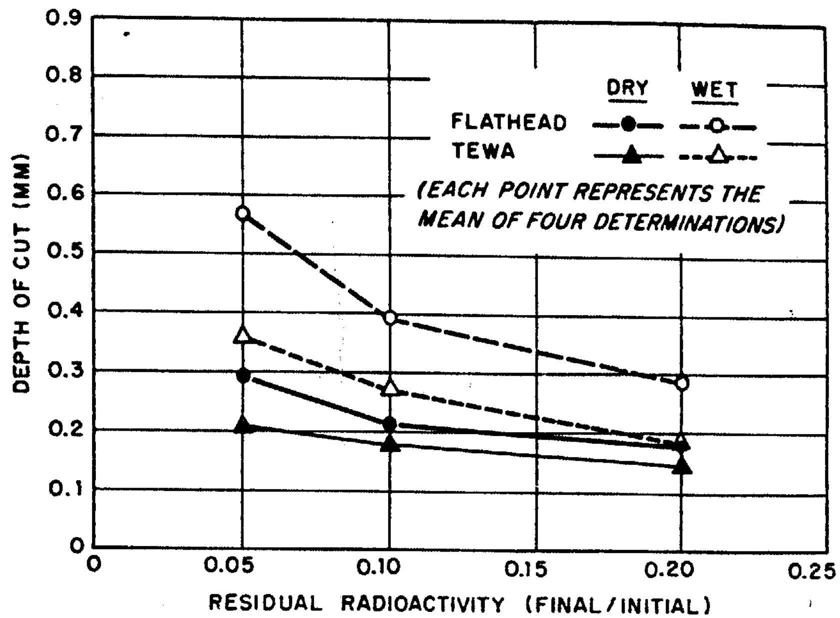

Figure 5.7 Gamma activity distribution in samples wetted after being contaminated.

Chapter 6

SKIN DECONTAMINATION AND PROTECTION METHODS

The decontaminating crews and technical personnel involved in Operation Castle frequently contaminated their hands with radioactivity. Most cases could be remedied by using such decontamination procedures as cleansing with soap, or detergent plus corn meal, or other agents with water. Near the end of the operation there was one instance in which an individual's hands became highly contaminated (higher than a scale reading of 20 mr/hr beta-gamma). Repeated use of stardard decontamination and other procedures over a 3-day period failed to remove the contamination appreciably. A sample of mechanics' waterless hand cleaner which was tried removed the contamination to background in 5 minutes after only three cleaning cycles.

Barrier creams have been formulated to prevent dirt from getting into the pores of the skin. It was thought that some barrier creams might also have the ability to prevent radioactive contamination from adhering to the skin.

At Operation Redwing, naval officers, enlisted men, and civilian scientists and engineers worked aboard Program 2 test ships while they were contaminated by fallout from nuclear tests. These men had extensive training and experience in operating in contaminated areas. In general, they appeared to be aware of the relation between hazard and intensity of radiation fields. They respected, but did not fear radiation, and they avoided it as much as possible.

Protective clothing and radiation detection instruments were available for the use of all persons entering radiation fields. Fortunately, the dosage control problem was not as difficult as anticipated. The possibility of exceeding gamma radiation exposure limitations was unlikely during a normal work period aboard the ships. However, the limitations to long-term beta exposure are so low that, to prevent transferring the contaminant to the mouth, the hands had to be thoroughly cleaned and monitored.

6.1 OBJECTIVES

The purpose of this phase of Project 2.8 was to determine the extent to which the hands of personnel working in fallout areas became contaminated and to develop more-effective methods of removing radioactive contamination from the skin or protecting it by making the skin less susceptible to the retention of radioactive contamination.

6.2 PROCEDURES

Before boarding the ships after Shot Zuni, half of the men protected their hands with a water-repellent barrier cream. Upon their return ashore all the men were processed through the Personnel Decontamination Center where two hand counters were situated: one, at the entrance to the showers and the other at the exit. Beta counts were taken from the palms of the hands before and after cleaning. Two cleaning methods were employed: half the men used Sta-Lube Hand Cleaner, an ammoniacal, petroleum-based, waterless cleanser manufactured by Laird, Incorporated, 4001 Bandini Boulevard, Los

Angeles, California; the other half took a whole-body soap-and-fresh-water shower. Approximately 15 cm^3 of the waterless cleanser was thoroughly rubbed onto the hands until fluid and then removed with cloth toweling. In showering, only normal amounts of soap and water were used.

The NRDL large-area beta counter was used for assessing beta contamination on the hands. This instrument consists of a modified AN/UDR-9 radiac set, a preamplifier, and a detector. The AN/UDR-9 was modified to include an Eagle Signal Company 5-minute Microflex timer in place of the normal switching and timing circuits. This modification simplified the operation of the instrument. The preamplifier is a 3-tube device with a gain of approximately 1,000. The detector uses an 8-by-10-by-⅛-inch sheet of National Radiac Sintilon B plastic scintillant. The scintillant is coupled with 10^6 centistoke DC-200 Silicone oil to a segmented Plexiglas light pipe coupled to a DuMont Type 6364 photomultiplier tube. The detector-preamplifier combination is contained in a light-tight box with a removable cover. The instrument was set to give a 30-second count.

6.3 RESULTS AND DISCUSSION

The hand-contamination levels for all Program 2 personnel returning from work aboard the contaminated test ships (except for those who were omitted due to instrument failure) are presented as cumulative frequency distributions in Figure 6.1 and as geometric means in Table 6.1. These data have been related to approximate microcuries (Reference 3), and to the maximum permissible contamination level as recommended by two different authors (References 4 and 5). The mean radiation level at the time of entry to areas not protected by washdown is given for the most radioactive ship as an approximation of the radiation levels encountered.

After Shot Tewa, instrument background rose to 140 times normal, then decayed, indicating the probability of a fallout at the Personnel Decontaminating Center, and the adjacent housing area. This widespread, uncontrolled contamination tended to put an upward bias on the hand contamination resulting from Shot Tewa.

TABLE 6.1 GEOMETRIC MEANS OF HAND CONTAMINATION OF PERSONNEL ABOARD TEST SHIPS, PROGRAM 2

Shot	Mean γ Level of Area Aboard the Most Radioactive Ship	Geometric Mean of Hand Contamination	
	mr/hr	Counts *	approx. μc
Navajo	35	4.24	0.04
Zuni	100	15.9	0.16
Tewa	350	57.4	0.6

* Values are net counts per 30 seconds multiplied by 10^{-3}.

Instrument resolution, determined primarily by background radiation, limited the accuracy of data for the lower contamination levels. All persons having less than the minimum resolvable contamination were recorded having the minimum resolvable amount on their hands.

Insufficient data were obtained from Shot Zuni on barrier cream. Further tests of barrier creams were cancelled for subsequent shots when orders were issued for recovery crews to wear rubber-impregnated cotton gloves.

The data for the soap plus water and waterless cleaning methods are presented (Figures 6.2 and 6.3) as initial versus final hand contamination levels. These data are scattered to

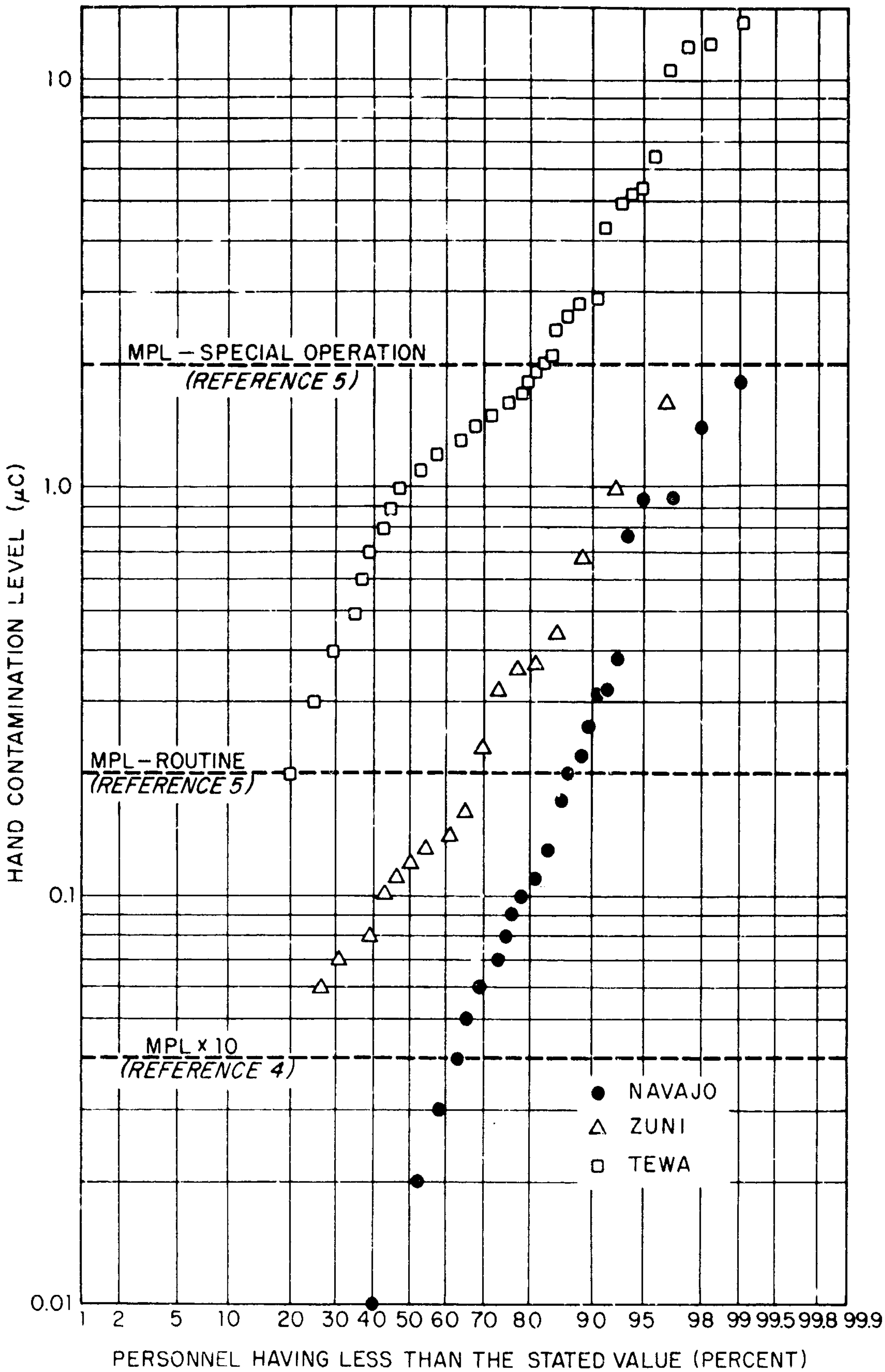

Figure 6.1 Mixed fission products on palms of both hands (μc).

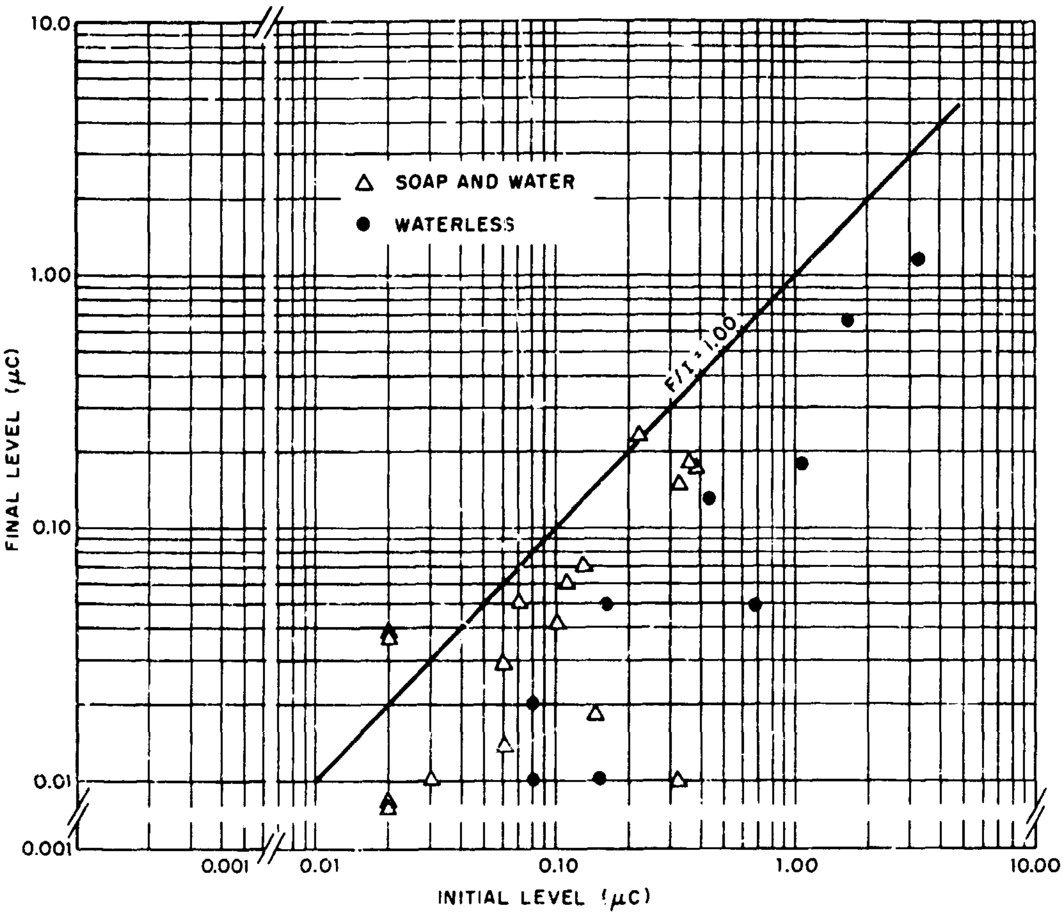

Figure 6.2 Comparison of two methods of cleaning hands contaminated with fission product fallout from Shot Zuni.

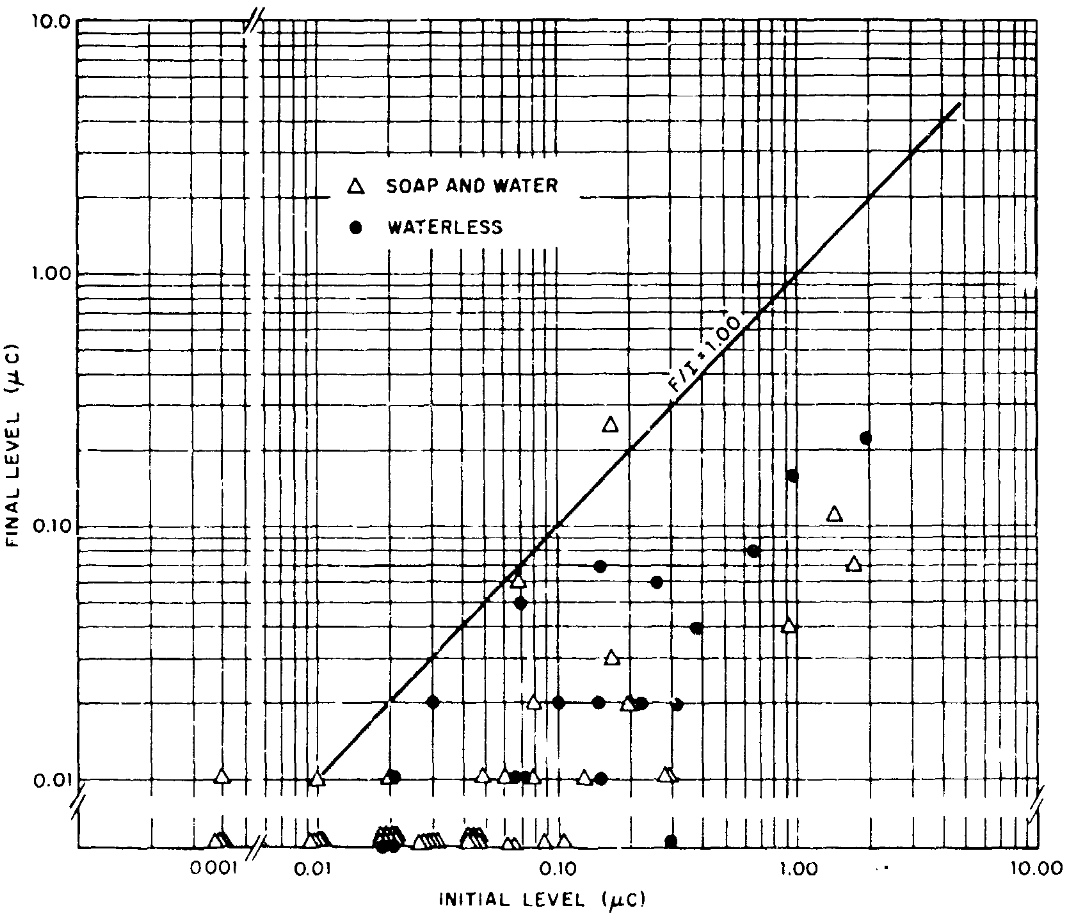

Figure 6.3 Comparison of two methods of cleaning hands contaminated with fission product fallout from Shot Navajo.

such a degree as to make a quantitative comparison of the methods impossible. The two cleaning methods were approximately equal in effectiveness.

There were very few cases of stubborn skin contamination. In one case, however, it was necessary to scrape the callouses on the palm of a ship crew member with a knife to remove the contaminant. The scraping was not deep enough to cause discomfort.

There was no evidence of "beta burn" on any of the personnel participating in this experiment. The highest count rate observed was 5×10^6 c/m or approximately 25 μc after Shot Tewa. Exposure time was approximately 2 hours.

The data on the contamination of hands are probably typical for well-trained personnel operating in the given radiation fields. However, the data should not be extrapolated to situations involving untrained personnel or more intense radiation fields.

It is expected that the hand contamination hazard to a military operation would basically depend upon actual radiation fields and character of the contaminant, the operation commander's knowledge of radiation conditions, personnel training and decontamination equipment, and restrictions on time and movement imposed by the operation.

6.4 CONCLUSIONS

The hands of personnel with good radiological-safety training became contaminated with fallout material under field test conditions. The geometric mean of hand-contamination level varied directly with radiation field intensity.

Approximately 25 μc of mixed fission products in contact with the hands for 2 hours gave no evidence of irritation.

Soap plus water and ammoniacal petroleum-based waterless cleaner were equally effective in removing the fission product contamination from the hands.

Chapter 7

MONITORING AND HAZARD ASSESSMENT METHODS

Experience at Operations Castle and Wigwam indicated that data for evaluating shipboard countermeasure methods were best provided by portable radiac instruments. The mobility of these instruments made it possible to obtain in any specific region the great number of measurements especially needed for decontamination studies. Both beta and gamma instruments have been used to determine the effectiveness of various decontamination methods. The validity of test results has been questioned because of differences in relative beta and gamma values before and after decontamination. Consequently, an evaluation of the methods for assessing radiological hazards must be undertaken to clarify the meanings of measurements made with these instruments.

A survey group was organized within Project 2.8 not only to provide radiological data for decontamination studies and supplementary radiological data for shielding and washdown studies but also to ascertain their usefulness and limitations. The radiological data included direct measurements of gamma intensity and beta activity, beta and gamma counts of wipe samples, and film-badge accumulated dose data.

7.1 OBJECTIVES

It was the purpose of this portion of Project 2.8 to evaluate monitoring and hazards assessment methods and to provide radiological data for Projects 2.7, 2.8, 2.9, and 2.10, Operation Redwing, involving the YAG-39, YAG-40, and LST-611. Specifically it sought to ascertain the usefulness and limitations of the radiological data provided by the various hazard assessment methods performed by the survey group. It is intended only to show how and what accumulated data should be used for the various supported studies.

7.2 OPERATIONS

Monitoring support was given two test ships (YAG-39 and YAG-40) throughout the operation; however, maximum effort was provided for Shot Zuni. Gamma measurements were made to determine the intensity of radioactive fields at specified locations and times. Beta measurements were made and wipe samples taken to ascertain the localized radioactivity on contaminated surfaces.

The survey unit supplemented shielding and washdown data with film dosimetry. The films were placed at various locations aboard the test ships, collected after each shot, processed, and measured at the site. The dosimetry films were DuPont 502, 508, 510, and 1290.

The technical surveys were performed on the contaminated test ships in Eniwetok Lagoon at approximately H + 56; however, the survey of the YAG-39 after Shot Tewa was not started until H + 75. Approximately 200 survey or sampling locations were surveyed on each ship after each shot. Gamma surveys were made with AN/PDR-T1B meters. Beta measurements were made with NRDL beta meters (Reference 6) RBI-12 and RBI-13. The latter one is simply the former with increased sensitivity. All survey data were checked, corrected, and duly transferred to multicopy forms for distribution to other project investigators.

A single wipe sample was taken at each station. This was done by rubbing a 7-cm filter paper by hand over an area of approximately six square inches. These samples were counted at Parry Island with both beta and gamma counters. Beta counts were made with a Geiger tube and the gamma counts with a scintillation detector (AN/UDR-9). This information was recorded on multicopy forms for distribution to other project investigators.

Project 2.9 personnel made both beta and gamma decay measurements on sample surfaces that were retrieved for the test ships after Shots Zuni and Tewa.

7.3 DISCUSSION OF RESULTS

In addition to the discussion of results from decontamination, wipe samples, and film badges, consideration is given to applying the combined measurement as a means of estimating washdown hazard reduction.

7.3.1 Measurements from the Decontamination Studies. The field decontamination studies included direct measurements of gamma intensity and beta activity. They not only covered the overall radiation reduction for a whole ship but also included limited studies, which tested various methods and procedures upon materials, sections, and auxiliary gear of the ship.

Measurement of the overall gamma hazard reduction provided by a decontamination operation may be realized by using gamma data from measurements made at a 3-foot height. Obtaining data for limited studies aboard a contaminated ship is a more complex problem which normally involves measuring radiation from articles or surfaces that radiate differently from their surroundings. Suggested methods included directional gamma measurements, beta measurements, and wipe sample measurements. The first suggestion, although theoretically sound, proved unsatisfactory at Operation Castle because the necessary equipment was too heavy and unwieldy to operate. Consequently, no directional gamma measurements were attempted at Operation Redwing. Objections to using beta measurements were based upon the premise that backscattering and adsorption by both the contaminated particles and the contaminated surface material introduce errors. Selective decontamination (preferential decontamination of beta-emitting isotopes relative to gamma-emitting ones) may also cause the beta measurements to be incorrect. Beta measurements, however, are not affected by surrounding activity and may provide a measure of surface decontamination.

Because no directional gamma-detection device was available, gamma measurements were made at 1-inch heights in an attempt to maximize the surface gamma effects relative to the surrounding gamma effects and to obtain thereby a gamma measurement of surface decontamination.

If the surfaces of the whole ship were decontaminated to an equal extent, all three types of measurements (3-foot-height gamma, 1-inch-height gamma, and beta) would indicate the same decontamination (no selective decontamination). Although this condition was approached in some instances, the ideal condition for data comparison could not be realized because of the partial washdown that the ships had undergone and because of the nature of the decontamination operation. Where certain surfaces were extensively decontaminated relative to its surroundings the gamma measurements made at 1-inch heights indicated a higher decontamination effect and beta measurements indicated the highest decontamination effect.

The results in Tables 7.1 and 7.2 showed that beta and gamma values of F/I (final reading divided by initial reading) were similar except for those for the YAG-40 at Shot Zuni, (Z_{40}). It was on Z_{40} that extensive decontamination was conducted on the Section 2 deck. Examine this situation by separating the influence upon the gamma readings at Section 2. The major sources of surrounding influence are the flight deck immediately forward of Section 2, and Section 3 immediately aft. The average gamma readings taken at 3-foot heights for these areas follow:

Average Flight Deck, F = 24 mr/hr
I = 96 mr/hr

Average Section 3, F = 10 mr/hr
I = 81 mr/hr

On the basis of an unpublished experiment conducted at the Stoneman Tests, about 10 percent of the radiation levels measured at these two areas would be the average meas-

TABLE 7.1 DECONTAMINATION EFFECTS FOR AREA BETWEEN THE FLIGHT DECK AND THE MAIN MAST, SECTION 2

Shot *	Average Values of F/I Ratios †				
	Gamma		Beta	Wipe	
	at 3 feet	at 1 inch		Gamma	Beta
Z_{40} ‡	0.038	0.021	0.0043	0.0143	0.0201
F_{40}	0.20	0.18	0.27	—	—
N_{39}	0.23	0.28	—	—	—
T_{39}	0.22	0.25	0.22	0.039	0.24
T_{40}	0.22	0.27	0.44	0.09	0.20

* Letters Z, F, N, and T designate Shots Zuni, Flathead, Navajo and Tewa respectively. The subscript numerals designate the test ship.
† F/I: Final reading/Initial reading, decay corrected.
‡ Extensive countermeasures experiments.

urable amount in Section 2. On the assumption the measured radiation levels at Section 2 similarly may be separated into two components, radiation from the surrounding sources and local radiation, by taking 10 percent of the above values and subtracting, the following results are obtained:

Section 2

	Measured Gamma Radiation	Surrounding Radiation	Local Radiation
At 3 ft			
Final	4.7 mr/hr	(24 + 10) 10 pct = 3.4 mr/hr	1.3 mr/hr
Initial	124 mr/hr	(96 + 81) 10 pct = 18 mr/hr	106 mr/hr
	F/I = 0.038		F I = 0.012
At 1 in			
Final	4.75 mr/hr	(24+10) 10 pct = 3.4 mr/hr	1.35 mr/hr
Initial	236 mr/hr	(96+81) 10 pct = 18 mr/hr	218 mr/hr
	F/I = 0.021		F/I = 0.0062
Beta Final	21.5 μc		
Initial	5050 μc		
	F/I = 0.0043		

The estimated F/I ratios would be 0.012 and 0.0062. These figures are in the same order of magnitude as the beta measured F/I. The difference noted upon the flight deck cannot be fully explained, but holdup of large amounts of fallout debris was noted in the tie-down channels after decontamination. From the findings here and Castle results, it may be assumed that no appreciable selective decontamination occurred at any of the tests and that the beta measurements are valid indication of surface decontamination.

Calculation of standard deviations for Section 2 of a single test gave values of 28, 37, and 65 percent before decontamination and 48, 80, and 140 percent after decontamination for gamma measurements at 3-foot heights, gamma measurements at 1-inch heights, and beta measurements respectively. In this instance, the non-uniformly contaminated section was made more irregular by decontamination. The calculation was made only to show this and to indicate that for an area of equal size more gamma measurements at 1-inch heights and many more beta measurements would be necessary to attain the same precision as gamma measurements made at 3-foot heights.

TABLE 7.2 DECONTAMINATION EFFECTS FOR FLIGHT DECKS

Shot *	Average Values of F/I Ratios †				
	Gamma		Beta	Wipe	
	at 3 feet	at 1 inch		Gamma	Beta
Z_{40}	0.25	0.18	0.043	0.027	0.032
F_{40}	0.28	0.26	0.31	—	—
N_{39}	0.64	0.74	—	—	—
T_{39}	0.71	1.02	0.69	0.016	0.0096
T_{40}	0.58	0.61	0.33	0.31	0.26

* Letters Z, F, N, and T designate Shots Zuni, Flathead, Navajo and Tewa respectively. The subscript numerals designate the test ship.

† F/I: Final reading/Initial reading, decay corrected.

Figures 7.1 through 7.5 show the relative amounts of topside radiation at each section of the ship at the time of initial survey by each of the three types of measurement. The section with the highest average radiation level was assigned a 100-percent value. The relative effects of washdown upon the topsides are shown for each ship participation as determined by the three methods. The gamma measurements made on 3-foot heights most consistently showed a relatively higher residual contamination value. Gamma measurements made at 1-inch heights showed a median value. These findings were true in every case for the washdown section of the ship that was in contact with the no-washdown section.

7.3.2 Wipe-Sample Results. Wipe samples with gamma and with beta counters were suggested as a method of surface decontamination evaluation. The gamma and beta count ratios presented in Tables 7.1, 7.2 and 7.3 were very inconsistent and varied considerably with each shot as well as with the surface sampled. Some cases of wipe-sample saturation (wipe sample laden to capacity physically with fallout debris) on initial wipes were noted. This inconsistency may indicate probable selective decontamination or selective washdown and a dependency upon the isotopic content of the fallout. Unfortunately, the many variables inherent with wipe sampling along with inadequate basic information about fallout and relative removabilities of isotopes obscured any observable trends. The decontamination ratios and the washdown residual ratios obtained by wipe samples, however, did qualitatively indicate trends found by the other methods of measurements. Otherwise, wipe samples were unsatisfactory in affixing decontamination or washdown values. The data indicate that wipe samples should be limited to their application as a measurement of the removability of the residual contaminant. Furthermore, the measure of remov-

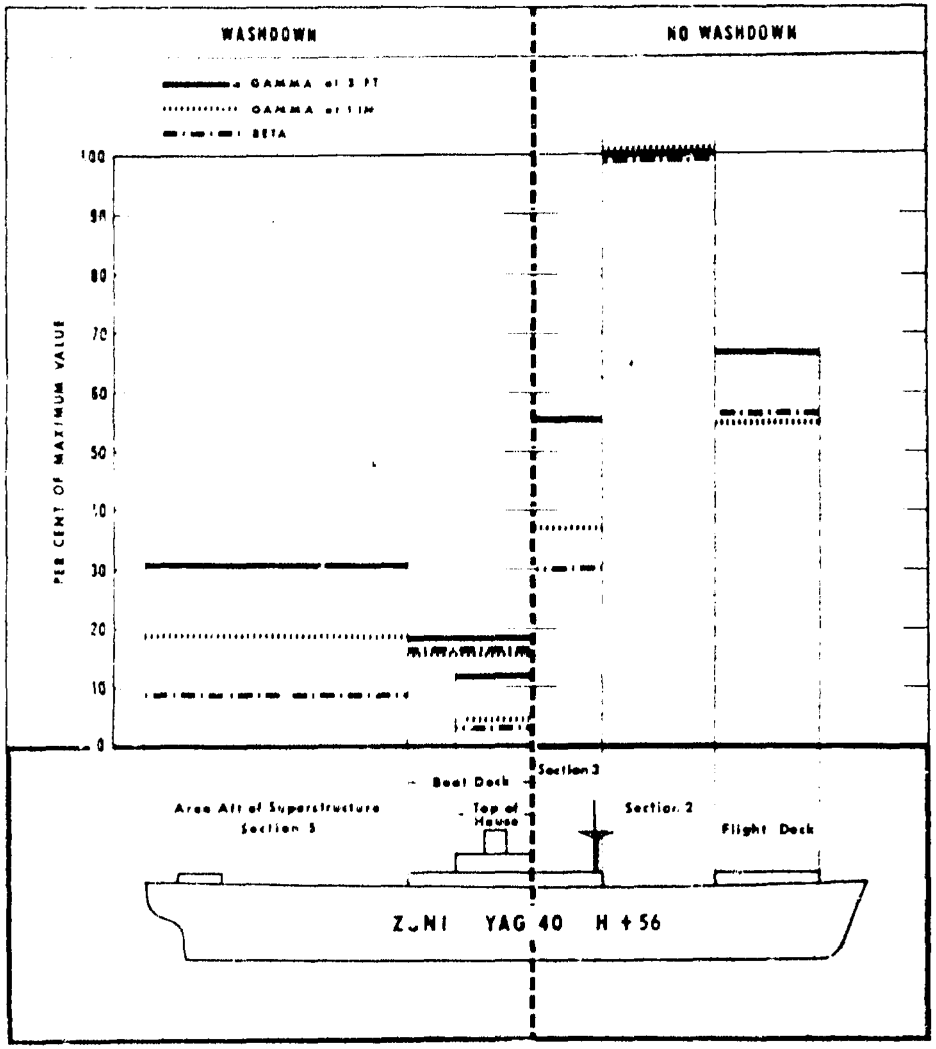

Figure 7.1 Relative residual radiation levels aboard YAG-40 at H + 56 hours after Shot Zuni.

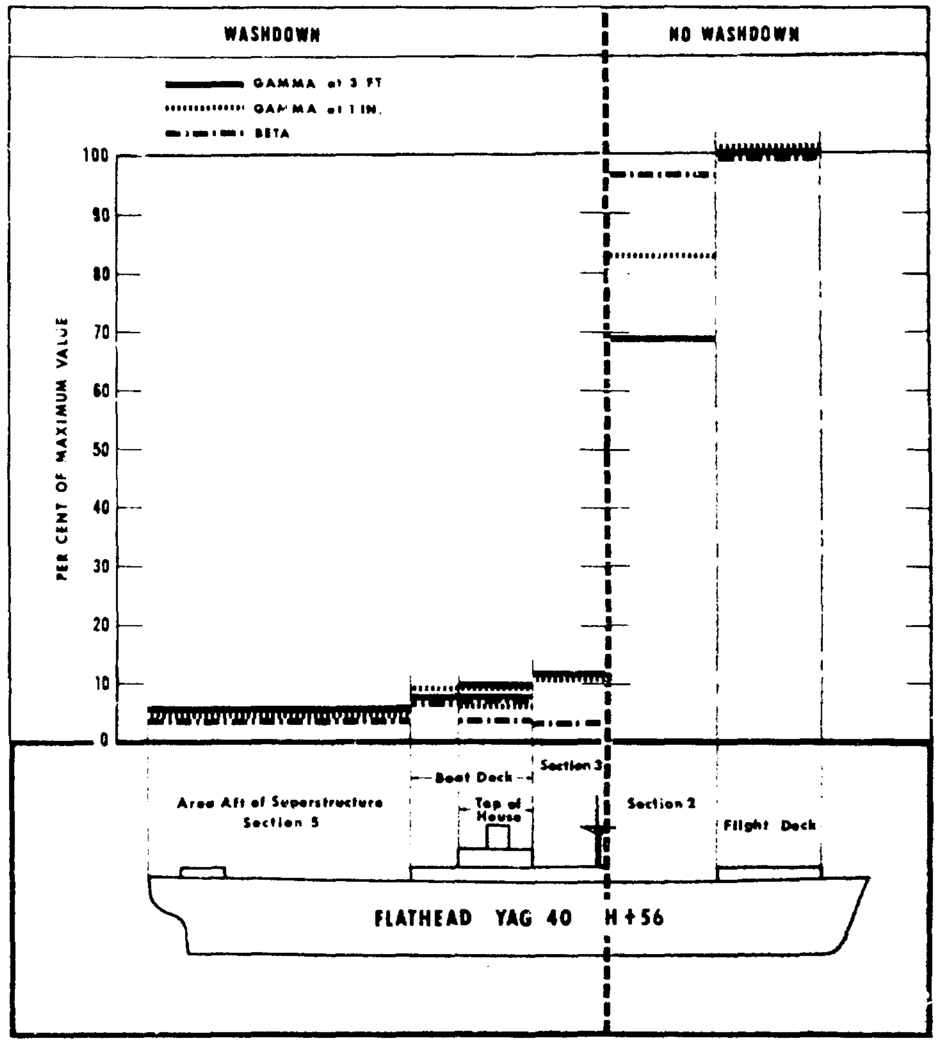

Figure 7.2 Relative residual radiation levels aboard YAG-40 at H + 56 hours after Shot Flathead.

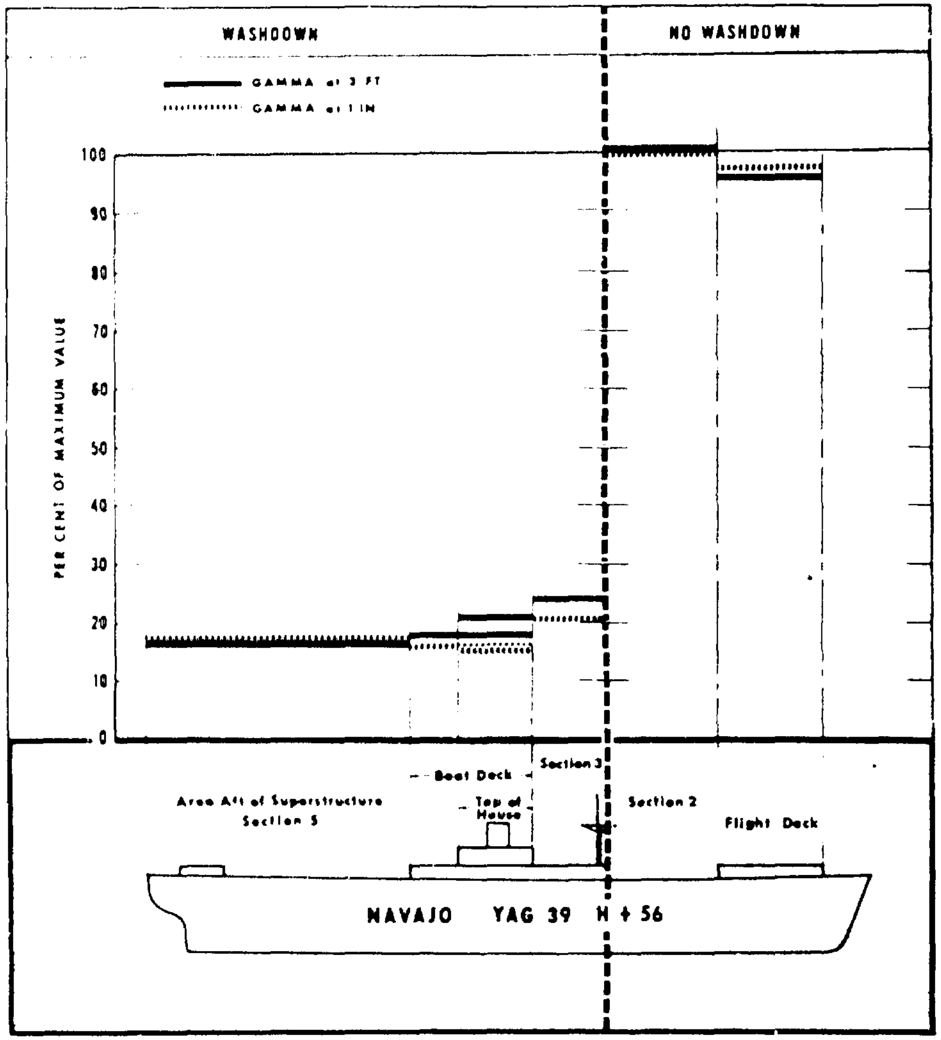

Figure 7.3 Relative residual radiation levels aboard YAG-39 at H + 56 hours after Shot Navajo.

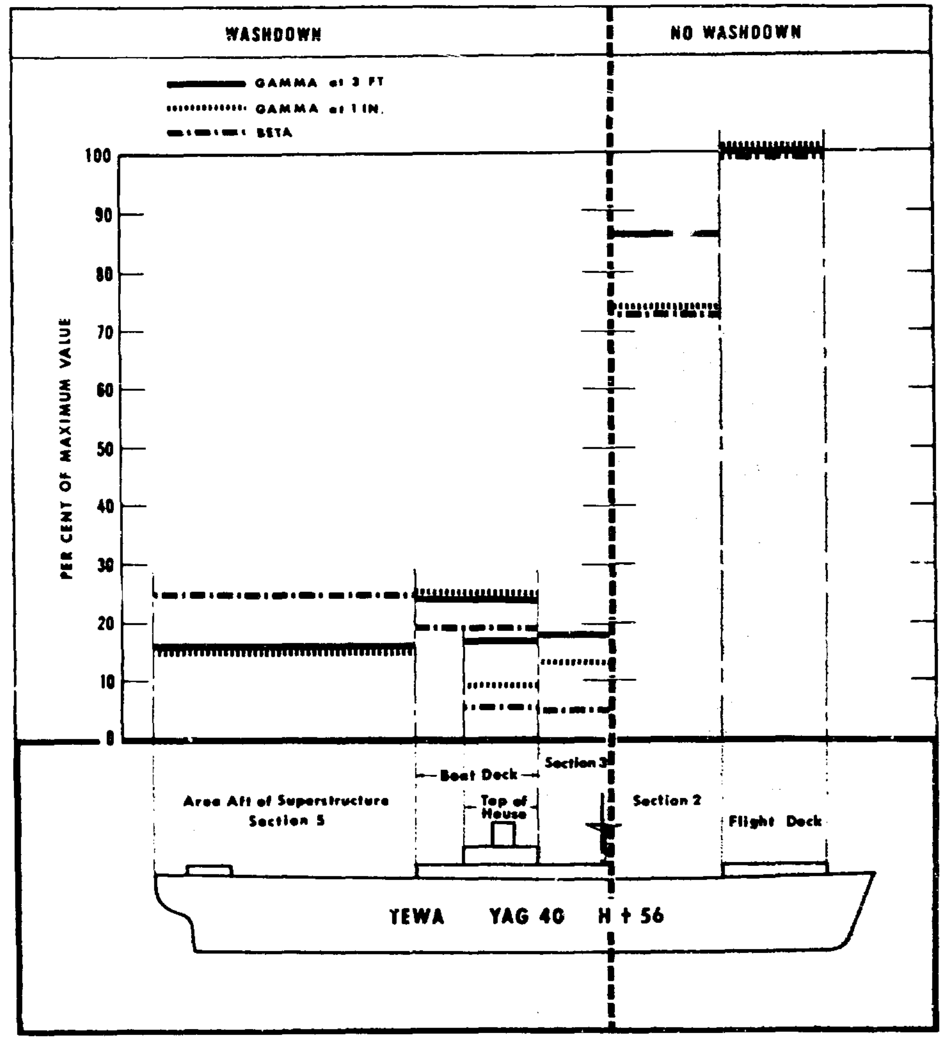

Figure 7.4 Relative residual radiation levels aboard YAG-40 at H + 56 hours after Shot Tewa.

ability is dependent not only upon the surface but also upon the physical nature of the fallout contaminant carrier material.

7.3.3 Film-Badge Dosimetry. Dose rate and surface contamination distribution experienced by test ships at Castle (Reference 1) were shown diagrammatically in the test report of that operation. The accumulated dose distribution as measured by film badges during Project 2.8 are included in this report. The film badges, sealed in polyethylene envelopes, were fastened in support racks with metal clip so that they would be free of all surfaces. Figures 7.6 through 7.13 show the film badge values throughout the ships for each shot participation. Because each ship had a partial washdown system, the shielding effectiveness at each film station was merely indicated by the dose received. Because of the large number of sampling stations, influence of localized concentrations of contamination may be detected; this information may help to clarify any discrepancies

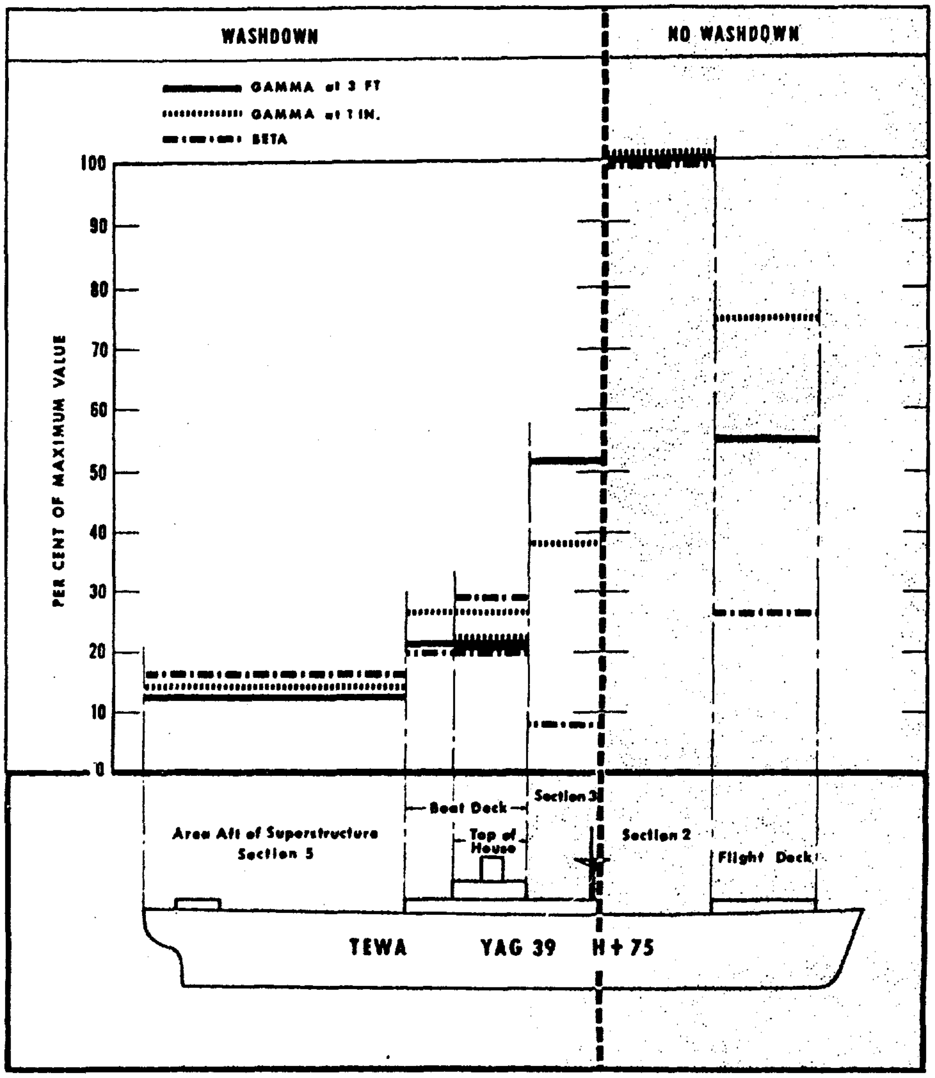

Figure 7.5 Relative residual radiation levels aboard YAG-39 at H + 75 hours after Shot Tewa.

recorded by instruments of the Shielding Project. Dose was accumulated until the films were retrieved after the ships had returned to the Eniwetok Lagoon. The elapsed time was 56 hours except for T_{39} which was 75 hours. Some discrepancies in the film readings were

(Continued on Page 69.)

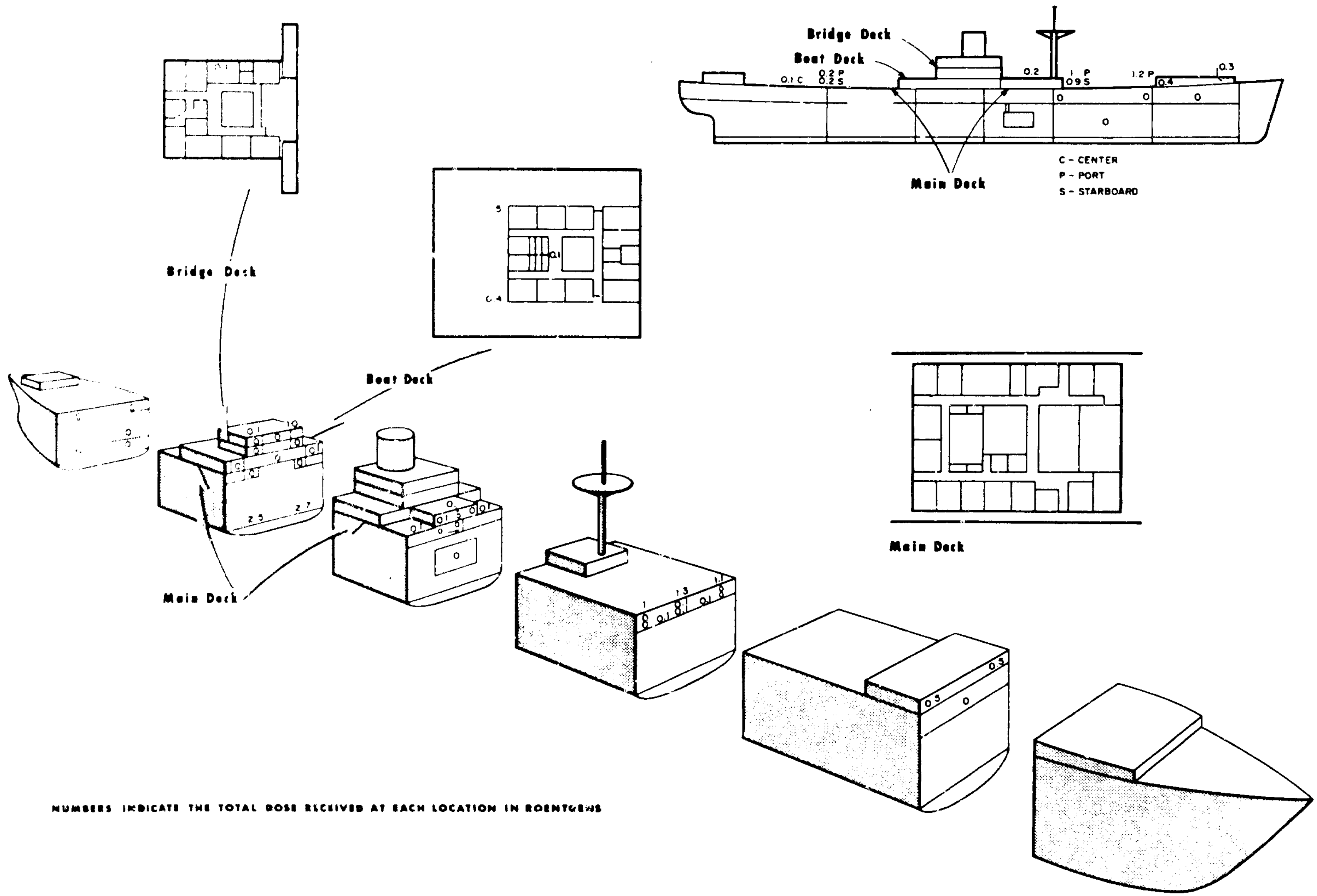

Figure 7.6 Dose distribution aboard the YAG-39 for Shot Zuni (as determined by film badges).

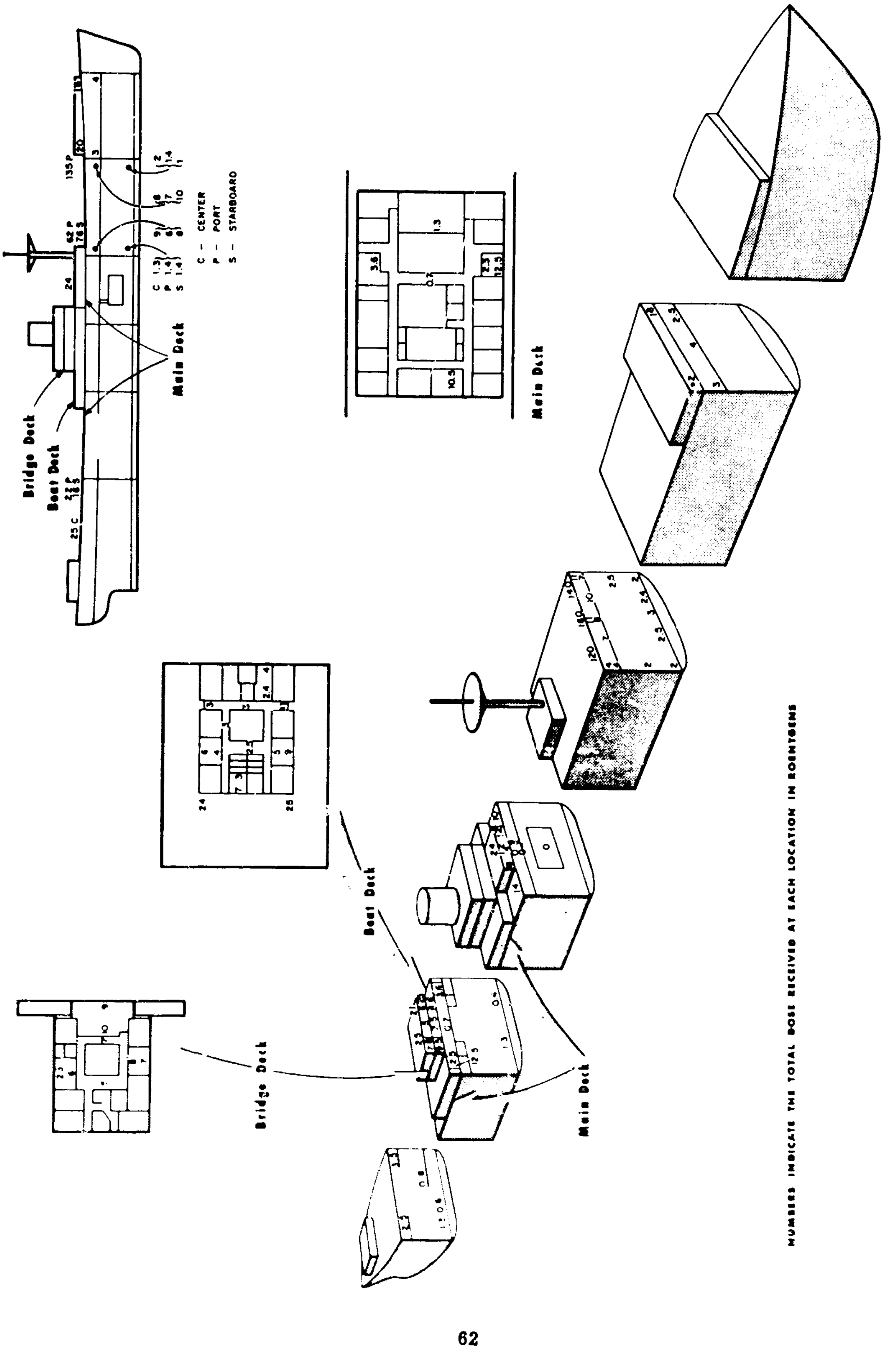

Figure 7.7 Dose distribution aboard the YAG-40 for Shot Zuni (as determined by film badges).

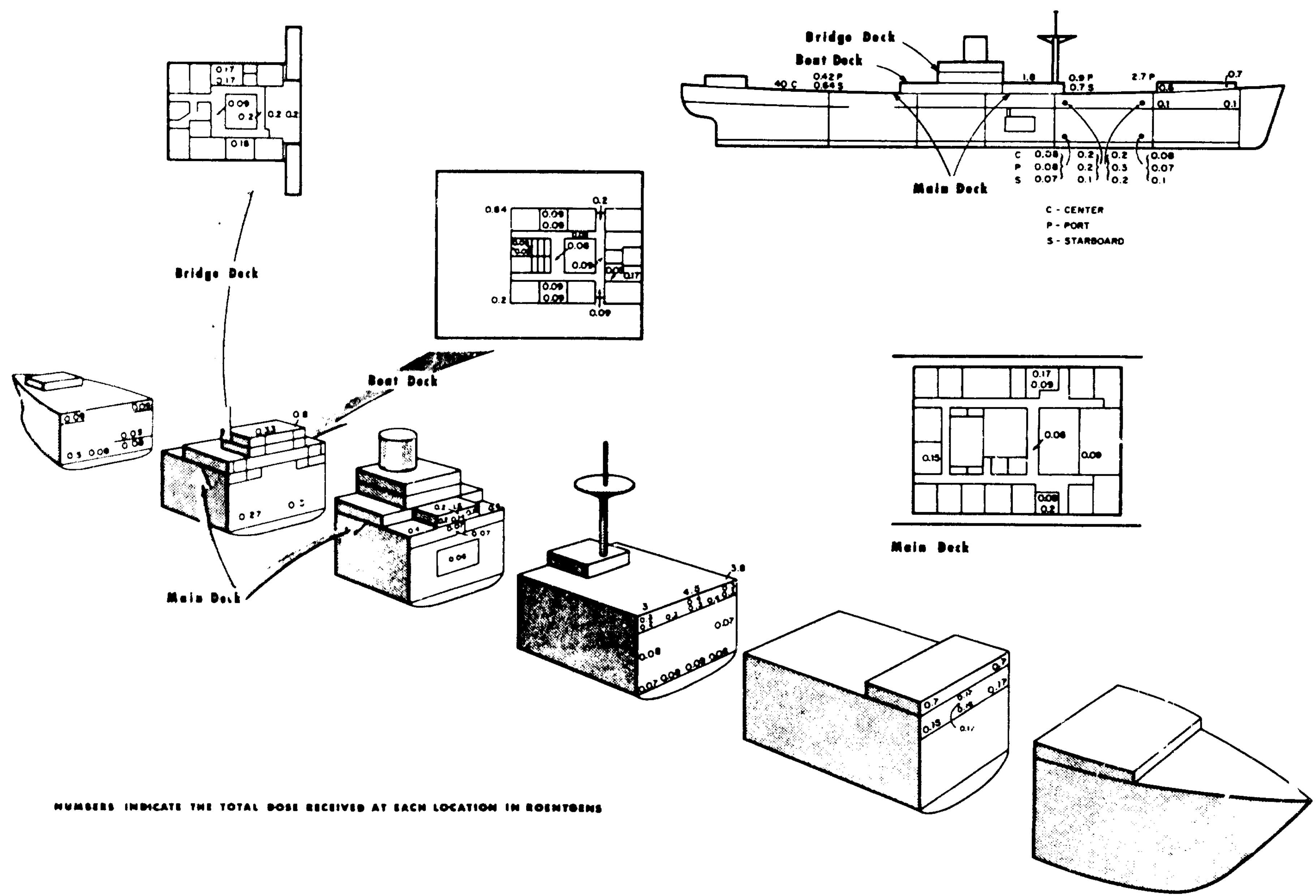

Figure 7.8 Dose distribution aboard the YAG-39 for Shot Flathead (as determined by film badges).

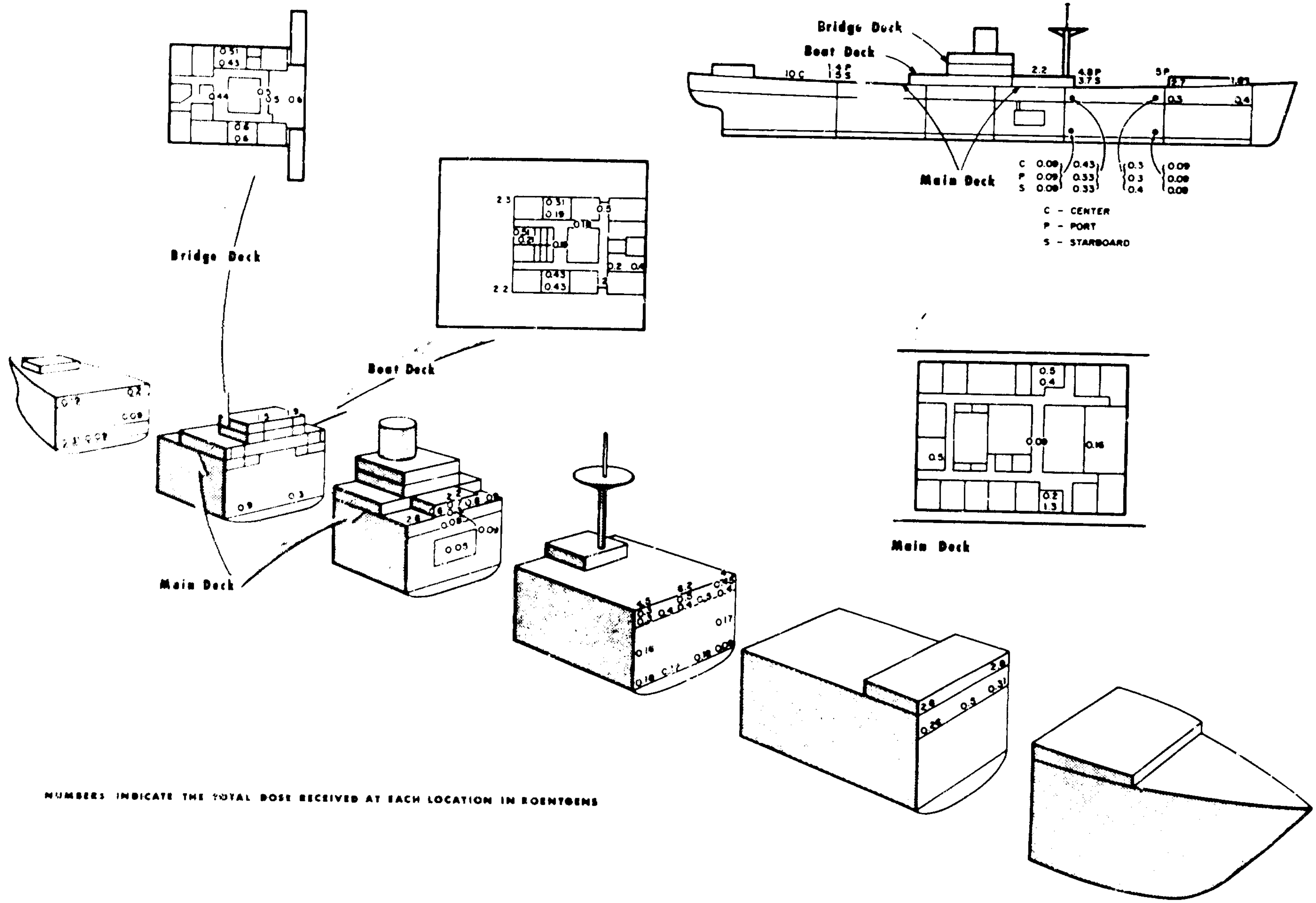

Figure 7.9 Dose distribution aboard the YAG-40 for Shot Flathead (as determined by film badges).

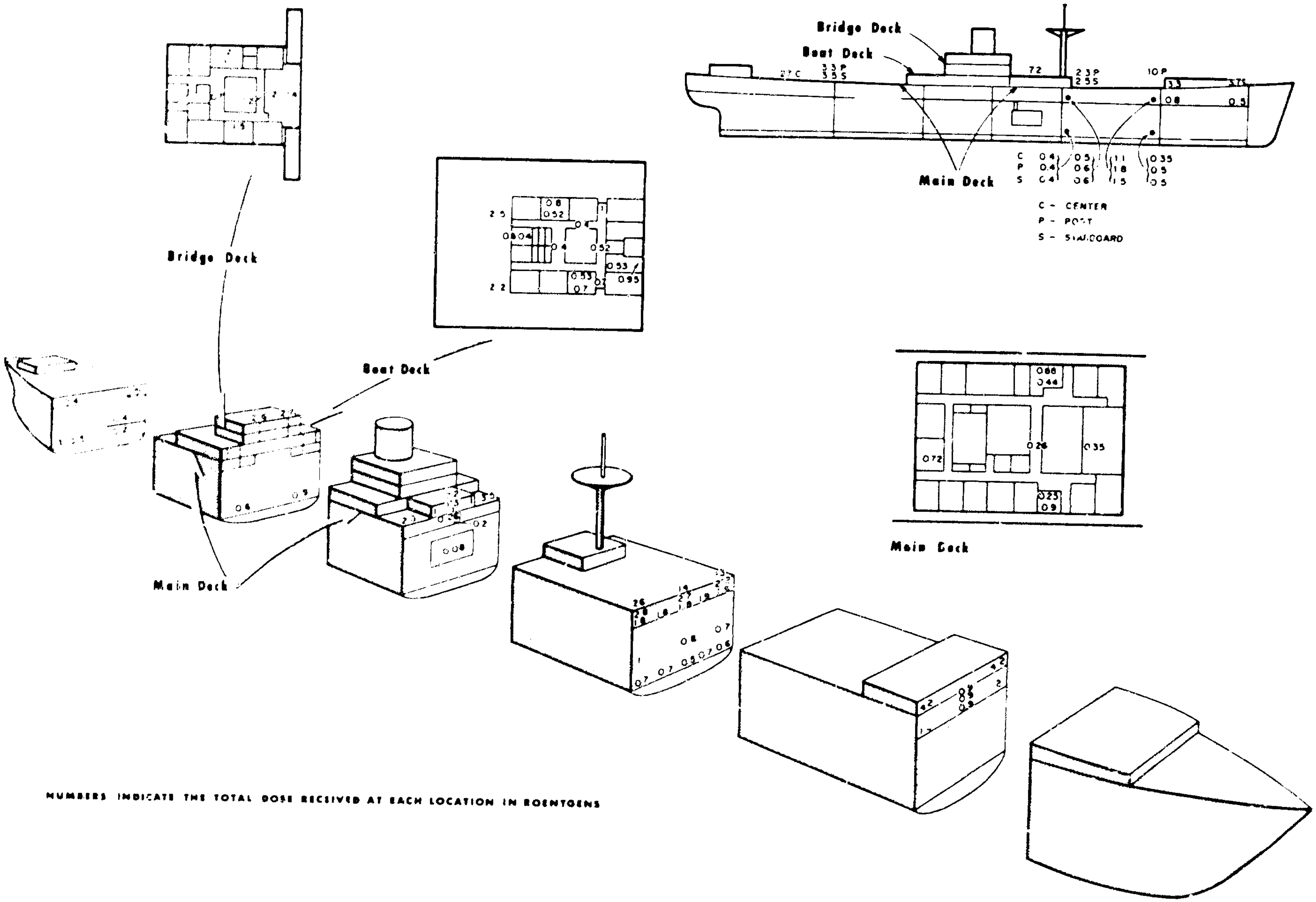

Figure 7.10 Dose distribution aboard the YAG-39 for Shot Navajo (as determined by film badges).

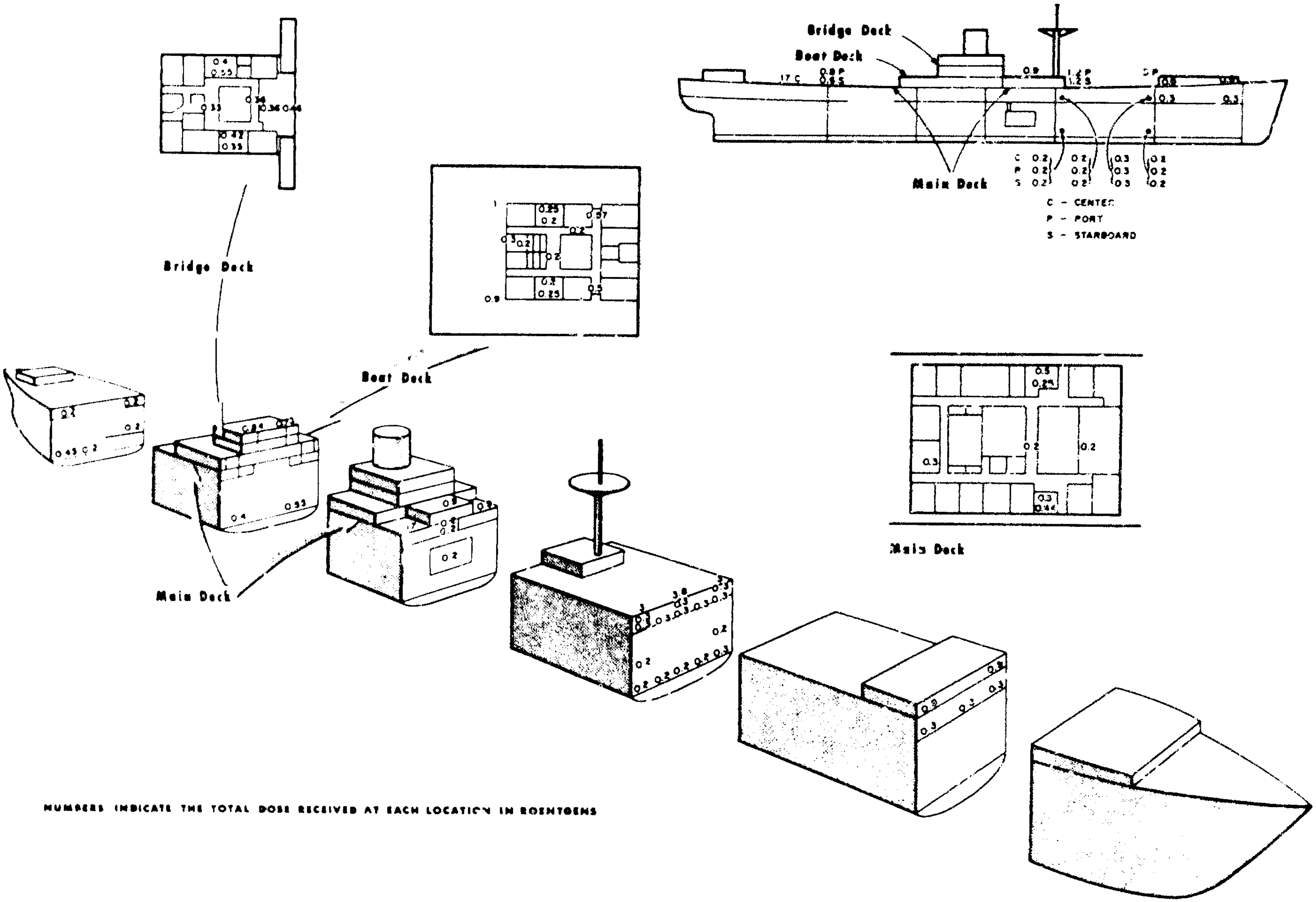

Figure 7.11 Dose distribution aboard the YAG-40 for Shot Navajo (as determined by film badges).

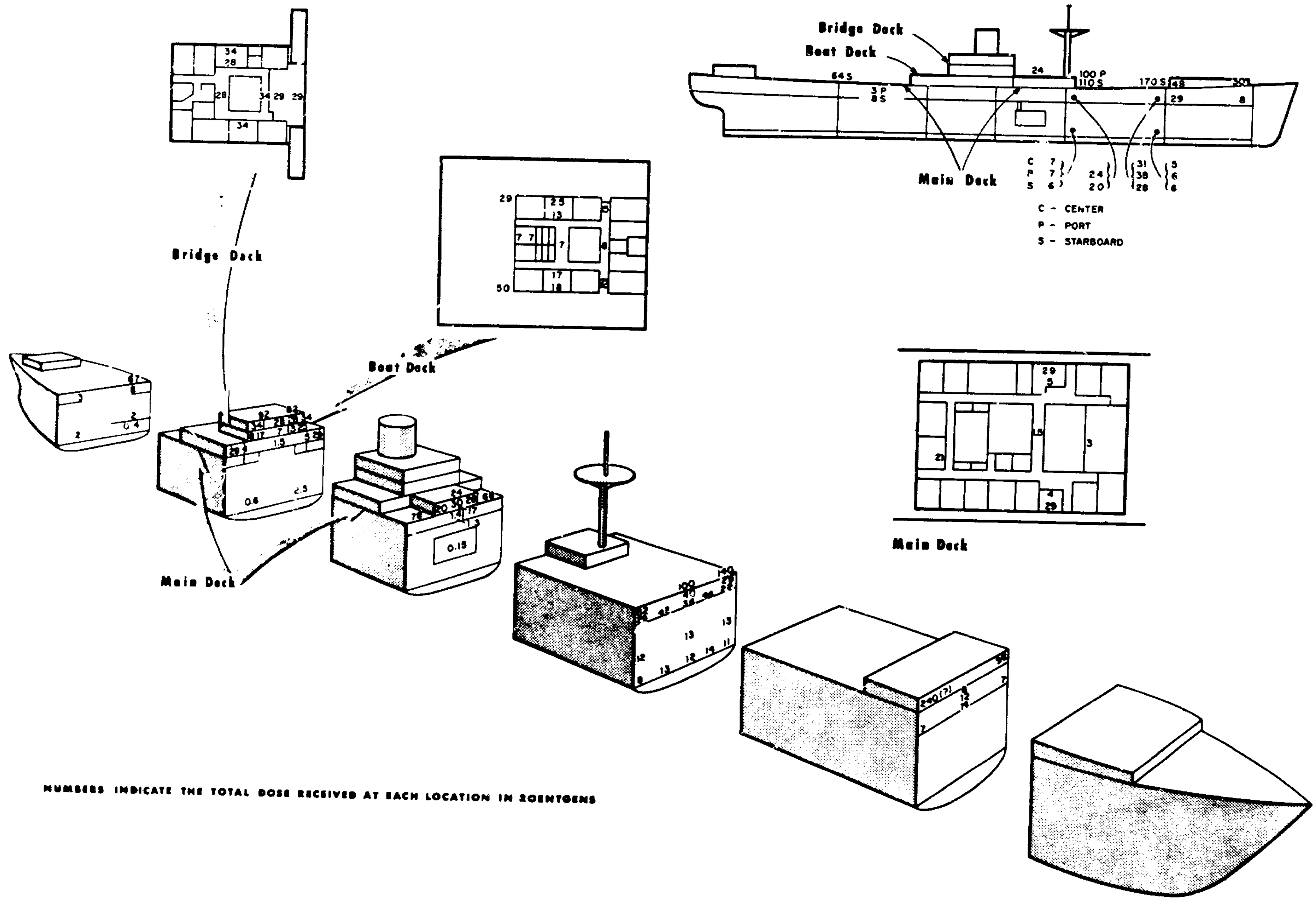

Figure 7.12 Dose distribution aboard the YAG-39 for Shot Tewa (as determined by film badges).

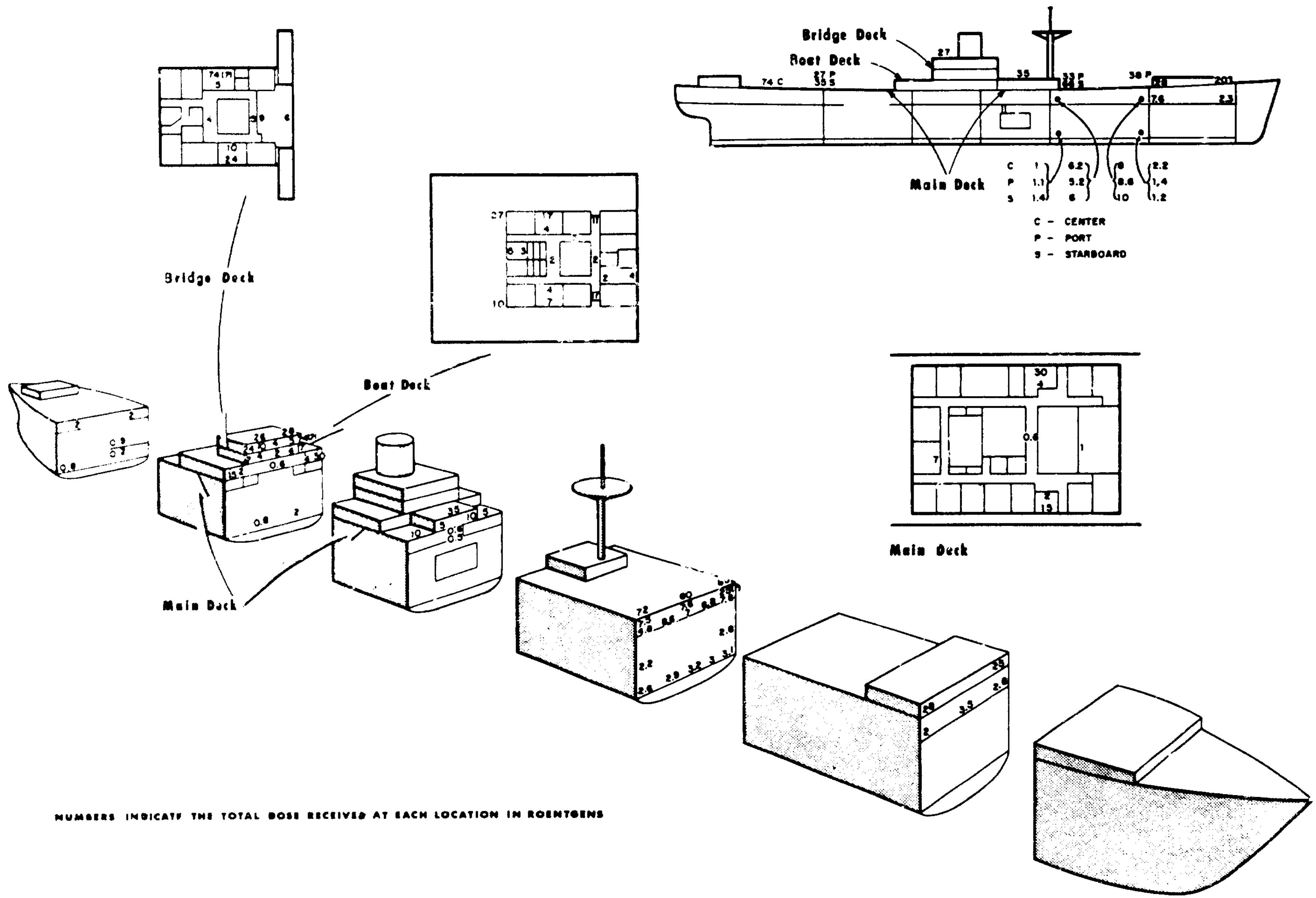

Figure 7.13 Dose distribution aboard the YAG-40 for Shot Tewa (as determined by film badges).

difficult to explain and duplication of films or more extensive sampling throughout the ships would have helped to provide more reliable data.

7.3.4 Application of Combined Measurements. In case of partial or total instrument failure within the washdown project, the combined survey data provided by Project 2.8 were to be employed to estimate the washdown effectiveness. In order to evaluate the relative merits of such a countermeasure system or the relative hazard diminution provided by such a system, the various dose components experienced must be defined. The procedure to obtain dose component estimation is introduced as an alternate hazard evaluation method pertaining to washdown studies. Because this section is primarily interested only in monitoring and hazard-assessment data, and how they may be applied, this discussion is limited to the problems that are involved by the assessment method used. No washdown effectiveness results are included.

This method was handicapped in this operation because of one or more various deleterious conditions that existed during some of the test runs. In one case, the intervention of rain limited the usefulness of the data, in other cases low contamination and low dose levels on the ships rendered some of the film data useless. The influence of localized contamination on film wrapping or objects near the film gave incorrect data. The limited number of film samples made it difficult to affix dose values at some locations. Emergency decontamination operations conducted aboard the ships prior to their return to Eniwetok Lagoon may have altered the data significantly. Nevertheless, acceptable washdown effectiveness information resulted from the test series and under more favorable experimental conditions the applicability of this hazard evaluation method would be enhanced and may be profitably exploited.

TABLE 7.3 MEASURED HAZARD RATIOS OF WASHDOWN EFFECTS

Shot *	R_5/R_2 for Gamma † at 3 ft	R_5/R_2 for Gamma † at 1 in	R_5/R_2 Beta	Tw/T Film ‡ Main Deck	Tw/T Film ‡ Second Deck	R_5/R_2 for Wipes Gamma	R_5/R_2 for Wipes Beta
	1	2	3	4	5	6	7
Z_{39}	ND §	ND	ND	0.09	ND	ND	ND
Z_{40}	0.315	0.19	0.088	0.18	0.58 ¶	0.45	0.50
F_{39}	ND	ND	ND	0.16	—	ND	ND
F_{40}	0.066	0.052	0.042	0.30	—	0.015	0.046
N_{39}	0.172	0.175	ND	0.20 ¶	0.25	ND	ND
N_{40}	ND	ND	ND	0.23	—	ND	ND
T_{39}	0.127	0.143	0.163	0.50	0.155 ¶	0.11	0.45
T_{40}	0.187	0.201	0.343	0.40	0.29 ¶	0.26	0.078

* See footnote (*), Table 7.1.
† Ratio of activity at Section 5 (washdown) to that at Section 2 (no washdown).
‡ Ratio of film dose at Section 5 to that at Section 2.
§ ND, No data.
¶ Where Columns 4 and 5 both had numbers, the ¶-marked value was used in the calculation for Table 7.4.

The washdown effect as determined by comparing measurements taken at Section 2 (no-washdown) with measurements taken at Section 5 (washdown) is shown in Table 7.3. The first two columns list rate (mr/hr ratios) and the third column lists $\mu c/A$ ratios. The gamma at 1-inch heights and beta ratios were included for comparative purposes. The film gamma measurements in Columns 4 and 5 show the total dose ratios between the two areas. The indicated film-dose ratios should be higher than those shown in the first three columns because the film dose included the transit airborne dose which is presumably the same for both sections. The wipe-sample ratios, Columns 6 and 7, were extremely irregular and were only listed to show this characteristic.

Mere comparison of total deck doses between washdown and no-washdown areas is not the complete picture of hazard or washdown evaluation, just as a comparison of the residual deck dose is not a measure of washdown effectiveness. During high-intensity fallout, ship operational plans may include the abandonment of weatherside stations to shielded interiors for the period of fallout. To evaluate the effectiveness of the washdown system under this scheme of operations, the relative values of airborne and residual dose, and available shielding factors must be known.

The airborne and deposited dose ratios may be estimated from the information in Table 7.3.

Let: T = total dose over extended time t, no-washdown
Tw = total dose over extended time t, washdown

then: $\frac{Tw}{T}$ = values in Columns 4 and 5 of Table 7.3.

Let: R = dose from residual contamination, no-washdown
Rw = dose from residual contamination, washdown

and $\frac{Rw}{R} \, . \, . \, \frac{R_5}{R_2} = \frac{\text{radioactivity at time t, washdown}}{\text{radioactivity at time t, no-washdown}}$

then

$$Rw = \frac{R_5}{R_2} R \qquad (7.1)$$

also

$$T = R + A + B \qquad (7.2)$$

$$Tw = Rw + A + B + C \qquad (7.3)$$

Where: A = Transit airborne dose
B = dose from contaminated sea surrounding the test ship
C = dose from fallout deposited in the washdown section but which is subsequently washed off by washdown

It is assumed that $B << R$ or A, and $C << Rw$ or A. R_5/R_2, T and Tw are experimentally measured and Equations 7.1, 7.2, and 7.3 may be solved simultaneously for A, R and Rw, and ratios given in Table 7.4 obtained.

Also, to eliminate the effects of localized contamination, the film doses at the second deck level were compared and the resulting ratios shown in Column 5 of Table 7.3 were used for the calculated values shown in Table 7.4 for cases Z_{40}, T_{39}, and T_{40}. By using second-deck dose measurements the geometric aspects are materially improved in that localized influences are greatly diminished. However, selective wash-off may have caused a difference in the gamma energies in the two areas and thereby affected the shielded film doses obtained.

The relative doses from the air-borne (non-deposited) and the residual (deposited) contamination (Columns 1 and 2, Table 7.4) for both washdown and no-washdown areas are of particular interest. Generally, the relative air-borne dose varied considerably—from 0.2 to 5 times the washdown residual dose, and 0.03 to 0.7 of the no-washdown residual dose. In terms of total doses the air-borne doses varied from 0.2 to 0.8 of the total washdown dose and 0.03 to 0.4 of the total no-washdown dose.

With the above information and knowledge that shielding factors of 10:1 can be had below

TABLE 7.4 WASHDOWN EFFECTS, HAZARD COMPONENT RATIOS, CALCULATED

Shot	A/Rw* Gamma at 3 ft	A/R*†	A/T*‡	A/Tw*§	R/T†‡	Rw/Tw*§
	1	2	3	4	5	6
Z_{39}	—	—	—	—	—	—
Z_{40}	2.1	0.66	0.4	0.68	0.6	0.32
F_{39}	—	—	—	—	—	—
F_{40}	5.1	0.34	0.25	0.83	0.75	0.17
N_{39}	0.2	0.034	0.033	0.17	0.97	0.83
N_{40}	—	—	—	—	—	—
T_{39}	0.26	0.033	0.032	0.21	0.97	0.79
T_{40}	0.78	0.15	0.13	0.44	0.87	0.56

*A = dose from transit air-borne fallout cloud; Rw = dose from deposited residual contamination, washdown.

†R = dose from deposited residual contamination, no washdown.

‡T = total dose, no washdown, extended time t.

§Tw = total dose, washdown, extended time t.

decks for destroyer-size ships and factors of several hundred to one for capital ships, washdown effectiveness can then be estimated for various Navy vessels.

As an example, let the shielding factor afforded by a certain section of a ship be 30:1, and use the data and results from F_{40} (Flathead shot, test ship YAG-40) in Table 7.4.

$$A = 0.25\ T$$
$$R = 0.75\ T$$
$$Rw = 0.2\ A - 0.05\ T$$

Divide

A by 30 (shielding)

$$\frac{A}{30} = 0.00833\ T$$

Then, the no-washdown dose for personnel that took shelter during the fallout period becomes

$$T_{Pn} = R + \frac{A}{30} = 0.75\ T + 0.00833\ T = 0.75833\ T$$

and the washdown dose

$$T_{Pw} = Rw + \frac{A}{30} = 0.05\ T + 0.00833\ T$$
$$= 0.05833\ T$$

Consequently, the washdown effectiveness

$$W.E. = \frac{0.75833 - 0.05833}{0.75833} \times 100 = 92.3 \text{ percent}$$

The shielded deposited deck dose during fallout is assumed to be relatively small when compared with A.

Although it is clear that this countermeasure may be evaluated in this manner, great emphasis should be placed upon a complete explanation of the circumstance and meaning of any countermeasure effectiveness number.

7.4 CONCLUSIONS

Under these test conditions, beta measurements appear to be the best of the four methods for determining localized decontamination effectiveness.

Gamma measurements at 3-foot heights provided the best data in determining overall hazard reduction by decontamination.

Wipe sample methods gave only a qualitative indication of the removability of residual contamination.

Washdown effectiveness may be estimated by the combined use of film badges and monitoring data.

Gamma measurements at 1-inch heights on localized surfaces of the test ships were sufficiently affected by surrounding gamma fields to limit their usefulness.

Chapter 8

BASIC CONTAMINATION-DECONTAMINATION STUDIES

Basic contamination-decontamination experiments are conducted to study the mechanism of contamination and develop effective decontamination procedures. These experiments lead to a better understanding of the fundamentals involved in formulating appropriate steps for dealing with situations resulting from the detonation of nuclear weapons. Most of the experiments must be conducted in the laboratory with a simulant and the results extrapolated to a real situation. Field tests are used to check results and to guide in making more realistic laboratory simulants and procedures.

8.1 OBJECTIVES

The objectives of this phase of Project 2.6 were fourfold: (1) comparison of decontamination methods for their effectiveness on a weathered surface when fresh water and chemical additives are used; (2) determination of the effect of time of contact (aging) on the decontamination process; (3) determination of the contaminating properties of a simulant prepared with radioactive fallout and applied in a fog chamber; and (4) comparison of the contaminating properties of radioactive fallout with those of a simulant prepared from neutron-irradiated uranium in total carrier. (Total carrier is a solution of inactive bomb and sea-water products in the proportions in which they are present in fallout.)

Objectives 3 and 4 were not realized because insufficient activity was obtained from Shots Zuni and Flathead to produce a contaminant that could be counted with available instrumentation. It was planned to collect liquid fallout in a bucket, generate an aerosol in a fog chamber, and contaminate paint surfaces artificially. Samples from these plates were to be treated identically to those contaminated by fallout. A comparison of the results was expected to meet Objectives 3 and 4.

8.2 PROCEDURES

Test specimens were 8 1/4-inch-square aluminum plates. One side of eight plates was coated with full-system 5-H grind navy-gray paint and artificially weathered in the Atlas Weatherometer for 90 hours (equivalent to 90 days of natural weathering). Two plates were coated with Zolatone[1] and similarly weathered. The reverse side of the plates was grooved so they could be broken into thirty-six 1 1/4-inch-square samples without marring or disturbing the paint surface or the contaminant. The grooved side of the plates was covered with polyethylene to prevent contamination.

8.2.1 Specimen Exposure. Three navy-gray plates and one Zolatone plate were exposed for the full duration of fallout on the helicopter-landing platform of the YAG-39, well forward of that portion of the ship subject to washdown. These plates supplied the fallout

[1] A multi-color plastic coating applied by spraying, manufactured by Paramount Paint and Lacquer Company, Los Angeles, California.

samples. One navy-gray plate was exposed simultaneously to washdown and fallout on the boat deck of the YAG-39.

8.2.2 Decontamination Operations. After exposure to contamination, each plate was broken along the undercut grooves into $1\frac{1}{4}$-inch square samples. Twelve of these samples were used for radioactive decay studies and other tests; the remaining 24 were decontaminated in duplicate using 12 combinations of three methods and four decontaminating agents. The four decontaminating agents were fresh water alone (hereafter referred to as "no detergent" or "none"), and five-percent solutions of EDTA-4NA[1], ORVUS[2], and MIL C-7907 (Aer)[3] (salt-water detergent) in fresh water. The three methods were cold spraying at 75 F, hot spraying at 175 F, and hot spraying at 175 F with simultaneous brushing, henceforth called cold, hot, and hot plus brush, respectively. Each set of duplicates were decontaminated by one of the agent-method combinations for 10 seconds; previous laboratory experiments have shown that longer times do not significantly increase the amount of activity removed (Reference 7).

The navy-gray plates exposed on the flight deck were decontaminated on D + 1, D + 7, and D + 14 to determine the effect of aging on decontamination. The navy-gray plate exposed to fallout under the washdown spray and the Zolatone plate were decontaminated on D + 3. Each sample was counted, decontaminated, and recounted. These counts are listed as initial and residual, respectively.

8.2.3 Equipment and Instrumentation. All counting was done on the same instruments, a NaI crystal detector and a UDR/9 scaler.

The decontamination operations were conducted in a Detergometer (Reference 7). This apparatus is designed to simulate liquid decontamination methods, i.e., hosing, hot-liquid-jet, and hot-liquid-jet combined with scrubbing.

The fog chamber is a two-foot cube constructed of $\frac{1}{2}$-inch Lucite with an air-driven aspirator connected through the top face. Samples are exposed in it to an aerosol in a manner simulating fallout (Reference 8).

8.3 RESULTS AND DISCUSSION

8.3.1 Contamination. The average initial activity on the samples from each plate is plotted in Figures 8.1 and 8.2; the range on each plate is ±25 percent of the average count. All counts were decay-corrected to the hour 1000 on the day indicated. The activity level of the Flathead samples was approximately three to four times greater than that of the Zuni samples. This difference was due to a higher specific activity and was not a function of mass, since it is reported (Reference 9) that approximately 43 to 122 mg/ft^2 of total fallout occurred on the YAG-39 at Zuni, and none was detected at Flathead.

Zuni was detonated at the western tip of Tare, and the ground zero environment was coral and sea water. The visible fallout on the paint samples was a light coating of white particulate matter. Flathead was a barge shot, and visible surface contaminant was indistinguishable from the normal salt spray present on board ship. The Zuni contaminant

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[1] Tetra-sodium ethylene diamine tetracetate.

[2] Anionic alkyl aryl-sodium sufonate; manufactured by Proctor and Gamble, Cincinnati, Ohio.

[3] Manufactured by National Aniline Division of Allied Chemical and Dye.

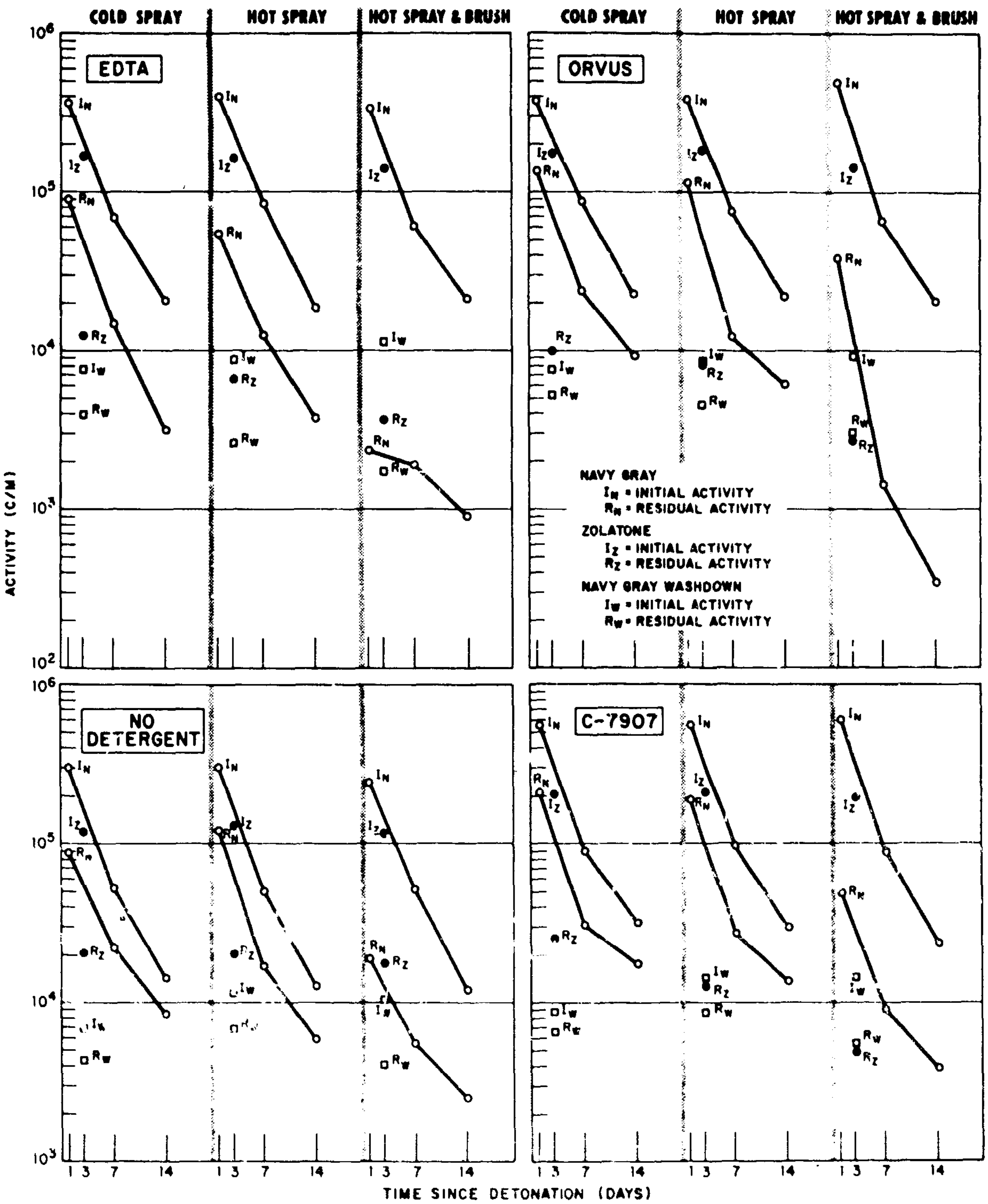

Figure 8.1 Activity on Zuni samples of navy-gray paint before and after decontamination.

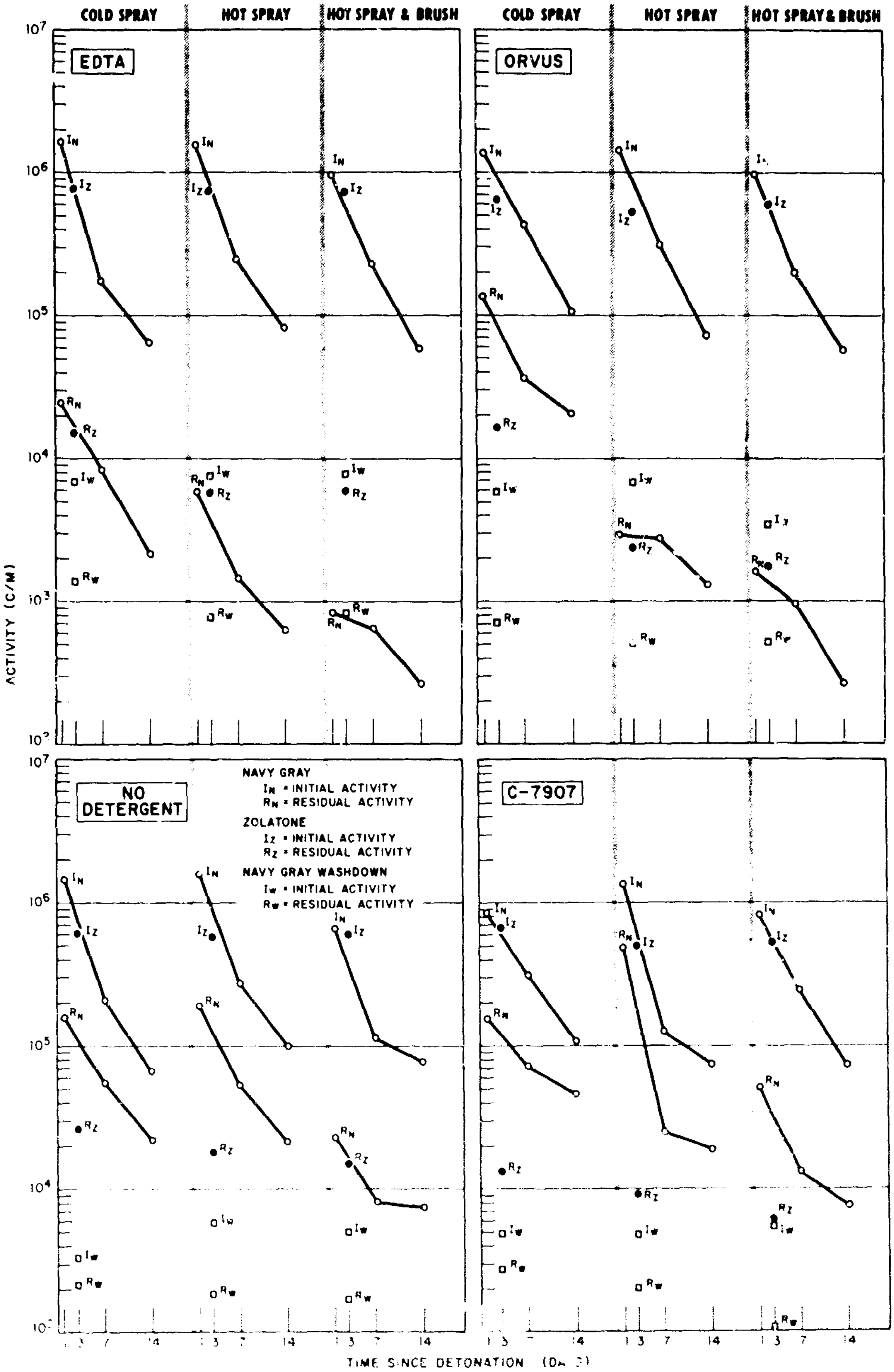

Figure 8.2 Activity on Flathead samples of navy-gray paint before and after decontamination.

was more effectively removed than the Flathead contaminant by washdown and decontamination procedures.

8.3.2 Decontamination. Pairs of duplicate samples from each contaminated plate were decontaminated by one of the twelve combinations of three methods and four decontaminating agents. The average initial and residual activities for each pair of duplicates for Zuni are plotted in Figure 8.1, those for Flathead, in Figure 8.2.

The average fraction remaining (residual activity divided by initial activity) for each pair of duplicate samples are listed in Tables 8.1 and 8.2 and plotted in Figures 8.3 and 8.4. All samples were decay-corrected to the hour 1000, on the day indicated, so that samples could be compared directly.

Decontamination of Navy-Gray Fallout Samples. The analysis of variance of the logarithms of fractions remaining, Tables 8.3 and 8.4, reveal an interaction of

TABLE 8.1 AVERAGE FRACTION REMAINING ON DUPLICATE ZUNI SAMPLES AFTER DECONTAMINATION WITH DIFFERENT DECONTAMINATING AGENTS AND METHODS

Navy-gray Forecastle Samples					Samples on D + 3				
Time since detonation, days	Agents	Spray Method: Cold	Hot	Hot + Brush	Surface	Treatment	Spray Method: Cold	Hot	Hot + Brush
D + 1	EDTA	0.25	0.14	0.007	Washdown	EDTA	0.50	0.30	0.13
D + 7		0.22	0.15	0.03	Navy-gray	Washdown			
D + 14		0.15	0.20	0.04		+ EDTA	0.02	0.01	0.006
Avg.		0.20	0.16	0.02	Zolatone	EDTA	0.07	0.04	0.03
D + 1	ORVUS	0.36	0.30	0.09	Washdown	Tide	0.69	0.54	0.33
D + 7		0.27	0.16	0.02	Navy-gray	Washdown			
D + 14		0.41	0.28	0.02		+ Tide	0.03	0.02	0.01
Avg.		0.34	0.24	0.03	Zolatone	Tide	0.06	0.04	0.02
D + 1	None	0.30	0.40	0.08	Washdown	Water	0.64	0.60	0.39
D + 7		0.42	0.34	0.11	Navy-gray	Washdown			
D + 14		0.60	0.46	0.21		+ Water	0.03	0.03	0.02
Avg.		0.42	0.40	0.12	Zolatone	Water	0.17	0.16	0.15
D + 1	C-7907	0.39	0.34	0.08	Washdown	C-7907	0.75	0.60	0.37
D + 7		0.34	0.28	0.10	Navy-gray	Washdown			
D + 14		0.56	0.46	0.17		+ C-7907	0.03	0.03	0.02
Avg.		0.42	0.35	0.11	Zolatone	C-7907	0.12	0.06	0.02

age, agent, and method for the navy-gray fallout samples. The interaction implies that at each age, the method-agent interaction is different or for each method, the age-agent interaction is different. An examination of the data indicated an overall increase in fraction remaining with increasing age.

The data also reveal that three-to-ten-times-larger fractions remained on Zuni than on Flathead.

Table 8.5 reveals the effectiveness of any method-agent combination when compared to cold spraying with water alone and is compiled by dividing the fraction remaining for plain water by the specified combination. Cold plain water left an average fraction remaining of 0.42 for Zuni, which value was arbitrarily taken as unity in making the method-agent comparisons; the average 0.21 was used similarly in the Flathead comparisons.

Thus, cold spraying with water alone left twice the fraction remaining that cold spraying with EDTA did. It is evident that hot plus brush is by far the superior method, and also hot is generally but not markedly better than cold. EDTA and ORVUS are nearly equally

TABLE 8.2 AVERAGE FRACTION REMAINING ON DUPLICATE FLATHEAD SAMPLES AFTER DECONTAMINATION WITH DIFFERENT DECONTAMINATING AGENTS AND METHODS

Navy-gray Forecastle Samples

Time since detonation, days	Agents	Spray Method: Cold	Hot	Hot + Brush
D + 1	EDTA	0.02	0.004	0.001
D + 7		0.05	0.006	0.003
D + 14		0.03	0.008	0.005
Avg.		0.03	0.006	0.002
D + 1	ORVUS	0.10	0.002	0.002
D + 7		0.09	0.009	0.005
D + 14		0.19	0.019	0.005
Avg.		0.12	0.007	0.003
D + 1	None	0.11	0.12	0.04
D + 7		0.26	0.20	0.07
D + 14		0.32	0.22	0.10
Avg.		0.21	0.17	0.06
D + 1	C-7907	0.18	0.36	0.06
D + 7		0.23	0.20	0.05
D + 14		0.43	0.25	0.11
Avg.		0.26	0.26	0.07

Samples on D + 3

Surface	Treatment	Spray Method: Cold	Hot	Hot + Brush
Washdown	EDTA	0.20	0.12	0.10
Navy gray	Washdown + EDTA	0.002	0.001	0.001
Zolatone	EDTA	0.02	0.008	0.008
Washdown	Tide	0.12	0.03	0.15
Navy gray	Washdown + Tide	0.001	0.001	0.001
Zolatone	Tide	0.03	0.004	0.003
Washdown	Water	0.63	0.32	0.34
Navy gray	Washdown + Water	0.005	0.003	0.003
Zolatone	Water	0.04	0.03	0.02
Washdown	C-7907	0.58	0.43	0.20
Navy gray	Washdown + C-7907	0.005	0.005	0.002
Zolatone	C-7907	0.02	0.02	0.01

TABLE 8.3 ANALYSIS OF VARIANCE OF LOGARITHMS OF FRACTION REMAINING ON DIFFERENT SURFACES EXPOSED AT SHOT ZUNI

Variation Due to:	Degrees of Freedom	Navy Gray: Mean Square	F*	Zolatone: Mean Square	F†	Washdown: Mean Square	F
Age, A	2	0.1288	1.57	—	-	—	—
Method, M	2	4.4077	53.6‡	0.3508	9.12‡	0.2353	23.8‡
Decontaminating Agent, D	3	0.9720	11.8‡	0.4966	12.9‡	0.1076	10.9‡
MD	6	0.1127	1.37	0.0385	—	0.0084	—
AM	4	0.0170	—	—	—	—	—
AD	6	0.1190	1.45	—	—	—	—
AMD or Error	12	0.0822	—	0.0029	—	0.0099	—
Error	36	0.0120	—	—	—	—	—
Total	71						

* Using AMD as error.
† Using MD as error.
‡ Significant at 1 percent probability level.

effective and much more so than the two other agents.

Decontamination of Zolatone Fallout Samples. Twenty-four samples from the single Zolatone plate were counted and decontaminated on D + 3. Since these samples were decontaminated on only one day, no aging effect could be studied. An examination of Figures 8.1 and 8.2 shows that Zolatone was more easily decontaminated than

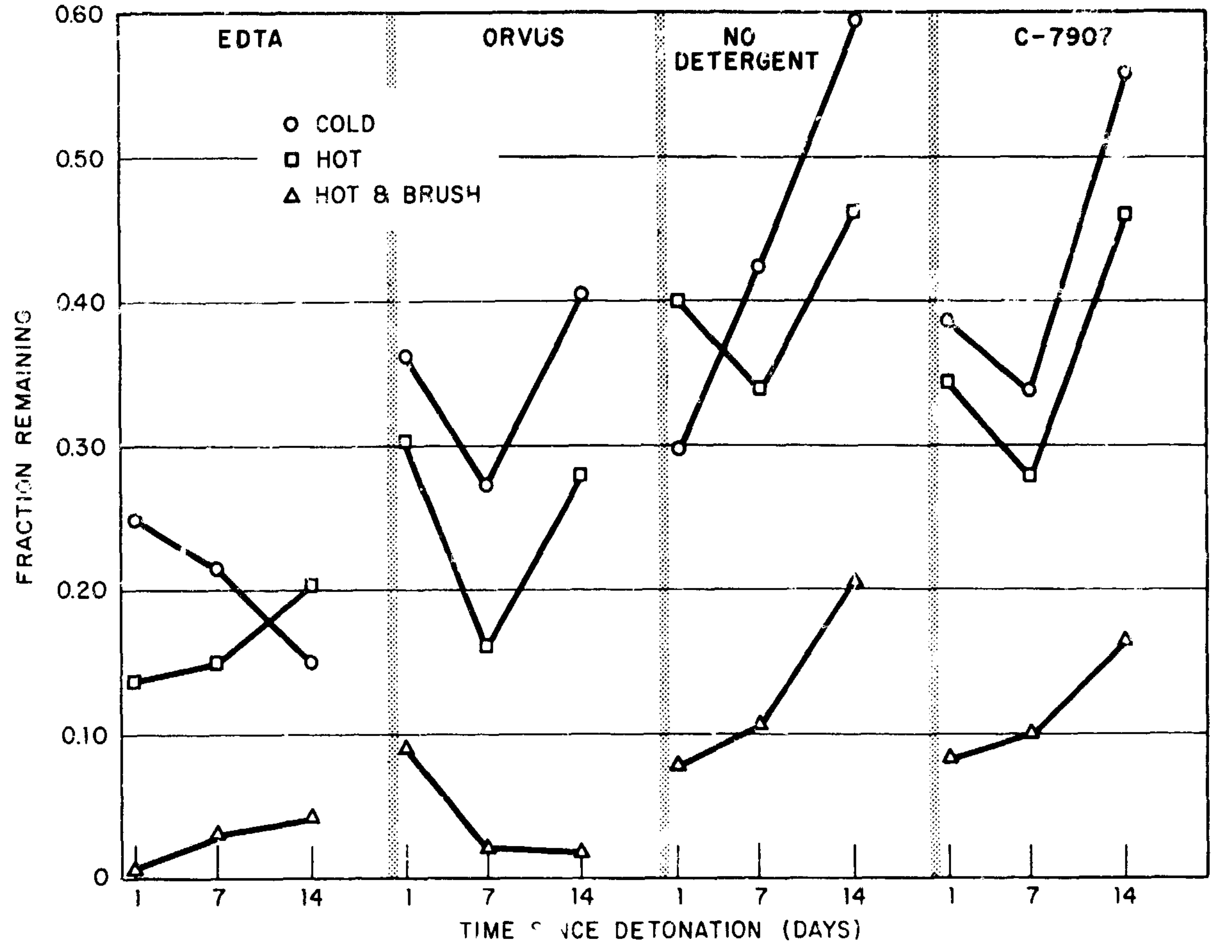

Figure 8.3 Fraction of Zuni activity on navy-gray paint samples after decontamination.

navy-gray paint by a factor of four to five. The fractions remaining (Tables 8.1 and 8.2) show the Zolatone results for the three methods were more alike than on navy-gray paint but still retained the ranking of cold, hot, and hot plus brush.

Table 8.6 clearly shows the factors by which each of the fractions remaining for the method-agent combinations surpass cold spraying with water alone in decontaminating effectiveness. Cold water left an average fraction remaining of 0.06 for Zuni which value was arbitrarily taken as unity in making method-agent comparisons; the average 0.04 was used similarly in the Flathead comparisons.

For Zuni, Zolatone was more effectively decontaminated than navy-gray paint (with cold and hot methods), Zolatone having only about one fourth the residual activity of navy-gray paint. There was no difference in decontaminability when hot plus brush was used. For Flathead, the trend was the same; however, with C-7907, Zolatone was consistently better than navy-gray paint by a factor of ten.

Washdown Samples. The level of activity of samples exposed to fallout and washdown simultaneously was determined on D + 3: 9,680 c/m for Zuni and 5,370 c/m for Flathead. To compare the effect of washdown on test surfaces, it was assumed that had

TABLE 8.4 ANALYSIS OF VARIANCE OF LOGARITHMS OF FRACTION REMAINING ON DIFFERENT SURFACES EXPOSED AT SHOT FLATHEAD

Variation Due to:	Degrees of Freedom	Navy Gray Mean Square	Navy Gray F *	Zolatone Mean Square	Zolatone F †	Washdown Mean Square	Washdown F
Age, A	2	0.9293	15.8 ‡	—	—	—	—
Method, M	2	5.3045	90.4 ‡	0.4354	6.09 §	0.1342	2.35
Decontaminating Agent, D	3	8.5767	146. ‡	0.4723	6.60 §	0.5131	9.00
MD	6	0.5834	9.95 ‡	0.0715	—	0.0415	—
AM	4	0.0090	—	—	—	—	—
AD	6	0.0837	1.43	—	—	—	—
AMD or Error	12	0.0586	—	0.0219	—	0.0570	—
Error	36	0.0114	—	—	—	—	—
Total	71						

* Using AMD as error.
† Using MD as error.
‡ Significant at 1 percent probability level.
§ Significant at 5 percent probability level.

TABLE 8.5 EFFECTIVENESS RATIOS OF DECONTAMINATION METHODS (COMPARED TO PLAIN WATER)

	Shot Zuni			Shot Flathead		
	Cold	Hot	Hot + Brush	Cold	Hot	Hot + Brush
EDTA	2	3	20	7	37	95
ORVUS	1	2	13	2	30	63
Plain water	1	1	4	1	1	3
C-7907	1	1	4	1	1	3

TABLE 8.6 EFFECTIVENESS RATIOS OF METHOD-AGENT COMBINATIONS (COMPARED TO COLD SPRAY WITH WATER)

	Shot Zuni			Shot Flathead		
	Cold	Hot	Hot + Brush	Cold	Hot	Hot + Brush
EDTA	2	4	6	2	5	5
ORVUS	3	4	8	1	10	13
Plain water	1	1	1	1	1	2
C-7907	1	3	8	2	2	4

the washdown system been inoperative these samples would have received the same level of initial activity as the fallout samples on the forecastle. Comparing the washdown counts with comparable (interpolated) counts on fallout samples of D + 3—220,000 c/m for Zuni and 674,000 c/m for Flathead—the ratios of the counts is a measure of the effect of washdown. The ratios were 0.044 for Zuni and 0.008 for Flathead. The effectiveness of wash-

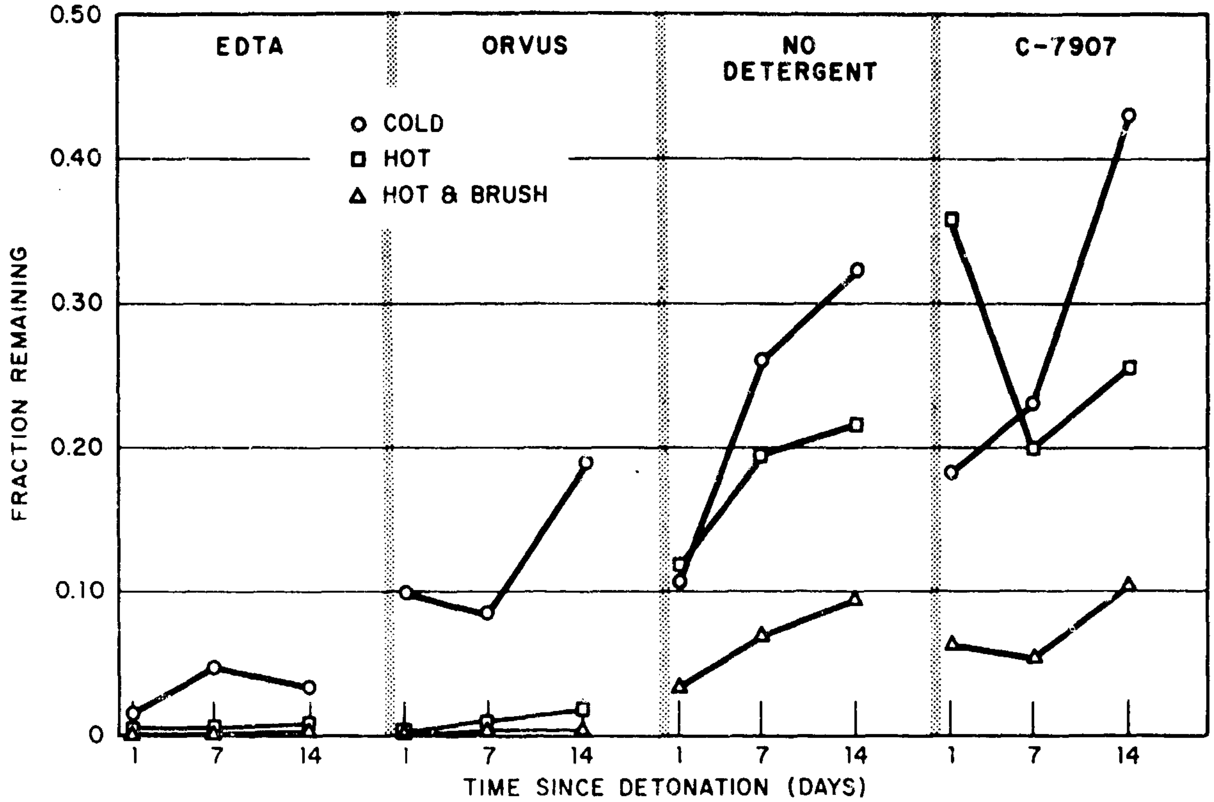

Figure 8.4 Fraction of Flathead activity on navy-gray paint samples after decontamination.

down in reducing gamma radiation intensity has been reported elsewhere (Reference 10) as 84 percent (0.16 fraction remaining) for Zuni and 98 percent (0.02 fraction remaining) for Flathead. These results were obtained by comparing the activity readings from instruments in washed-down and unwashed-down areas of a ship. The washdown system was far more effective on Flathead fallout than it was on Zuni.

The level of residual activity on the washdown samples on D + 3 was lower than the residual activity on samples decontaminated on D + 7 and D + 14, except when EDTA or ORVUS was used on D + 14 (Figures 8.1 and 8.2). This same statement can also be made, in many instances, about the initial washdown and residual fallout sample activities.

Comparisons of the decontamination effectiveness of agents and methods on washdown surfaces need to be made on a different basis than the ones made for the navy-gray and Zolatone fallout samples, since the washdown initial was less because of the pre-treatment. Comparing the washdown initial with the washdown residual activity yields very large fractions remaining. If the interpolated D + 3 initial activity of the fallout samples is used as the initial (220,000 c/m and 674,000 c/m for Zuni and Flathead, respectively) to compute fraction remaining, the combined effect of the washdown and decontamination processes are evaluated and listed in Tables 8.1 and 8.2 as "navy-gray on D + 3, washdown plus decontamination". These resulting fractions remaining can be compared directly with those without washdown.

Statistical Error. The reproducibility of results and experimental error for the two shots were equivalent for the navy-gray fallout samples. Comparisons for the washdown navy-gray and Zolatone show that differences between duplicates obtained at Flathead were many times more variable than those obtained at Zuni; this increase in internal variability, however, did not prevent the detection of highly significant differences among methods and detergents for Flathead. A more comprehensive and detailed report of the statistical treatment of the data will be published in Reference 11.

8.4 CONCLUSIONS

The effect of aging of the contaminant on navy-gray paint was small and, in general, decontamination was less effective with increasing age of the contaminant.

Decontamination by hot spraying was only slightly better than it was with cold spraying. Combining brushing with hot spraying gave greater effectiveness than either alone.

There was no advantage in using a five-percent freshwater solution of C-7907 over water alone. Using solutions of EDTA or ORVUS had many and approximately equal advantages.

The effect of washdown as measured by small painted samples indicated that washdown prevented 95 percent or more of the fallout activity from remaining on the surfaces.

There were three to ten times larger fractions remaining from Zuni than from Flathead.

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