AD NUMBER

ADB951596

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; Jul 1952. Other requests shall be referred to Chemical Corps and Biological Labs., Army Chemical Center, MD.

AUTHORITY

DNA ltr, 5 Mar 1980

PHOTOGRAPH THIS SHEET

AD B951596

DTIC ACCESSION NUMBER

LEVEL

UNANNOUNCED

INVENTORY

AEC
WT-376

DOCUMENT IDENTIFICATION

1952

None

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS	GRA&I	☐
DTIC	TAB	☐
UNANNOUNCED		☒
JUSTIFICATION		
Release Ltr. on file		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
2		

DISTRIBUTION STAMP

DTIC
ELECTE
S MAR 27 1980 D
D

DATE ACCESSIONED

80 3 21 125

DATE RECEIVED IN DTIC

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDA-2

DTIC FORM OCT 79 70A

DOCUMENT PROCESSING SHEET

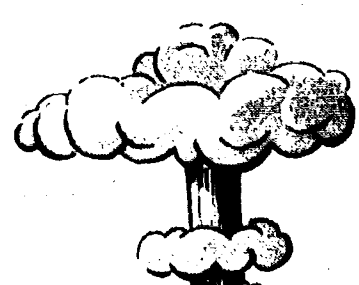
[redacted]

JANGLE

NEVADA PROVING GROUNDS
OCTOBER-NOVEMBER 1951

TESTS OF SERVICE EQUIPMENT AND OPERATION

[redacted]



ARMED FORCES SPECIAL WEAPONS PROJECT
WASHINGTON, D.C.

[redacted]

[redacted]

[redacted]

UNCLASSIFIED

FORMERLY RESTRICTED DATA

Handle As Restricted Data In Foreign Dissemination Section 144B, Atomic Energy Act, 1954

RESTRICTED DATA

This document contains restricted data as defined in the Atomic Energy Act of 1946. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18 U. S. C. Sections 793 and 794. The transmission or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

UNCLASSIFIED

[redacted]

Statement A
Approved for public release
Distribution unlimited

[redacted]

WT-376

This document consists of 229 plus 4 pages (counting all preliminary pages in all reports and all unnumbered blanks)

Copy [illegible] of 232 copies. Series B

OPERATION JANGLE

TESTS OF SERVICE EQUIPMENT AND OPERATION

Project 6.3-1 Evaluation of Military Individual and Collective Protection Devices and Clothing (WT-401)

Project 6.3-2 Evaluation of Potential Respiratory Hazards Associated with Vehicular Operations in a Radioactively Contaminated Area (WT-402)

Project 6.7 Clothing Decontamination and Evaluation of Laundry Methods (WT-347)

Project 6.8 Evaluation of U.S. Army Field Water Supply Equipment and Operations (WT-340)

[redacted]

OPERATION JANGLE

PROJECT 6.3-1

EVALUATION OF MILITARY INDIVIDUAL AND COLLECTIVE PROTECTION DEVICES AND CLOTHING

by

JOHN R. HENDRICKSON

July 1952

CHEMICAL CORPS CHEMICAL AND RADIOLOGICAL LABORATORIES

ARMY CHEMICAL CENTER, MARYLAND

[redacted]

PROJECT 6.3-1

PREFACE

The purpose of Project 6.3-1 was to determine the adequacy of items of protective equipment for use in radioactively contaminated areas. The work at the test site was performed under the direction of the author, who was Project Officer.

The report is a compilation of four individual reports covering separate items of equipment.

[redacted]

PROJECT 6.3-1

ACKNOWLEDGMENTS

The assistance of Lt. Col. Charles Robbins and Lt. Robert L. Hanzel in the planning and conduct of this project is gratefully acknowledged.

The cooperation of Major Alfred H. Parthum, Jr., Office of the Quartermaster General, in providing the test clothing; Mr. Norman Arnold and Captain David W. Armstrong, Aberdeen Proving Ground, and Lt. Col. John S. Sandiland, Army Field Forces, in operation of the armored vehicles was material to the conduct of the project.

Pvt. John Sweeney, as assistant to the project officer, was of invaluable aid during the test phase of the project. The volunteer enlisted men, too numerous to mention by name, who participated in the evaluation of protective clothing were of great assistance which is gratefully acknowledged.

[redacted]

[redacted]

PROJECT 6.3-1

CONTENTS

[redacted]

ILLUSTRATIONS

TABLES

[redacted]

PROJECT 6.3-1

ABSTRACT

Under conditions resulting from surface and underground detonations of atomic bombs, tests were conducted on Chemical Corps impregnated and unimpregnated protective clothing, Individual Protective Mask M9A1 with M11 Canister, Tank Collective Protector E26 and E22, and Protective Ointment M5. Both impregnated and unimpregnated clothing were capable of preventing contact between the skin and radioactive dusts. Unimpregnated clothing demonstrated better contamination-decontamination characteristics, but the secondary radiation from all clothing was negligible. The protective cover was effective in preventing contamination of clothing. The M9A1 mask with M11 canister furnished complete protection against inhalation of radioactive dust. The filtering efficiencies of the E26 tank collective protectors were found to be very high, and no deficiencies were found in the unit. The filtering efficiencies of the E22 tank collective protectors were also high. Panels coated with M5 ointment were found to be much more highly contaminated than bare panels.

[redacted]

[redacted]

CHAPTER 1

PROTECTIVE CLOTHING[9]

1.1 INTRODUCTION

1.1.1 Objective

The object of this phase of Project 6.3 was to determine the adequacy of Chemical Corps protective clothing to prevent radioactive dust produced by atomic bomb detonations (surface and underground) from contacting the skin of the wearer.

1.1.2 Historical

During the period between World War I and World War II, Chemical and Radiological Laboratories developed an impregnation process for clothing to protect the wearer against war gases. A mixture of nine parts of N,N'bis (2,4,6 Trichlorophenyl) dichlorourea and one part of zinc oxide was developed to neutralize mustard gas. This compound, known as XXCC$_3$, is used as an impregnate in standard items of clothing issue to produce[3] Chemical Corps protective clothing. The class I protective uniform consists of standard helmet and gas mask and the following items impregnated with XXCC$_3$: underclothing, socks, boots, gloves and coveralls. Class II protective uniform is the same as Class I except an unimpregnated undershirt may be worn. Class III uniform is composed of the same items, but none are impregnated.

The individual protective cover, Fig. 1.1, was designed to provide protection against chemical warfare agents sprayed from aircraft. It is constructed of .002 inch flame and moisture resistant cellophane. For cold climate use, the cover is lined with scrim to increase resistance to cracking. The soldier is instructed to dispose of the cover after it becomes contaminated. The cellophane cover was recently de-standardized in favor of a cover, now under development, which is more easily donned.

1.1.3 Properties of Protective Clothing

The protective uniform should prevent radioactive dust from contacting the skin, should be difficult to contaminate and easy to decontaminate by simple laundering procedures. Another desirable property in the protective clothing, not tested under this project, is protection against the thermal effects of atomic bomb detonations. It is obvious

[redacted]

that one protective uniform be used in chemical, bacteriological, and radiological warfare.

1.2 EXPERIMENTAL PROCEDURE

1.2.1 Clothing on Racks (Fig. 1.2)

At 2,000 feet downwind (40° north of east) from Ground Zero, ten racks were set up for exposure of protective clothing to the surface detonation. The following items of clothing were mounted on the racks:

1. Individual protective cover
2. Individual protective cover
3. Impregnated herringbone twill coverall
4. Impregnated herringbone twill coverall
5. Unimpregnated cotton sateen coverall
6. Unimpregnated cotton sateen coverall
7. Unimpregnated herringbone twill coverall
8. Impregnated herringbone twill coverall encased in an individual protective cover
9. Impregnated cotton sateen coverall encased in an individual protective cover
10. Impregnated cotton sateen coverall

All impregnated clothing contained 7 to 15% by weight of $XXCC_3$.

Six hours after the detonation, the clothing was collected and removed to the Control Point at the test site, where each item was monitored with a side-window PR-3 Beta-Gamma survey meter from a distance of six inches, as the level of activity was above the range of the Chemical Corps clothing monitor.

1.2.2 Clothing in M26 Tanks

During the surface detonation, clothing was exposed at the five crewmen's positions within each of two M26 tanks. The tanks were located 2,000 feet downwind, 15° east of south, from Ground Zero. The

[redacted]

Fig. 1.1 Individual Protective Cover

[redacted]

Fig. 1.2 Ten Clothing Racks with Protective Clothing and Individual Protective Covers Located 2,000 feet and 3,000 feet NE of Ground Zero During Surface Detonation

front of one tank and the side of the other faced the blast. All crew hatches were open.

Six hours after the detonation, the clothing was collected and monitored according to the procedure used on the clothing from the racks.

1.2.3 QMC Controlled Contaminator[12] (Fig. 1.3)

Five types of coveralls (see Table 1.5) were contaminated uniformly in the QMC controlled contaminator, using dust collected near the surface crater. Each batch was run for 10 minutes with 1/4 pound radioactive dirt. The "shake-off" dirt was removed by an air blast and collected in a bag filter. The laundering and drying of the coveralls was accomplished in the QMC portable laundry unit, employing the standard QMC laundering formula with General Aniline detergent. The same laundering procedure was used for each batch. Monitoring of the coveralls was done before and after laundering at nine points.

1.2.4 Clothing Worn by Men (Fig. 1.4)

Men walking, crawling, and riding in armored vehicles passed through the contaminated areas produced by both the surface and underground detonations. The clothing worn included coveralls, drawers, undershirts, socks, gloves and boots; either impregnated or plain.

Four hours after the surface detonation, eight teams of men worked for a period of one hour in the contaminated areas (Fig. 1.5). Five days after the underground detonation, one team walked and one team walked and crawled through the 10 to 500 milliroentgen per hour area (Fig. 1.6), downwind from Ground Zero. The walking team traveled approximately 1/2 mile in 1/2 hour. The walking and crawling team crawled ten yards in the 300 milliroentgen per hour zone.

At 25-1/2 hours after the surface detonation, crewmen wearing Class I protective clothing entered the two M26 tanks and drove through the contaminated area.

1.3 TEST RESULTS

1.3.1 Clothing on Racks (Tables 1.1 and 1.2)

The results of the contamination of rack-mounted protective clothing 2,000 feet from the surface detonation were as follows: The average contamination, measured at six inches approximately eight hours after the detonation, was 0.025 mr/hr. The range of readings on clothing items was 0.01 to 0.04 mr/hr. The helmet was the most highly contaminated item, having a reading 0.37 mr/hr. The average permissible level of contamination for clothing, presupposing use throughout lifetime of wearer and a large safety factor, is 7 mr/hr[8].

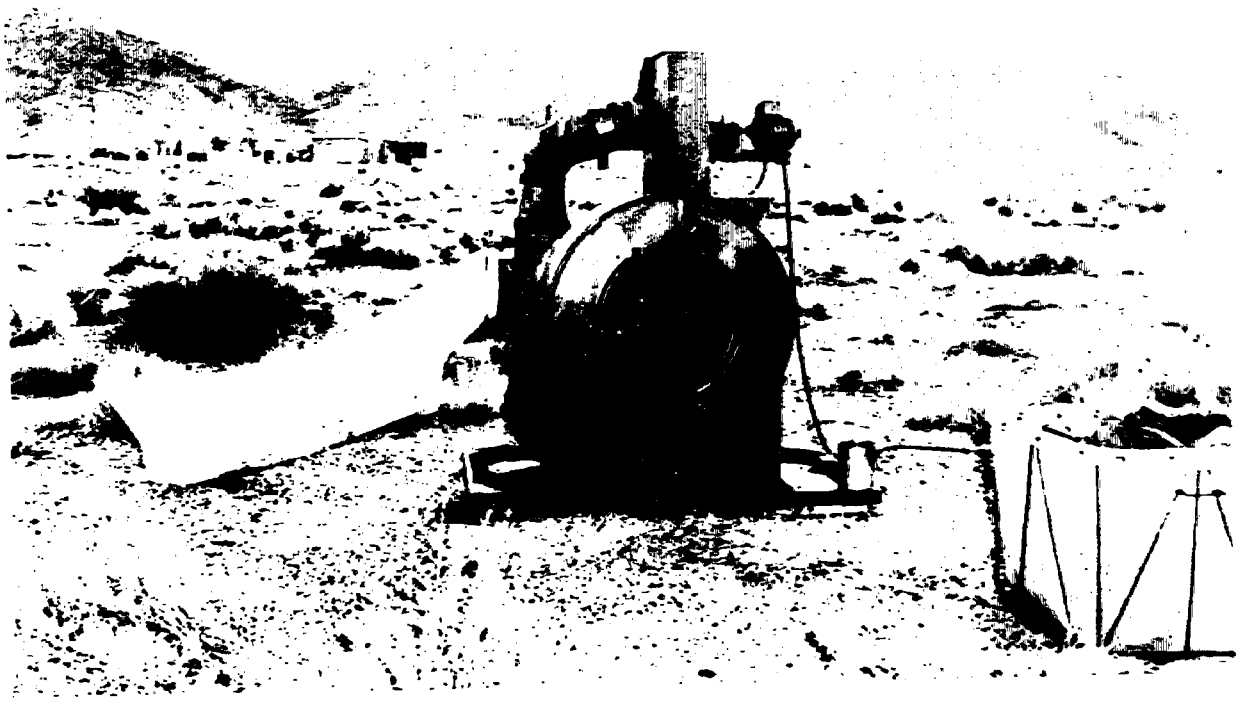


Fig. 1.3 Bag Filter Attached to QMC Contaminator for Collecting "Shake-off" Dirt from Protective Clothing

Fig. 1.4 Typical Chemical Corps Uniform Worn by Men in Contaminated Areas after Surface and Underground Nuclear Detonations. (Note: M9A1 Protective Mask)

[redacted]

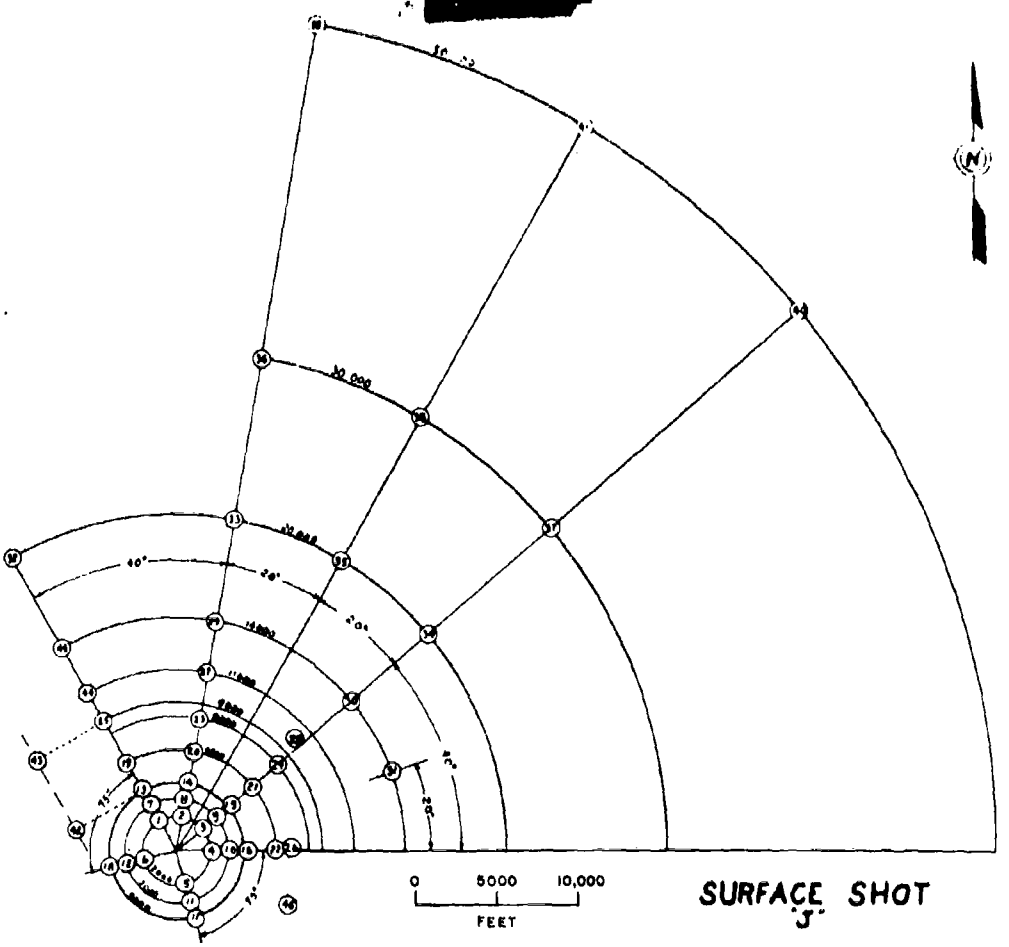


Fig. 1.5 Areas in which various teams of men wearing protective clothing walked for one hour after H+4 hours, and area of M26 Tank operations. Direction of wind: Northerly during detonation.

Walking Area 1	Stations	2, 8, 14, 20, 23, 27
2		1, 7, 13, 19, 25, 44
3		3, 9, 15, 21, 24, 28
4		29, 33, 36, 39
5		5, 11, 17, 4, 10, 16, 22, 26, 46, 31
6		30, 34, 37, 40
7		6, 12, 18, 42, 43, 45, 32
8		35, 38, 41

M26 Stationary Tanks exposed during detonation at Station 5.
M26 Tanks Itinerary after detonation: Station 5 north to point 800 feet east of ground zero, thence west to within 200 feet of the crater and returning southward.

[redacted]

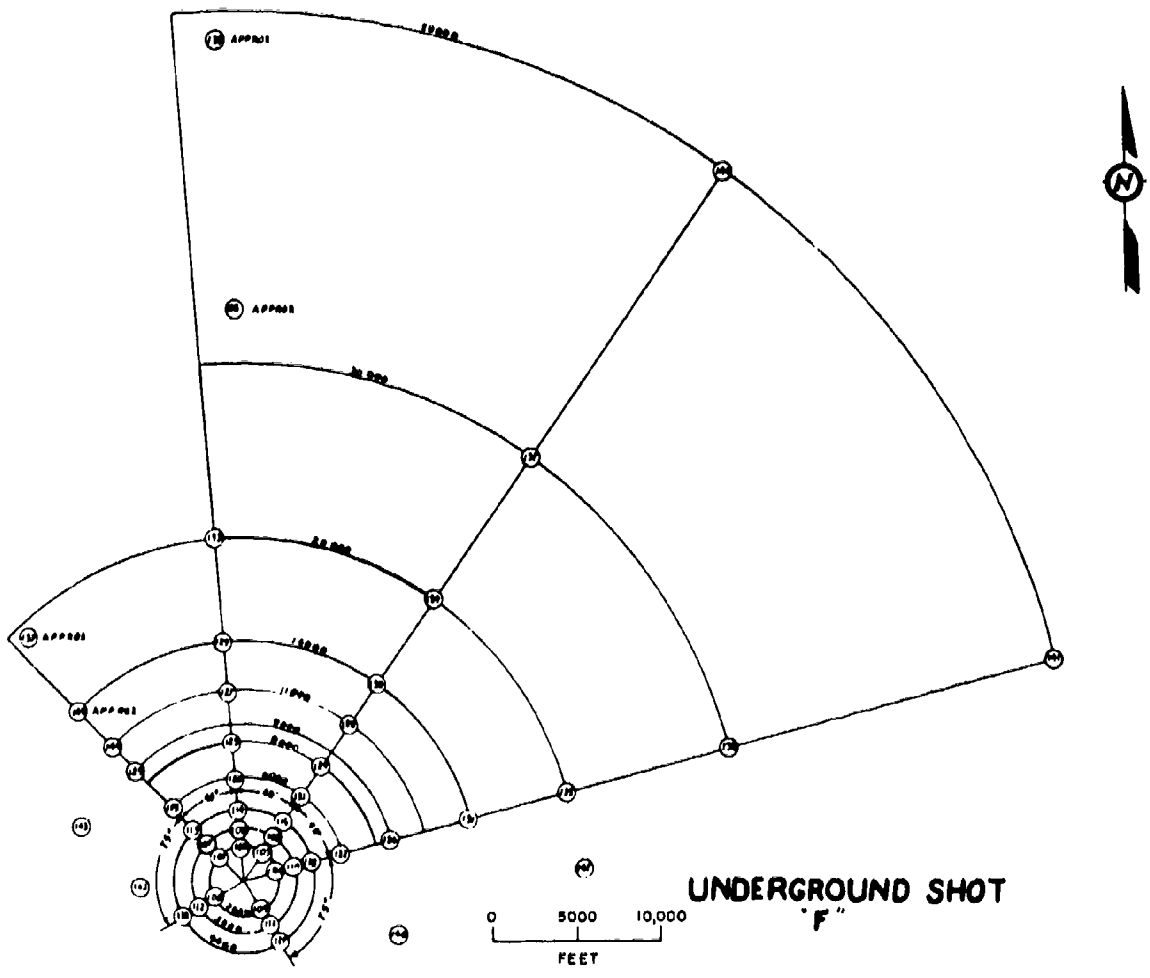


Fig. 1.6 Area in which teams of men wearing protective clothing walked and crawled for ½ hour, on H+5 days; and itinerary of M26 tanks and personnel carrier, T18E1. Direction of Wind: Northerly during detonation.

Area in which protective clothing was worn: Men walked from 10 mr/hr zone near Station 107 to 500 mr/hr zone near Station 101. Some crawled for 10 yards in 300 mr/hr zone between Stations 101 and 107. Stationary armored vehicles exposed during detonation at Station 101. Itinerary of armored vehicles after detonation: Station 106 north to Station 101, thence to tip of crater, thence to Station 104 and return via same route.

[redacted]

PROJECT 6.3-1

Table 1.1

Results of Contamination of Protective Clothing on Racks at 2000 Feet from Ground Zero on the NE Leg of the Surface Shot - (Exposed from H to H + 6 hrs)

Number Assigned to Articles	Clothing Outergarment Coverall and/or Cover	Date of Measurement @ H + 8 hrs	Ave. Contamination in mr/hr @ 6" corrected for Background
* 1	Impregnated Cotton-Sateen w/cover	19 Nov 51	0.03
* 2	Laundered, Impregnated HBT w/cover	19 Nov 51	0.03
3	Cotton-Sateen, Impregnated	19 Nov 51	0.04
4	HBT, Impregnated	19 Nov 51	0.03
5	Individual Protective Cover #1	19 Nov 51	0.03
6	Individual Protective Cover #2	19 Nov 51	0.03
7	Laundered HBT	19 Nov 51	0.01
8	Laundered Cotton-Sateen	19 Nov 51	0.03
9	Laundered, Impregnated HBT	19 Nov 51	0.01
10	Cotton-Sateen	19 Nov 51	0.01
11	Tee-Shirt, Cotton	19 Nov 51	0.03
12	Boots	19 Nov 51	0.04
13	Helmet	19 Nov 51	0.37

* The clothing underneath the covers was uncontaminated.

[redacted]

[redacted]

PROJECT 6.3-1

TABLE 1.2

Results of Contamination of Protective Clothing on Racks at 3000 Feet from Ground Zero on the NE Leg of the Surface Shot - (Exposed from H to H + 6 hours)

Number Assigned to Articles	Clothing Outergarment and/or Cover	Date of Measurement @ H + 8 hours	Ave. Contamination in mr/hr @ 6" corrected for background
1	Laundered, Impregnated HBT	19 Nov 51	0.06
2	Impregnated HBT	19 Nov 51	0.10
3	Laundered Cotton-Sateen	19 Nov 51	0.06
4	Cotton-Sateen	19 Nov 51	0.05
5	Impregnated Cotton-Sateen	19 Nov 51	0.05
* 6	Laundered, Impregnated HBT w/cover	19 Nov 51	0.05
* 7	Impregnated Cotton-Sateen w/cover	19 Nov 51	0.06
8	Individual Protective Cover #1	19 Nov 51	0.05
9	Individual Protective Cover #2	19 Nov 51	0.05
10	Laundered HBT	19 Nov 51	0.07
11	Combat boots	19 Nov 51	0.07
12	Tee-Shirt, Cotton	19 Nov 51	0.03
13	Helmet	19 Nov 51	4.7

* The clothing underneath the covers was uncontaminated.

[redacted]

below which no contamination is required even when presupposing a continuing lifetime exposure and a large safety factor, is 7 mr/hr.

The results of contamination at 3,000 feet downwind from Ground Zero show that the average contamination measured at six inches eight hours after the detonation, was 0.06 mr/hr, or slightly higher than the average at 2,000 feet. The range of activities was 0.03 to 0.10 mr/hr on clothing. Again the helmet was the most highly contaminated giving a reading of 4.7 mr/hr.

The protective cover proved very effective but became brittle from the heat. However, the fact that the covers were manufactured in 1942 may have been responsible for the brittleness.

1.3.2 Clothing in M26 Tanks (Tables 1.3 and 1.4)

The activities on the clothing in the two M26 stationary tanks were lower than the activities of clothing exposed on racks. The average contamination was 0.01 mr/hr at six inches eight hours after the detonation.

Contamination of clothing on men in mobile tanks was greater than on coveralls in same unmanned stationary tanks.

1.3.3 Clothing from QMC Contaminator (Tables A.1 and A.2)

The correction curve, Fig. 1.7, was used to correct the activities of the clothing from the contaminator to one hour after the detonation. The resulting contamination levels are shown in Table 1.5. The impregnated clothing was more highly contaminated than the corresponding unimpregnated. The laundering efficiency for unimpregnated clothing was higher than for impregnated.

1.3.4 Clothing Worn by Men (Tables 1.6, 1.7, 1.8, A.3, A.4)

Of protective clothing worn by men after the surface detonation, gloves and boots worn into areas near Ground Zero were the most highly contaminated, giving readings ranging from .01 to 9 mr/hr at six inches when monitored 26 hours after the detonation. Contamination of underclothing was negligible.

Of the clothing worn into the contaminated area produced by the underground detonation, the maximum reading was 3.7 mr/hr. The men who crawled received only 2 to 4 mr from their clothing while receiving a total dosage of 1 to 2 roentgens, as measured by film badges which recorded radiation from both the clothing and the ground.

The contamination of clothing worn by men riding through the area contaminated by the surface shot was also negligible.

[redacted]

PROJECT 6.3-1

TABLE 1.3

Contamination of Coveralls Placed in Two Stationary M-26 Tanks During the Surface Detonation (Clothing Exposed from H to H + 6 hours)

No.	Type of Coverall	Seat	Comp't	Tank No.	PR-3 Meter Reading in mr/hr @ 6" at H + 8 hrs corrected for background
1	Laundered, Impregnated HBT	Commander	Upper	418 head-on	0.02
2	Laundered HBT	Gunner	Upper	418 head-on	0.01
3	Laundered, Impregnated HBT	Loader	Upper	418 head-on	0.02
4	Laundered HBT	Driver	Lower	418 head-on	0.01
5	Laundered, Impregnated HBT	Ass't. Driver	Lower	418 head-on	0.02
6	Laundered, Cotton-Sateen	Commander	Upper	424 side-on	0.01
7	Impregnated Cotton-Sateen	Gunner	Upper	424 side-on	0.01
8	Impregnated Cotton-Sateen	Loader	Upper	424 side-on	0.00
9	Cotton-Sateen	Driver	Lower	424 side-on	0.01
10	Cotton-Sateen Impregnated	Ass't. Driver	Lower	424 side-on	0.00

[redacted]

[redacted]

TABLE 1.4

Contamination of Coveralls Worn by Crewmen in Two Mobile Tanks After the Surface Detonation

No.	Type of Coverall	Seat	Comp't	Tank No.	Ave. Reading on PR-3 Survey Meter in mr/hr at 6" at H + 26 hrs corrected for background
1	Unimpregnated Cotton-Sateen	Ass't. Driver	Lower	418	0.03
2	Impregnated Cotton-Sateen	Driver	Lower	418	0.03
3	Impregnated Cotton-Sateen	Commander	Upper	418	0.05
4	Unimpregnated Cotton-Sateen	Gunner	Upper	418	0.03
5	Laundered, Unimpregnated HBT	Ass't. Driver	Lower	424	0.03
6	Laundered, Impregnated HBT	Driver	Lower	424	0.03
7	Laundered, Impregnated HBT	Commander	Upper	424	0.01
8	Gloves (1,4, &5)				0.02
9	Gloves, Impregnated (2,3,6, &7)				0.03
10	Undershirts (1,4, &5)				0.00
11	Undershirts, Impregnated (2,3,6, &7)				0.01
12	Drawers (1,4, &5)				0.01
13	Drawers, Impregnated (2,3,6, &7)				0.01
14	Socks (1,4, &5)				0.00
15	Socks, Impregnated (2,3,6, &7)				0.00

[redacted]

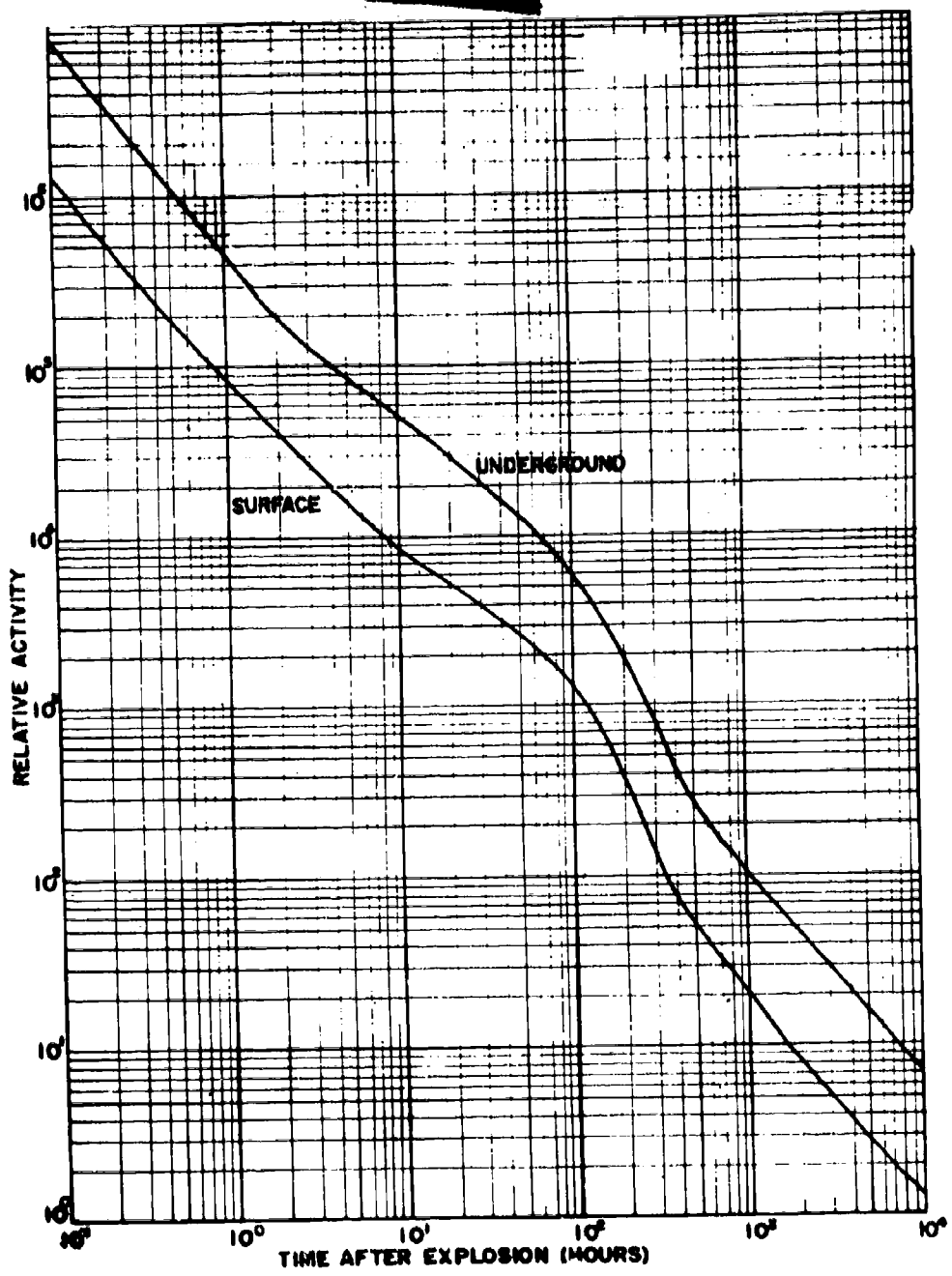


Fig. 1.7 Decay Factors for Correcting Activities to H Hour plus 1 Hour

TABLE 1.5

Contamination of Coveralls Placed in QMC Controlled Contaminator and Laundered at Indian Springs, Nevada

Batch	No. Coveralls	Coveralls	Batch	Average PR-3 Readings in mr/hr at 6" at H + 1 hours corrected for background		% Retention of Contamination	% Removal of Contamination
				After Contamination	After Laundering		
1	5	Laundered HBT	1	356	49	13.8	86.2
2	5	Impregnated HBT	2	840	283	33.7	66.3
3	5	Laundered, Impregnated HBT	3	888	375	42.2	57.8
4	5	Cotton-Sateen	4	366	33	9.0	91.0
5	4	Impregnated Cotton-Sateen	5	796	261	32.8	67.2

[redacted]

PROJECT 6.3-1

TABLE 1.6

Contaminated Areas in Which Various Teams Walked for One Hour While Wearing Protective Clothing after Surface Detonation (See Fig. 1.5)

Team No.	Distance Downwind from Ground Zero	Direction
1	2-11,000 ft	N
2	11-20,000 ft	NW
3	2-9,000 ft	NE
4	14-50,000 ft	N
5	2-14,000 ft	E & SE
6	14-50,000 ft	NE
7	2-8,000 ft	NW & SW
8	20-50,000 ft	NNE

[redacted]

[redacted]

PROJECT 6.3-1

TABLE 1.7

Protective Clothing Worn After Surface Detonation by Men Walking in Contaminated Areas (See Fig. 1.5 and Table 1.6)

Total Number Suits	Coveralls *	Team Numbers
7	Laundered HBT	1, 3, 4, 5, 6, 7, & 8
8	Impregnated HBT	1, 2, 3, 4, 5, 6, 7 & 8
7	Laundered and Impregnated HBT	2, 3, 4, 5, 6, 7 & 8
3	Cotton-Sateen	1, 3, & 6

* Underneath the coveralls, drawers and undershirts were worn. The underclothing was either impregnated or unimpregnated to match the corresponding coveralls. In addition, uniforms with impregnated clothing included impregnated socks, boots and gloves. Uniforms with unimpregnated clothing were matched with unimpregnated socks, boots and gloves.

TABLE 1.8

Protective Clothing Worn After Underground Detonation (See Fig. 1.6)

Number	Coveralls	Team **
2	Laundered Herringbone Twill	1
6	Impregnated Herringbone Twill	1 and 2
2	Laundered, Impregnated HBT	1
2	Cotton Sateen	1 and 2
8	Cotton Sateen, Impregnated	1 and 2

* Team 1 crawled and walked

** Team 2 walked only

[redacted]

1.4 DISCUSSION OF RESULTS

The level of contamination of the clothing under the test conditions was very low, indicating no hazard to the wearer. The fact that underclothing worn by the men crawling after the underground detonation was still uncontaminated indicates that the clothing is adequate to prevent contact between radioactive dust and the skin of the wearer. The impregnated clothing, in general, retained more radioactive dust than did the unimpregnated items. It is significant, however, that the level of radiation due to dust on clothing throughout the tests was negligible.

1.5 CONCLUSIONS

1. Impregnated herringbone twill clothing is more easily contaminated than impregnated cotton sateen clothing. However, the difference is slight.

2. Class I and Class III protective clothing furnish adequate protection against the penetration of radioactive dust under the soil conditions encountered in the test.

3. Cotton-sateen clothing has contamination-decontamination characteristics superior to those of herringbone twill.

4. Under the soil and weather conditions encountered at the Nevada Test Site, contamination of clothing worn by personnel in the area contaminated by an atomic detonation would not constitute a military hazard.

[redacted]

CHAPTER 2

EVALUATION OF M9A1 INDIVIDUAL PROTECTIVE MASKS[4]

2.1 INTRODUCTION

2.1.1 Objective

The objective of this phase of Project 6.3 was to determine the adequacy of the Chemical Corps Individual Protective Mask M9A1 to protect the wearer from inhalation of radioactive dust resulting from an atomic bomb detonation.

2.1.2 Historical

The M9A1 Protective Mask, Fig. 1.4, developed by Chemical and Radiological Laboratories during the latter part of World War II, was designed to protect the wearer against all known war gases and toxic aerosols. As standardized in May 1951, the mask consists of a medium weight rubber face-form with M11 canister[5] attached to the face-piece. The M11 canister contains a paper particulate filter and an activated charcoal (ASC) filter in series. The mask is held tightly against the face by a head harness. Previous to this test, the M9A1 mask had been found suitable for protection against chemical and bacteriological agents.

2.2 EXPERIMENTAL PROCEDURE

The apparatus for determining the overall radiometric efficiency of the mask consisted of a molded rubber nose-piece with a cotton-wad filter (Fig. 2.1). The periphery of the nose-piece was sealed to the volunteer wearer's face with adhesive tape. The mask was worn in the usual manner over the nose-piece. The volunteers who wore the mask test units were members of the teams walking and riding through the contaminated area after the surface detonation for the clothing tests described in Chapter 1. After the wearers returned from the tests, the cotton wads were counted to determine their radioactivity.

2.3 TEST RESULTS

No radioactivity was found on the cotton wads returned from the surface shot when counted 25 hours after the detonation. Five M11 canisters from masks worn by personnel who entered the contaminated area for a period of 1/2 hour approximately 3-1/2 hours after the underground

[redacted]

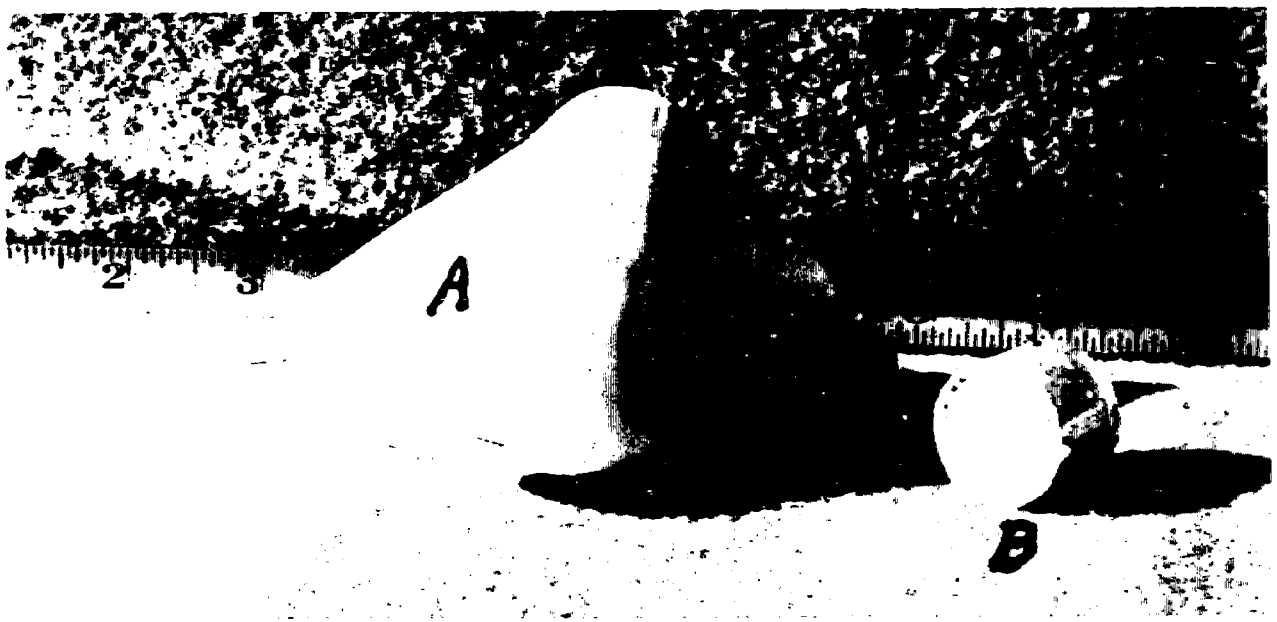


Fig. 2.1 Nosepiece and Cotton Filter Worn Under Protective Mask M9A1 by Men Walking in Areas.

A. Rubber Nosepiece. B. Cotton Filter (fits into the nosepiece).

detonation, were disassembled and counted for evaluation of the radiation hazard. The activities, corrected to one hour after the detonation, ranged from 1.12 mc to 5.20 mc.

2.4 DISCUSSION OF RESULTS

Since no measurable amount of radioactivity reached the cotton wad of the test nose-piece, it may be assumed that the filtering efficiency of the mask unit approached 100% under the low-contamination conditions of the surface shot.

The radiation from the M11 canisters (Table 2.1), used by men working in the contaminated area after the underground detonation, was not dangerous and would not constitute a hazard (1 to 5 mc at H + 1 hr).

2.5 CONCLUSIONS

1. The M9A1 Protective Mask was adequate to prevent inhalation of radioactive particles under the conditions of the test.

2. The accumulation of radioactivity in the M11 Canister, under the test conditions, was not sufficient to produce a radiation hazard.

2.6 RECOMMENDATIONS

None, as work is continuing on the development of individual protective devices.

[redacted]

PROJECT 6.3-1

TABLE 2.1

Radioactivity Collected in M11 Canisters by Men Walking in Contaminated Area While Wearing M9A1 Protective Masks, for One-Half Hour (3½-4 Hours After the Underground Detonation)

Canister Number	Sample Number	Radioactivity mc @ H + 1 hr for 2" diameter samples	Radioactivity mc @ H + 1 hr for M11 Canister
18	1	4.38×10^{-2}	
18	2	3.60×10^{-2}	
18	3	5.68×10^{-2}	
18	Average	4.55×10^{-2}	1.12
41	1	6.94×10^{-2}	
41	2	9.95×10^{-2}	
41	3	8.69×10^{-2}	
41	Average	8.53×10^{-2}	2.10
46	1	15.2×10^{-2}	
46	2	16.1×10^{-2}	
46	3	9.91×10^{-2}	
46	Average	13.7×10^{-2}	3.37
50	1	24.4×10^{-2}	
50	2	14.1×10^{-2}	
50	3	24.8×10^{-2}	
50	Average	21.1×10^{-2}	5.20
52	1	13.2×10^{-2}	
52	2	5.95×10^{-2}	
52	3	21.4×10^{-2}	
52	Average	13.5×10^{-2}	3.33

[redacted]

[redacted]

CHAPTER 3

EVALUATION OF TANK COLLECTIVE PROTECTORS E26[1] AND E22[2,11]

3.1 INTRODUCTION

3.1.1 Objective

The object of this phase of Project 6.3 was to determine the adequacy of the Tank Collective Protector E26 to protect a tank crew from the inhalation of radioactive particles while operating in an area contaminated by detonation of an atomic bomb.

3.1.2 Historical

During the late stages of World War II, the Chemical and Radiological Laboratories developed a device, the Tank Collective Protector E22, for the protection of tank crews against chemical warfare agents. Further developmental work has produced the Model E26. This three man protector consists of one Air Purifier E2 and a Tank Mask E56-M10A1-E20 for each man.

The principal parts of the air purifier are a blower, a centrifugal separator, and replaceable paper and charcoal filter units. The purifier operates on 24 volt direct current and delivers approximately 12 cubic feet of air per minute.

The Tank Mask E56 consists of a fully molded rubber face blank with a full-face vinylite eye shield. The face-piece is equipped with a lip microphone connected to the tank communication system. Wire reinforced rubber tubing connects the mask and the air purifier through a M10A1 canister in a carrier worn by the crew member. The system is designed so that the crewman can quickly disconnect the tubing and use the mask and canister as an individual protector when emergency abandonment of the tank is necessary.

The Tank Collective Protector E22, predecessor to the E26, is similar to the E26 in basic design. The E22 is larger in overall dimensions and is not equipped with the individual M10A1 canisters for separate use in evacuation. During the planning stage of Project 6.3, the E26 was not available. Before the E26 was made available, detailed plans for the E22 tests were advanced enough that the test could be completed at no additional cost and but little additional effort; therefore, the E22 investigation was conducted.

[redacted]

3.2 EXPERIMENTAL PROCEDURE

3.2.1 Tank Collective Protectors E26 in Armored Vehicles (Figures 3.1 and 3.2)

During the surface and underground detonations, two M26 tanks, in which E26 collective protectors were installed, were exposed. At the underground detonation, a T18E1 personnel carrier equipped with an E26 protector was exposed.

During the detonations the vehicles were stationary and not manned. At the surface detonation, the two tanks were located 2,000 feet upwind (southeast) of Ground Zero, with all crew hatches open. One tank faced the blast with engines running; the other tank was parked with one side exposed to the blast and with engines not operating.

During the underground detonation, the two tanks and the personnel carrier were situated 2,000 feet downwind (northwest) of Ground Zero. One tank and the personnel carrier faced toward Ground Zero, with engines running and hatches open. One tank was parked with a side toward the blast, with engines off and hatches closed.

Shortly after each detonation, the effluent air filter samples were removed to the laboratory on the test site for counting of radioactivity. The influent particulate filters from the air purifier and the M10A1 canisters were transported to the Army Chemical Center, Maryland, where radioactivities were determined and calculations were made.

3.2.2 Tank Collective Protector E22

One type of apparatus (Fig. 3.3), used in determining filter efficiencies of the E22 tank collective protectors consisted of an adapter, a filter pack made up of one layer of Chemical Corps Type 6 paper and two layers of Chemical Corps Type 5 paper, and a blower to draw the sample through the filter. The rate of flow through the filter unit was 3 cfm, while the capacity of the collective protector was 18 - 19 cfm. The excess air passed through the vents in the adapter. Three collective protectors were tested with this type apparatus at 4,000 feet from Ground Zero.

The second type of apparatus is diagrammatically illustrated in Fig. 3.4. The apparatus consisted of a shielded Geiger-Mueller tube and an electronic circuit to measure and record instantaneously the level of radioactivity in the effluent of the collective protector. A filter sampler similar to the first apparatus was included in this type sampler. A separate Geiger-Mueller tube and electronic circuit were

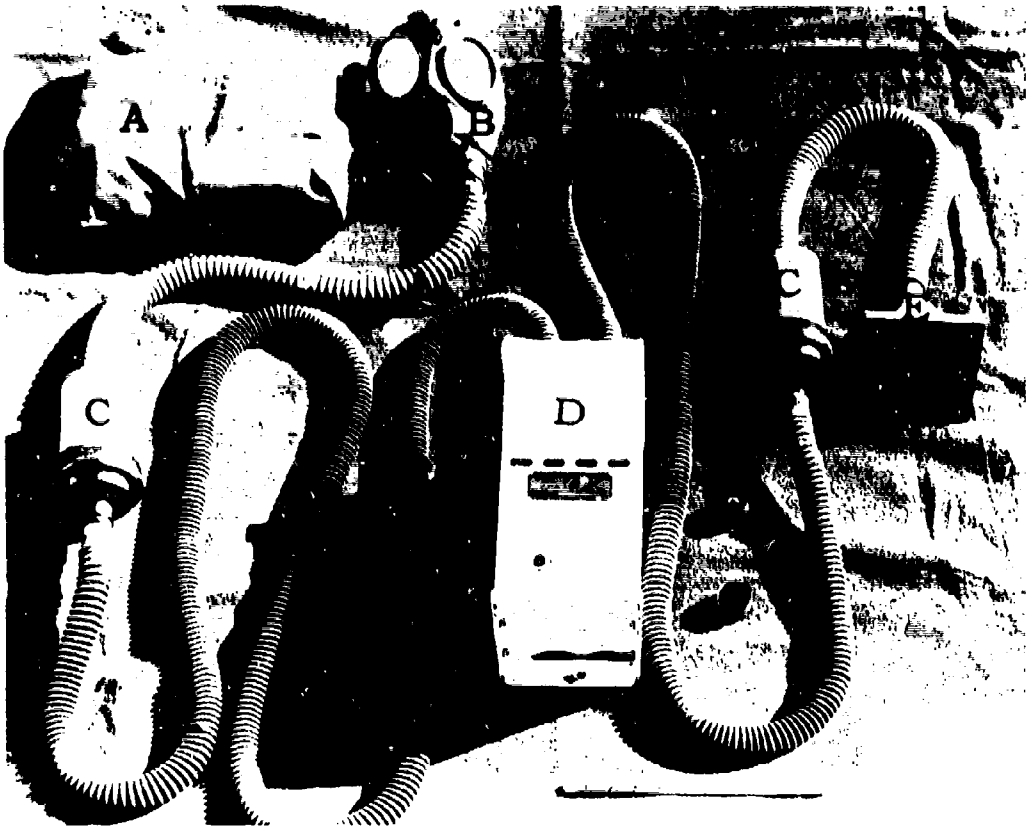


Fig. 3.1 Three Man, E26 Tank Collective Protector (Air Purifier) Evaluated in Stationary and Mobile M26 Tanks and T18E1 Personnel Carrier During the Surface and Underground Detonations. A. Carrier for Protective Mask. B. Tank Protective Mask, E59. C. M10 Canister. D. E26 Tank Collective Protector. E. Test Filter, Chemical Corps Type 6.

Fig. 3.2 Turret Compartment Crew wearing Tank Masks connected by Hoses to a Three-Man, E26 Tank Collective Protector mounted inside an M26 Tank.

A. M10A1 Canister connected in series between Tank Mask and Tank Collective Protector Filter; B. Tank Mask Holder; C. Tank Mask

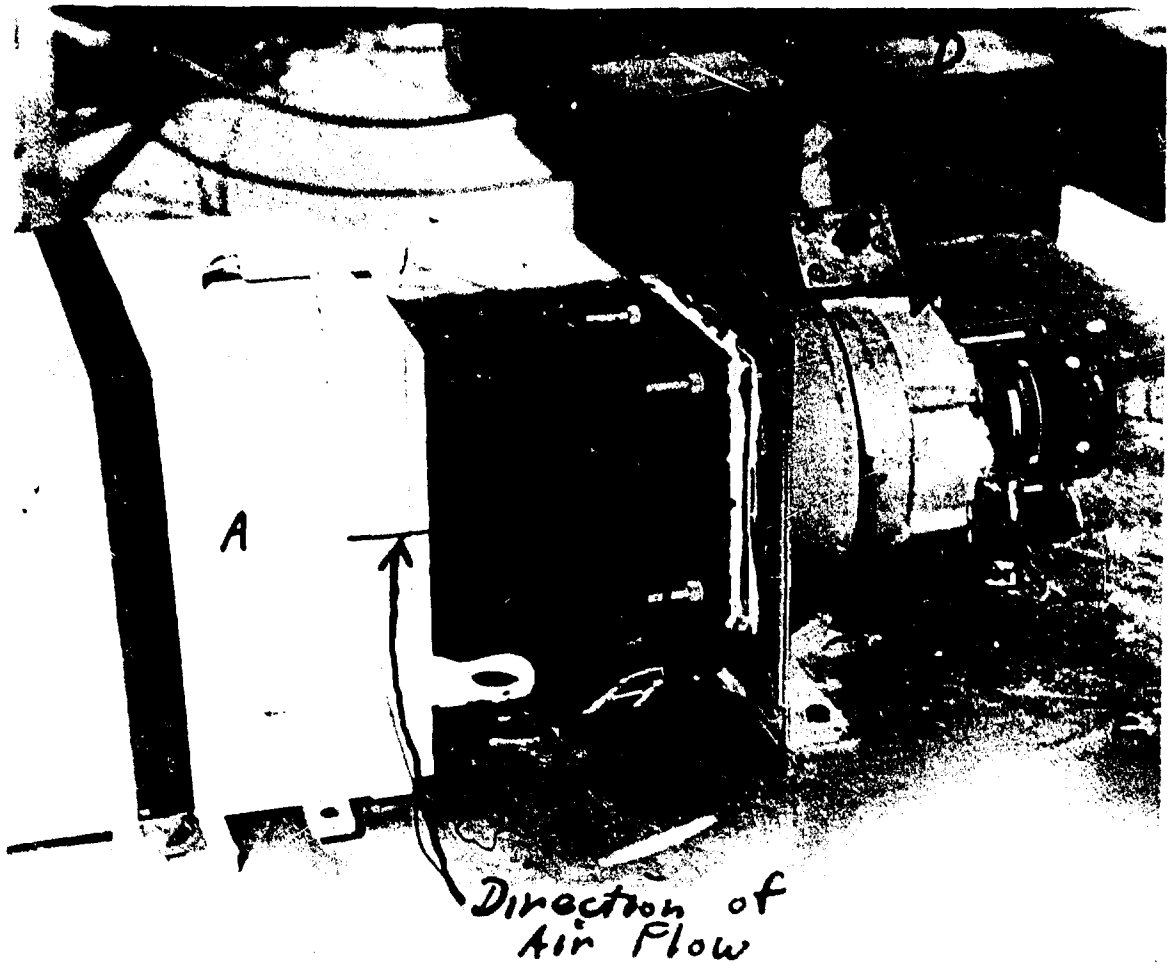
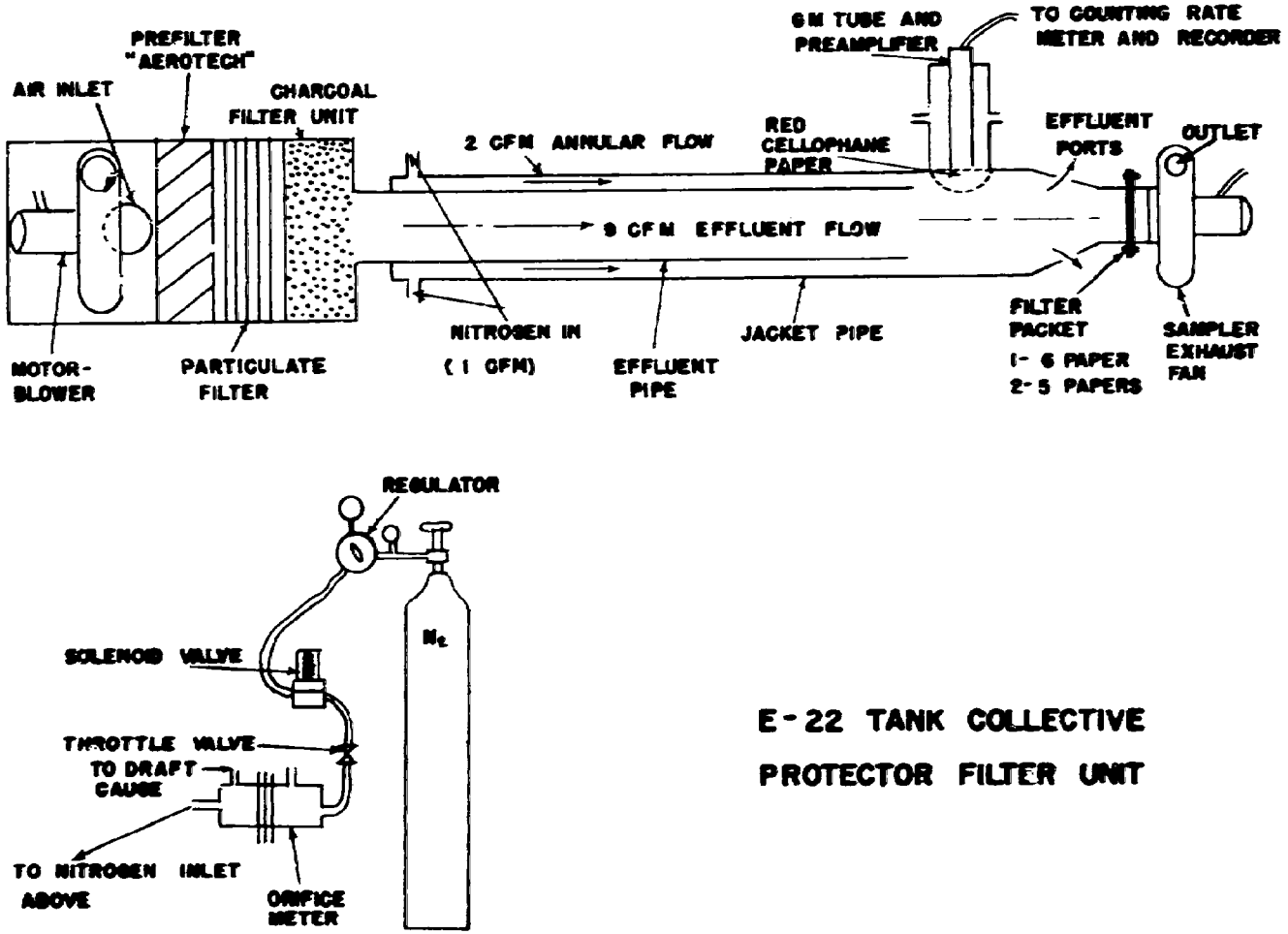


Fig. 3.3 E22 Tank Collective Protector Filter Efficiency Evaluation Unit Mounted on Platforms at Stations 13, 14 and 15, respectively, 4,000 feet from Ground Zero and Operating during Surface Detonation

A. E22 Tank Collective Protector Filter unit, consisting of electrically-operated blower, centrifugal separator for large particles, pleated Chemical Corps Type 6 Paper Filter, and Charcoal Filter connected in Series. B. Filter Packet, composed of one layer of Type 6 and two layers of Type 5 Chemical Corps Filter Paper mounted in series. C. Exhaust Fan and Motor for drawing air sample aliquot through above filter packet. D. 24 volt Air Force Batteries used to operate above exhaust fan and Tank Collective Protector Filter Unit. E. Platform. F. Ports to release excess air from Tank Collective Protector Unit.



E-22 TANK COLLECTIVE
PROTECTOR FILTER UNIT

Fig. 3.4 Diagram of Apparatus for Measuring the Filter Efficiency of an E22 Tank Collective Protector

used to measure and record the instantaneous background at each station. Three of the instantaneous recording units were used at 20,000 feet from Ground Zero.

Five minutes before the surface detonation, the six test units were started by a timing signal and relay system. After two hours, the units were stopped by a preset timing device. The filter paper samples were collected approximately four to six hours after the detonation and were transported in individual plastic bags for counting at the laboratory operated by the National Institute of Health at the test site.

3.3 TEST RESULTS

3.3.1 Tank Collective Protectors E26 in Armored Vehicles

During the surface detonation, the level of radioactivity near the tanks was too low to permit determination of radiometric filter efficiencies of the E26 protectors. Radiation from the protectors was negligible.

After the underground detonation the radiometric filtering efficiencies of the particulate filters in the E2 air purifier were calculated from the following formula:

$$\text{Efficiency} = 100 \quad \frac{d/m_1}{d/m_1 + d/m_2 + d/m_3 \ldots + d/m_n} \qquad (3.1)$$

where d/m is the counting rate of activity collected corrected to identical geometry conditions. This formula holds true only in the event that the penetration of the last layer is negligible. The efficiency of the M10A1 canister, as previously evaluated, is high enough that this assumption is reasonable[7]. The amount of dust retained between the particulate filter and the canister is negligible also. Therefore, Formula 3.1 above can be simplified to:

$$\text{Efficiency} = 100 \quad \frac{A}{A + B} \qquad (3.2)$$

where A = total corrected activity on particulate filter

where B = total corrected activity on M10A1 canister

The values of total corrected activity on the influent particulate filter are given in Table B.2. The total corrected activities of the M10A1 canisters are given in Table B.3. The efficiencies, given

in Table B.1 are well over 99.9%. The radiations, as measured by a Tracerlab laboratory monitor, from the components of the three collective protectors are given in Tables B.4, B.5, and B.6.

3.3.2 Tank Collective Protector E22, Platform Mounted

The filter efficiencies of the E22 tank protectors 4,000 feet downwind from the surface detonation are given in Table B.7. The influent concentration at one station was not determined because the sampler, a part of the Project 2.5a apparatus, jammed the counter. The radiometric filter efficiencies of the other two were 89.8 and 98.9% respectively.

The instantaneous radiometric readings from one of the test units at 20,000 feet from Ground Zero are given in Table B.8. The efficiency calculations are given in Table 3.1. Data were not obtained from the other two units. In one case, the background was so high that the electronic recorders went off scale, and at the other station, the paper on the electronic recorder slipped, causing unreliable readings.

3.4 DISCUSSION OF RESULTS

The indicated high radiometric filtering efficiency of the particulate filter in the E26 Collective Protector, coupled with the high efficiency of the M10A1 Canister, indicates that the E26 Protector is quite satisfactory for protection of vehicle crews against the inhalation and ingestion of radioactive dust. The tanks were not located in the area of greatest contamination, but the contamination was great enough to make the test conclusive.

The filter efficiencies for the E22 tank collective protectors served to verify the results of the tests on the E26 models, giving efficiencies of the same magnitude. The results of the tests indicate that both the instantaneous recording and filter pack apparatus provide adequate means of determining the filtering efficiencies of devices similar to the tank collective protector.

3.5 CONCLUSIONS

1. The E26 Tank Collective Protector furnishes adequate protection against the inhalation of radioactive dust resulting from the detonation of an atomic bomb.

2. The instantaneous recording method and the filter pack method are both satisfactory means of determining filtering efficiencies of devices similar to the tank collective protector.

TABLE 3.1

Calculation of Filter Efficiency of E22 Tank Collective Protector at Station 35, 20,000 ft NNE and Downwind from Surface Detonation

1.	Average Reading* of Instantaneous Effluent (H+1 hr) ..... 24 CPM
2.	Time that Particulate Cloud was Over Station 35 ..... 13 minutes
3.	Volume of Effluent Air Seen by GM Tube ..... 0.5 cuft.
4.	Geometry of GM Tube ..... 50 %
5.	Rate of Flow of Air Past GM Tube ..... 9.0 CFM
6.	Activity of Influent Filter Paper Corrected for Time, Geometry, Flow and Background ..... 14.13×10^5 CPM

$$\% \text{ Filter Efficiency} = 100 \left[\frac{14.13 \times 10^5}{14.13 \times 10^5 + \frac{(24)(9)(13)}{(.50)(0.5)}} \right]$$

$$= 99.09\%$$

* See Table B.8, Appendix B

[redacted]

CHAPTER 4

CONTAMINATION OF M5 INDIVIDUAL PROTECTIVE OINTMENT[10]

4.1 INTRODUCTION

4.1.1 Objective

The object of this phase of Project 6.3 was to compare the contaminability of aluminum panels coated with M5 Protective Ointment with the contaminability of bare panels when exposed to the surface and underground detonations of atomic bombs, in order to obtain information relative to the contaminability of skin coated with M5 ointment.

4.1.2 Historical

The M5 Protective Ointment, a chloramide, was developed as an aid in the protection and decontamination of skin exposed to vesicant chemical warfare agents, particularly the mustard gases.

4.2 EXPERIMENTAL PROCEDURE

The samples for this test consisted of 2-1/2" x 3" plates of 18 gage aluminum. At each station, one horizontal and one vertical plate were coated with ointment, and an uncoated control plate was mounted beside each sample. Forty-six stations were located at distances from 2,000 to 50,000 feet from Ground Zero. Additional panels were mounted on two M26 tanks and a T18E1 Personnel Carrier. During both shots, the armored vehicles were stationary, but after the underground detonation new panels were mounted and the vehicles were driven past the surface crater.

The panels were removed approximately four hours after each detonation and were flown to the Army Chemical Center, Maryland, where radioactivity was measured by a Geiger-Mueller tube and scaler. The activities were calculated to H + 1 hour, using the decay factors of Figure 1.1.

4.3 TEST RESULTS

The results of radioactivity measurements on the panels mounted on the armored vehicles show that in every case, the corrected activity of the corresponding uncoated control panel.

[redacted]

[redacted]

The greatest contamination was found at 30,000 feet downwind from Ground Zero, in the path of the greatest radioactive fall-out. This contamination was 60 microcuries per square centimeter at H + 1 hour on the horizontal panel. The lightest contamination was found on the upwind panels.

4.4 DISCUSSION OF RESULTS

As the ointment on the aluminum panels was quite viscous due to low temperature at the time of the shots, the number of radioactive particles retained on the samples was probably smaller than would be retained by ointment on a warm surface such as human skin.

4.5 CONCLUSIONS

1. Ointment-coated aluminum panels definitely collect and retain more radioactivity than do bare aluminum panels.

2. It can be concluded from the results of the panel tests that radiological contaminability of human skin exposed to atomic detonation would be increased by use of M5 Protective Ointment.

[redacted]

APPENDIX A

TABLE A.1

Decontamination Data Sheet

Pounds 51

Date 24 Nov 51 Water B. G. 1045 cpm Type Load Cml C Impregnated

Step	Operation	Water Level (in.)	Temp. °F.	Time	Supplies	pH	Solution Activity - CPM		
						Lab.	Raw	True	Adjusted 8" Water
1	Suds	5	90 100	5	General Aniline Det. 6 oz.	7.9	55,106	54,061	35,680
2	Suds	5	130	5	General Aniline Det. 3 oz.	8.5	25,654	24,609	16,242
3	Suds	5	140	5	General Aniline Det. 2 oz.	8.5	13,508	12,463	8,226
4	Rinse	8	140	3	---	8.2	7,450	6,405	6,405
5	Rinse	8	120	3	---	8.1	5,150	4,105	4,105
6	Rinse	8	100	3	---	8.1	4,338	3,293	3,293
									73,951

APPENDIX A

TABLE A.2

Decontamination Data Sheet

Pounds 31

Date 24 Nov 51 Water B. G. 1034 cpm Type Load Cml C Unimpregnated

Step	Operation	Water Level (in.)	Temp. °F	Time	Supplies	pH	Solution Activity - CPM		
						Lab.	Raw	True	Adjusted 8" Water
1	Suds	5	90 100	5	General Aniline Det. 6 oz.		25,596	24,292	16,033
2	Suds	5	130	5	General Aniline Det. 3 oz.		10,070	8,766	4,786
3	Suds	5	140	5	General Aniline Det. 2 oz.		5,374	5,070	3,346
4	Rinse	8	140	3	---		2,320	1,016	1,016
5	Rinse	8	120	3	---		1,890	586	586
6	Rinse	8	100	3	---		1,828	524	524

APPENDIX A

Table A.3 (See Fig. 1.5)

Contamination of Protective Clothing Worn by Men Walking One Hour in Contaminated Areas of Surface Shot at H + 6 Hours

Man	Clothing of Team #1 (See Fig. B.1.11)	Ave. Readings on PR-3 Survey Meter at 6" @ H + 26 hours
#1	Laundered HBT Coverall	0.16 mr/hr
	Gloves, Cotton	1.38
	Undershirt, Cotton	0.01
	Drawers, Cotton	0.01
	Socks, Cotton	0.04
	Boots	1.09
	Helmet, Steel	0.18
	Gas Mask, M9A1	0.23
#2	Impregnated HBT Coverall	0.30
	Gloves, Cotton, Impregnated	0.88
	Undershirt, Cotton, Impregnated	0.04
	Drawers, Cotton, Impregnated	0.00
	Socks, Cotton, Impregnated	0.33
	Boots, Impregnated	0.02
	Helmet	0.17
	Gas Mask, M9A1	0.32

[redacted]

PROJECT 6.3-1

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #1 (See Fig. B.1.11)	Ave. Readings on PR-3 Survey Meter at 6" @ H / 26 hours
#3	Cotton-Sateen Coverall	0.16
	Gloves, Cotton	0.47
	Undershirt, Cotton	0.01
	Drawers, Cotton	0.01
	Socks, Cotton	0.00
	Boots	0.50
	Helmet	0.17
	Gas Mask, M9A1	0.22
	Clothing of Team #2	
#1	Impregnated HBT Coverall	0.29
	Impregnated Gloves, Cotton	0.02
	Impregnated Cotton Undershirt	0.03
	Impregnated Cotton Drawers	0.02
	Impregnated Socks, Cotton	0.00
	Impregnated Boots	0.04
	Helmet	0.17
	Gas Mask, M9A1	0.07
#2	Laundered, Impregnated HBT Coverall	0.22
	Cotton, Impregnated Gloves	0.02

[redacted]

APPENDIX A

Table A.3

Man	Clothing of Team #2 (See Fig. B.1.11)	Ave. Readings on PR-3 Survey Meter at 6" @ H / 26 hours
Cont'd #2	Cotton, Impregnated Undershirt	0.03
	Cotton, Impregnated Drawers	0.03
	Cotton, Impregnated Socks	0.03
	Boots, Impregnated	0.04
	Helmet	0.17
	Gas Mask (not worn)	-
	Clothing of Team #3	
#1	Laundered, HBT	0.01
	Cotton Gloves	0.06
	Cotton Undershirt	0.00
	Cotton Drawers	0.00
	Cotton Socks	0.00
	Boots	0.04
	Helmet	0.04
	Gas Mask, M9A1	0.05
#2	Impregnated HBT Coverall	0.01
	Impregnated Cotton Gloves	0.08
	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.00
	Impregnated Cotton Socks	0.00

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #3	Ave. Readings on PR-3 Survey Meter at 6" @ H / 26 hours
Cont'd #2	Impregnated Boots	0.07
	Helmet	0.03
	Gas Mask, M9A1	0.05
#3	Laundered, Impregnated HBT Coverall	0.00
	Impregnated Cotton Gloves	0.04
	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.00
	Impregnated Cotton Socks	0.01
	Impregnated Boots	0.03
	Helmet	0.01
	Gas Mask, M9A1	0.04
#4	Cotton-Sateen Coverall	0.02
	Cotton Gloves	0.04
	Cotton Undershirt	0.01
	Cotton Drawers	0.00
	Cotton Socks	0.01
	Boots	0.04
	Helmet	0.03
	Gas Mask, M9A1	0.05

[redacted]

PROJECT 6.3-1

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #4	Ave. Readings on PR-3 Survey Meter at 6" @ H / 26 hours
#1	Laundered HBT Coverall	0.08
	Cotton Gloves	0.38
	Cotton Undershirt	0.01
	Cotton Drawers	0.01
	Cotton Socks	0.01
	Boots	2.31
	Helmet	0.08
	Gas Mask	0.11
#2	Impregnated HBT Coverall	0.07
	Impregnated Cotton Gloves	0.98
	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.00
	Impregnated Cotton Socks	0.01
	Impregnated Boots	8.65
	Helmet	0.14
	Gas Mask, M9A1	0.13
#3	Laundered, Impregnated HBT Coverall	0.25
	Impregnated Cotton Gloves	0.88
	Impregnated Cotton Undershirt	0.01

[redacted]

[redacted]

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #4	Ave. Readings on PR-3 Survey Meter at 6" @ H / 23 hours
Cont'd #3	Impregnated Cotton Drawers	0.01
	Impregnated Cotton Socks	0.01
	Impregnated Boots	1.80
	Helmet	0.38
	Gas Masks, M9A1	0.38
	Clothing of Team #6	
#1	Laundered HBT Coverall	0.00
	Cotton Gloves	0.02
	Cotton Undershirt	0.01
	Cotton Drawers	0.00
	Cotton Socks	0.00
	Boots	0.00
	Helmet	0.00
	Gas Mask, M9A1 (not measured)	-
#2	Impregnated HBT Coverall	0.00
	Impregnated Cotton Gloves	0.03
	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.00
	Impregnated Cotton Socks	0.00
	Impregnated Boots	0.04

[redacted]

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #6	Ave. Readings on PR-3 Survey Meter at 6" @ H / 26 hours
Cont'd #2	Helmet	0.02
	Gas Mask	0.04
#3	Laundered Impregnated HBT Coverall	0.01
	Impregnated Cotton Gloves	0.04
	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.01
	Impregnated Cotton Socks	0.00
	Impregnated Boots	0.04
	Helmets	0.02
	Gas Mask, M9A1	0.05
	Clothing of Team #6	
#1	Laundered HBT Coverall	0.00
	Cotton Gloves	0.01
	Cotton Undershirt	0.00
	Cotton Drawers	0.01
	Cotton Socks	0.00
	Boots	0.01
	Helmet	0.03
	Gas Mask, M9A1	0.03
#2	Impregnated HBT Coverall	0.00
	Impregnated Cotton Gloves	0.00

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #6	Ave. Readings on PR-3 Survey Meter at 6" @ H / 26 hours
Cont'd #2	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.01
	Impregnated Cotton Socks	0.03
	Impregnated Boots	0.04
	Helmet	0.05
	Gas Mask, M9A1	0.05
#3	Laundered Impregnated HBT Coverall	0.02
	Impregnated Cotton Gloves	0.03
	Impregnated Cotton Undershirt	0.01
	Impregnated Cotton Drawers	0.01
	Impregnated Cotton Socks	0.02
	Impregnated Boots	0.05
	Helmet	0.03
	Gas Mask, M9A1	0.04
#4	Cotton-Sateen Coverall	0.05
	Cotton Gloves	0.01
	Cotton Undershirt	0.00
	Cotton Drawers	0.00
	Cotton Socks	0.00
	Boots	0.02

[redacted]

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #6	Ave. Readings on PR-3 Survey Meter at 6" @ H / 26 hours
Cont'd #4	Helmet	0.02
	Gas Mask, M9A1	0.04
	Clothing of Team #7	
#1	Laundered HBT Coverall	0.03
	Cotton Gloves	0.01
	Cotton Undershirt	0.01
	Cotton Drawers	0.00
	Cotton Socks	0.00
	Boots (not measured)	-
	Helmet (not measured)	-
	Gas Mask, M9A1 (not measured)	-
#2	Impregnated HBT Coverall	0.00
	Impregnated Cotton Gloves	0.01
	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.00
	Impregnated Cotton Socks	0.00
	Impregnated Boots	0.00
	Helmet	0.00
	Gas Mask, M9A1	0.03
#3	Laundered Impregnated HBT Coverall	0.00
	Cotton Gloves	0.00

[redacted]

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #7	Ave. Readings on PR-3 Survey Meter at 6" @ H + 26 hours
Cont'd #3	Cotton Undershirt	0.01
	Cotton Drawers	0.00
	Cotton Socks	0.00
	Boots	0.00
	Helmet	0.00
	Gas Mask, M9A1	0.03
	Clothing of Team #8	
#1	Laundered HBT Coverall	0.00
	Cotton Gloves	0.00
	Cotton Undershirt	0.01
	Cotton Drawers	0.01
	Cotton Socks	0.02
	Boots	0.09
	Helmet	0.07
	Gas Mask, M9A1	0.04
#2	Impregnated HBT Coverall	0.00
	Impregnated Cotton Gloves	0.08
	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.00
	Impregnated Cotton Socks	0.00
	Impregnated Boots	0.21

[redacted]

APPENDIX A

Table A.3 (Cont'd)

Man	Clothing of Team #8	Ave. Readings on PR-3 Survey Meter at 8" @ H / 26 hours
Cont'd #2	Helmet	0.08
	Gas Mask, M9A1	0.04
#3	Laundered Impregnated HBT Coverall	0.00
	Impregnated Cotton Gloves	0.07
	Impregnated Cotton Undershirt	0.00
	Impregnated Cotton Drawers	0.00
	Impregnated Cotton Socks	0.04
	Impregnated Boots	0.14
	Helmet	0.06
	Gas Mask, M9A1	0.01

[redacted]

APPENDIX A

TABLE A.4 (See Fig. 1.6)

Contamination of Protective Clothing Worn by Men Walking in Contaminated Area of Underground Shot

No. Men	Performance	Article of Clothing	Ave. Reading PR-3 Survey Meter at 6" @ H + 124 hrs corrected for background
3	Walked, Crawled	Impregnated Cotton-Sateen Coverall	2.60 mr/hr
	" "	Impregnated Cotton Gloves	3.70
	" "	Impregnated Cotton Undershirts	0.00
	" "	Impregnated Cotton Drawers	0.00
	" "	Impregnated Cotton Socks	0.12
	" "	Impregnated Boots	2.50
	" "	Helmet	0.23
	" "	Gas Mask, M9A1	0.37
1	" "	Unimpregnated Cotton Sateen	0.60
	" "	Cotton Gloves	0.70
	" "	Cotton Undershirt	0.04
	" "	Cotton Drawers	0.10
	" "	Cotton Socks	0.17
	" "	Boots	0.70
	" "	Helmet	0.20
	" "	Gas Mask, M9A1	0.25
4	" "	Impregnated HBT Coveralls	2.94
	" "	Impregnated Cotton Gloves	2.90
	" "	Impregnated Cotton Undershirts	0.00

[redacted]

APPENDIX A

TABLE A.4 (Cont'd)

Contamination of Protective Clothing Worn by Men Walking in Contaminated Area of Underground Shot

No. Men	Performance	Article of Clothing	Ave. Reading PR-3 Survey Meter at 6" @ H + 124 hrs corrected for background
4	Walked, Crawled	Impregnated Cotton Drawers	0.00 mr/hr
	" "	Impregnated Socks	0.00
	" "	Impregnated Boots	2.00
	" "	Helmets	0.20
	" "	Gas Mask, M9A1	0.45
1	" "	Laundered HBT Coverall	0.60
	" "	Cotton Gloves	0.80
	" "	Cotton Undershirts	0.00
	" "	Cotton Drawers	0.00
	" "	Cotton Socks	0.00
	" "	Boots	1.00
	" "	Helmets	0.30
	" "	Gas Mask, M9A1	0.20
5	" "	Impregnated Cotton-Sateen Coveralls	0.28
	" "	Impregnated Cotton Gloves	0.56
	" "	Impregnated Cotton Undershirts	0.00
	" "	Impregnated Cotton Drawers	0.00
	" "	Impregnated Cotton Socks	0.05
	" "	Impregnated Boots	0.53

[redacted]

PROJECT 6.3-1

APPENDIX A

TABLE A.4 (Cont'd)

Contamination of Protective Clothing Worn by Men Walking in Contaminated Area of Underground Shot

No. Men	Performance	Article of Clothing	Ave. Reading PR-3 Survey Meter at 6" @ H + 124 hrs corrected for background
5	Walked, Crawled	Helmets	0.12 mr/hr
	" "	Gas Masks, M9A1	0.09
1	" "	Cotton-Sateen Coverall	0.23
	" "	Cotton Gloves	0.80
	" "	Cotton Undershirts	0.00
	" "	Cotton Drawers	0.00
	" "	Cotton Socks	0.00
	" "	Boots	0.50
	" "	Helmet	0.10
	" "	Gas Mask, M9A1	0.00
4	Walking	Impregnated HBT Coveralls	0.43
	"	Impregnated Cotton Gloves	0.62
	"	Impregnated Cotton Undershirts	0.00
	"	Impregnated Cotton Drawers	0.00
	"	Impregnated Cotton Socks	0.01
	"	Impregnated Boots	0.65
	"	Helmets	0.17
	"	Gas Masks, M9A1	0.17
1	"	HBT Coverall, Laundered	0.30

[redacted]

[redacted]

PROJECT 6.3-1

APPENDIX A

TABLE A.4 (Cont'd)

Contamination of Protective Clothing Worn by Men Walking in Contaminated Area of Underground Shot

No. Men	Performance	Article of Clothing	Ave. Reading PR-3 Survey Meter at 6" @ H + 124 hrs corrected for background
1	Walking	Cotton Gloves	0.20 mr/hr
	"	Cotton Undershirt	0.00
	"	Cotton Drawers	0.00
	"	Cotton Socks	0.00
	"	Boots	0.77
	"	Helmets	0.10
	"	Gas Mask, M9A1	0.30

[redacted]

APPENDIX B

TABLE B.1

Radiometric Filter Efficiencies of E26 Tank Collective Protectors in Underground Detonation

		(A) *Total Corrected Activity on Part. Filt. @ H + 2200 hours	(B) **Total Corrected Activity on M-10 Canister @ H + 2200 hours	$100(\frac{A}{A+B})$ Filter Efficiency in Per Cent (Radiometric)
VEHICLE NO.	POSITION			
M-26 Tank 418S	In Hull	429 uc	4×10^{-2} uc	99.991
M-26 Tank 418S	In Turret	440	16×10^{-2}	99.964
M-26 Tank 424S	In Hull	231	2×10^{-2}	99.989
M-26 Tank 424S	In Turret	298	3×10^{-2}	99.990
T-18E1 Personnel Carrier	Inside	434	11×10^{-2}	99.975
			Average	99.982

* See Table B.2 for source of above figures

** See Table B.3 for source of above figures

APPENDIX B

TABLE B.2

Activities of Particulate Filters in Influent Stream of E-26 Tank Collective Protectors from Underground Detonation

Vehicle Number	Position	(A) CPM of 2" dia. circles at H+2200 hrs corrected for geom. & background	Time of Measurement	(B) (A x 183) CPM of Total Area of Filter Corrected	(C) $\frac{B}{*(3.70 \times 10^4)}$ Activity of filter in uc @ H + 2200 hrs
M-26 418S	In Hull	86,734	H+2200 hrs	1.587×10^7	429
M-26 418S	In Turret	88,655	H+2200 hrs	1.621×10^7	440
M-26 424S	In Hull	46,803	H+2200 hrs	8.57×10^6	231
M-26 424S	In Turret	60,225	H+2200 hrs	1.102×10^7	298
T18E1 Personnel Carrier	Inside	87,657	H+2200 hrs	1.603×10^7	434

* See Table 3.1 for calculation of filter efficiencies of E-26 tank collective protectors

APPENDIX B

**TABLE B.3

Activities of M-10 Canisters in Effluent Streams of E-26 Tank Collective Protectors in Underground Detonation

Vehicle Number	Position	(A) Ave. CPM on 2" dia. circle corrected for background	(B) (A) (10) CPM corrected for geometry	(C) (51.3) (B) CPM corrected for geom. and area	*(D) Decay Factor correct to H+2200 hrs		(E) (C) (D) 3.7×10^4 Total Activity in uc at H+2200 hrs
M-26 Tank 418S	In Hull	6	60	3,100	H + 1128 hrs	.45	4×10^{-2}
M-26 Tank 418S	In Turret	36	360	18,500	H + 864 hrs	.32	1.6×10^{-1}
M-26 Tank 424S	In Hull	4	40	2,000	H + 1130 hrs	.45	2×10^{-2}
M-26 Tank 424S	In Turret	6	60	3,100	H + 960 hrs	.37	3×10^{-2}
T18E1 Personnel Carrier	Inside	19	190	9,800	H + 1056 hrs	.41	1.1×10^{-1}

* Decay factors obtained from curve in Fig. 1.5

** See Table B.1 for calculation of filter efficiency of E-26 tank collective protectors

APPENDIX B

TABLE B.4

Radiation Hazard Results of E-26 Tank Collective Protectors in #18, M-26 Tank During Underground Detonation

Point of Measurement Tank No. 18	Radioactivity** in counts per minute @ H + 1 hour			
	Turret #44		Hull #49	
	Surface	6" Away	Surface	6" Away
Aerotech End	746×10^6	280×10^6	652×10^6	326×10^6
Aerotech End w/o Baffle Plate	3110	562	3110	777
Intake side (4 slots)	1201	209	1470	244
Side opposite intake	592	179.8	735	204
Wide sides	812	219	940	244
End w/3-hose connections	484	123.3	735	204
Particulate Filter Inlet	11,400	2,860	13,100	3,260
Particulate Filter Effluent	8,280	2,070	9,320	2,330
Charcoal Filter Inlet *	37.5	28.0	11.43	6.44
Charcoal Filter Effluent *	95.3	60.8	155	73.5

* After radioactive dust was wiped from charcoal holder, readings on charcoal filter were the same as background.

** As measured by Tracerlab Laboratory Monitor.

[redacted]

[redacted]

PROJECT 6.3-1

APPENDIX B

TABLE B.5

Radiation Hazard Results of E-26 Tank Collective Protectors in #24, M-26 Tank During Underground Detonation

Point of Measurement Tank No. 24	Radioactivity** in counts per minute @ H + 1 hour			
	Turret #46		Hull #47	
	Surface	6" Away	Surface	6" Away
Aerotech End	406 x 10^6	207 x 10^6	278 x 10^6	251 x 10^6
Aerotech End w/o Baffle Plate	3,910	577	2,140	371
Intake side (4 slots)	748	137.5	577	139.5
Side opposite intake	530	119.6	371	111.6
Wide sides	640	145.1	464	139.5
3-Hose Connection End	437	211	186.0	111.5
Particulate Filter Inlet	10,630	2,660	4,170	1,119
Particulate Filter Effluent	7,170	3,490	7,440	1,470
Charcoal Filter Inlet *	28.2	---	9.3	---
Charcoal Filter Effluent *	162.6	---	27.8	---

* After radioactive dust was removed from charcoal holder, readings on charcoal filter were the same as background.

** As measured by Tracerlab Laboratory Monitor.

[redacted]

[redacted]

PROJECT 6.3-1

APPENDIX B

TABLE B.6

Radiation Hazard Results of E-26 Tank Collective Protector in T18E1 Personnel Carrier During Underground Detonation

Point of Measurement	Radioactivity** counts per minute @ H+1 hour - #50 Troop Compartment	
	Surface	6" Away
Aerotech End	884×10^6	178.7×10^6
Aerotech End w/o Baffle Plate	4220	422
Intake Side (4 slots)	1420	249
Side opposite intake	615	130.7
Wide Sides	1173	219
3-Hose connection end	442	159.5
Particulate Filter Inlet	10,960	2,760
Particulate Filter Effluent	7,680	1,825
Charcoal Filter Inlet *	50.0	36.4
Charcoal Filter Effluent *	863	50.0

* After radioactive dust was wiped from Charcoal holder, readings on Charcoal were the same as background.

** As measured with Tracerlab Laboratory Monitor.

[redacted]

[redacted]

PROJECT 6.3-1

APPENDIX B

TABLE B.7

Filter Efficiencies of E-22 Tank Collective Protectors at 4,000 Feet Downwind from the Surface Detonation

Station Number	Direction from Ground Zero	Counts per Minute @ H + 24 hours Influent A	Effluent B	Filter Efficiency in Per Cent $100\left(\frac{A}{A+B}\right)$
13	NW	Jammed	541,800	---
14	N	106,630	12,153	89.77
15	NE	48,530	551	98.88

TABLE B.8

Instantaneous Radiometric Effluent Readings of E-22 Tank Collective Protector at Station 35, 20,000 Feet NNE and Downwind from Surface Detonation

Time that Particulate Cloud was Over Station #35 was 13 Minutes

Time of Reading	Counts per Minute Effluent	Background	Difference
H + 90 minutes	470	444	26
H + 91 minutes	340	330	10
H + 93 minutes	315	288	27
H + 94 minutes	264	240	24
H + 95 minutes	445	420	35
			Ave. 24 C.P.M.

See Table 3.1

[redacted]

[redacted]

PROJECT 6.3-1

BIBLIOGRAPHY

1. Chemical Corps Book of Standards (Edition of 15 November 1951) CCTC Authorization 1676, p. 14.

2. Ibid., CCTC Authorization 1182, p. 14.

3. Engquist, E. H., "Evaluation of Filter Material", Project 6.6 Operation Greenhouse Report (July 1951 - Secret).

4. The Gas Mask, Department of the Army Technical Manual TM3-205 (March 1951) p. 26.

5. Ibid., p. 53 and Figure 28, p. 54.

6. Ibid., p. 52.

7. Goshorn, Siegel and Gross, TCIR 166 Improved M1 Training, M1A1 Special and M10A1 Service Canisters (14 August 1944 - Confidential) p. 9.

8. Handbook of Atomic Weapons for Medical Officers, Department of the Army Pamphlet No. 8-11 (June 1951), p. 44.

9. Miscellaneous Gas Protective Equipment War Department Technical Manual TM3-290 (27 March 1944), pp. 5 - 20.

10. Ibid., p. 53.

11. Mitchell, J. P., Development of Pressure-Ventilated System of Tank-Crew Protection, MIT Memorandum Report No. 182 (11 October 1945).

12. "Project 6.7 Report", Operation Jangle, Office of the Quartermaster General.

[redacted]

[redacted]

OPERATION JANGLE

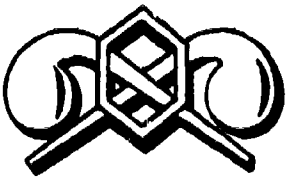
PROJECT 6.3-2

EVALUATION OF THE POTENTIAL RESPIRATORY HAZARD TO TANK CREWS REQUIRED TO OPERATE IN CONTAMINATED AREAS

by

ELMER H. ENGQUIST

July 1952



Chemical and Radiological Laboratories
Army Chemical Center, Maryland

[redacted]

[redacted]-2

PREFACE

This report covers work conducted under Operation JANGLE Project 6.3, "Evaluation of Protective Equipment", John R. Hendrickson, Project Officer. The work at the test site was coordinated and conducted under the direction of the author.

The cooperation of many Chemical Corps individuals, too numerous to mention by name, assigned to the above projects contributed to the accomplishments of the objectives of this study. In addition, an Ordnance Test Team, directed by Captain David W. Armstrong and Mr. Norman Arnold, Ballistics Research Laboratories, Aberdeen Proving Ground, Maryland, and an Army Field Forces Board No. 2 Test Team, directed by Lt. Col. John S. Sandiland, provided the necessary support in the operation of the M26 tanks and the Personnel Carrier, T18E1. Each group provided many valuable suggestions and direction to the author. The assistance of Pfc John Sweeney was particularly valuable to the author in carrying out the installation of test apparatus and the tank collective protectors in the vehicles.

PRECEDING PAGE BLANK - NOT FILMED

[redacted]

[redacted]

PROJECT 6.3-2

CONTENTS

[redacted]

[redacted]

ILLUSTRATIONS

[redacted]

PROJECT 6.3-2

TABLES

[redacted]

[redacted]

PROJECT 6.3-2

[redacted]

[redacted]

PROJECT 6.3-2

ABSTRACT

The objective of this investigation was to assess the inhalation hazard to armored vehicles crews during the exposure to an underground and surface detonation of an atomic weapon and during operation, following the detonation, of the armored vehicles within the contaminated area resulting from fall-out.

Two types of armored vehicles were employed in this study, two Medium Tanks, M26, and one Personnel Carrier, T18E1, Pilot Model No. 5. During the surface shot only the two tanks were exposed 2000 ft in an upwind direction from ground zero and operated to within approximately one-tenth mile of ground zero. No contaminated area was traversed during this operation since the fall-out was restricted to a long narrow corridor in the downwind direction.

During the underground shot all three vehicles were exposed at 2000 ft in a downwind direction in an area contaminated to a level of approximately 550 roentgens/hr at H-hr + 1/2 hr. One tank was exposed head-on, with hatches open, one tank side-on with hatches closed, and the Personnel Carrier, head-on with the commander's and driver's hatches open. Following the shot at H-hr + 50 hr, after decontamination, the vehicles were operated with one tank leading with hatches open, and the other vehicles following with hatches closed, up to and beyond the crater lip and return.

During both exposure of the vehicles during the underground shot and operation through the contaminated area the airborne activity exceeded by a large degree the maximum allowable concentrations established by the Department of Defense and the U. S. Atomic Energy Commission for lifetime exposure. Preliminary to this operation a study was made to develop a basis for short-time exposure to airborne activity without exceeding the maximum allowable concentrations retained within the body. This study is appended to this report. The activity level measured exceeded the standards for eight hour exposure by a factor of 10 to 380.

There is thus a potential respiratory hazard during the initial 24 hour period to armored vehicle crews not wearing protective masks. The degree of this hazard cannot be firmly established due to the lack of definitive medical data on the result of this exposure. However, adequate protection can be provided to armored vehicle crews through the use of protective masks, and/or, tank collective protectors, and their use in similar situations is recommended.

[redacted] [redacted]

It is further recommended that results of this study be applied to the development of the overall hazard only after adequate consideration for the external dose to which personnel would simultaneously be exposed.

[redacted]

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVE

The objective of this investigation was to assess the inhalation hazard associated with (1) exposure of armored vehicles to an underground and surface detonation of atomic weapons, and (2) operation of armored vehicles through areas contaminated with fission products resulting from fall-out from such detonations.

1.2 AUTHORITY

The study on armored vehicles was conducted under Operation JANGLE Project 6.3, "Evaluation of Protective Equipment". The personnel carrier was included in accordance with 1st Indorsement, G4/F4/64171, dated 24 October 1951, from Office, AC/S, G4, Department of Army, to Chief Chemical Officer, D/A, on basic letter from Office, Chief of Army Field Forces, Fort Monroe, Virginia, subject: "Atomic Weapons Effects Testing".

1.3 HISTORICAL

Previous atomic weapons test, with the exception of Test Baker at Operation CROSSROADS were detonated as low air drops or detonated on towers. Thus, they were essentially of the non-contaminating type of burst since a major fraction of the fission product activity rose with the cloud and was diluted in the atmosphere. On 5 June 1950 the Joint Chiefs of Staff directed that underground and surface tests of nominal (20-30 kiloton) atomic weapons be conducted. As a result the Department of Defense through the Armed Forces Special Weapons Project established Operation WINDSTORM to be conducted on Amchitka in the Aleutian Islands. Subsequently, this operation was cancelled because of unfavorable test conditions of weather and terrain. The test were then rescheduled as Operation JANGLE for conduct with scaled atomic weapons, of approximately 1.25 kiloton yield, at the Nevada Proving Ground, U. S. Atomic Energy Commission, Mercury, Nevada. The surface test was detonated on 19 November 1951.

[redacted] [redacted]

[redacted]

PROJECT 6.3-2

1.4 THEORETICAL

The maximum permissible concentrations of radioactive isotopes in air have been established by the U. S. Atomic Energy Commission as standards for the control of radioactive materials in laboratories using such isotopes[1,2]. These concentrations are stipulated to constitute no hazard to personnel engaged in isotope work on a lifetime basis.

No standards are available for guidance of military operations in contaminated areas. It is a logical assumption that such operations are conducted with consideration of the hazards of such operations and acceptable risks will be taken where necessary for the accomplishment of the mission. Thus, such operations should only be conducted after assessment of the potential hazard and with adequate consideration of the risk. In military operations in contaminated areas it is expected that exposures will not be guided by standards established on the basis of lifetime exposure but rather on one-time, or at best a few, exposures to the hazard.

A study was made prior to Operation JANGLE to provide such a basis for military exposure. The calculations of Hunter and Ballou were used to furnish individual and total beta activities for fission products at various times between 1 hr and 1 yr after detonation. Then the concentration in air necessary to cause the deposition and retention of the maximum permissible amounts of Sr^{90} was calculated for several times after detonation, and for various exposure times. Each of the other fission products considered hazardous was then compared at several times to Sr^{90} on the basis of relative activity and toxicity. The possibility that "bad actors" might appear as decay products of active material already in the body was considered. Then estimates were made of their radio-toxicity relative to Sr^{90}. This relative value was called the "Sr^{90} equivalent". The concentrations necessary to cause retention of 1 Sr^{90} equivalent at various times were calculated and a graph prepared showing maximum permissible concentrations of fission products from 1 hr to 1 yr after detonation for various exposure times. This study results in the development of a much higher maximum permissible concentration than those set for long term exposure[3].

---

[1]Handbook of Atomic Weapons for Medical Officers, Prepared by Armed Forces Special Weapons Project, Department of Army Handbook 8-11, June 1951.

[2]Subcommittee on Internal Dose of the National Committee on Radiation Protection, "Maximum Permissible Concentrations of Radioisotopes in the Air, Water, and in the Human Body". (1951)

[3]CRLIR 64 "Maximum Allowable Concentration of Fission Products in the Air as a Function of Exposure Time and Time After Detonation".

[redacted] [redacted]

[redacted]

PROJECT 6.3-2

This study was further extended with modifications of the assumptions, refinement of the calculations, and consideration of the plutonium hazard. This study developed even higher concentrations than the initial study[4]. The reports are included as Appendices A and B.

[4]CRLIR 81 "Maximum Allowable Concentration of Fission Products in the Air as a Function of Exposure Time and Time After Detonation (Continued)".

[redacted] [redacted]

[redacted]

CHAPTER 2

EXPERIMENTAL

2.1 INSTRUMENTATION

To determine the airborne activity in the vehicles, and on the exterior of the vehicles, a Chemical Corps filter sampler was used. This device samples approximately one cfm of air through a 100 sq cm sheet of Chemical Corps Type 6 filter material backed up with two sheets of Chemical Corps Type 5 filter material for support. This unit is shown in Fig. 2.1. The units were operated for one hour starting at five minutes prior to the shot.

2.2 VEHICLES

2.2.1 M-26 Tank

The filter sampler was installed in the bow between the driver and assistant driver, in the turret ahead of the loader's seat, and on the outside fender of the tank. These installations are shown in Fig. 2.2, and Fig. 2.3.

2.2.2 Personnel Carrier T18E1

The filter sampler was located in the crew compartment only in this vehicle.

2.3 EXPOSURE POSITION OF VEHICLES

2.3.1 During Shot

During the surface shot the two medium tanks, M26, were located 2000 ft, 15° east of south, from ground zero. One tank was located head-on, and one side-on, to ground zero. This location was upwind of the area of contamination and little, if any, significant fall-out occurred at the location of the vehicles.

The principle evaluation for the purposes of this report was conducted on the underground shot. The three vehicles were located at 2000 ft from ground zero in the fall-out direction. This area was contaminated

[redacted]

[redacted]

PROJECT 6.3-2

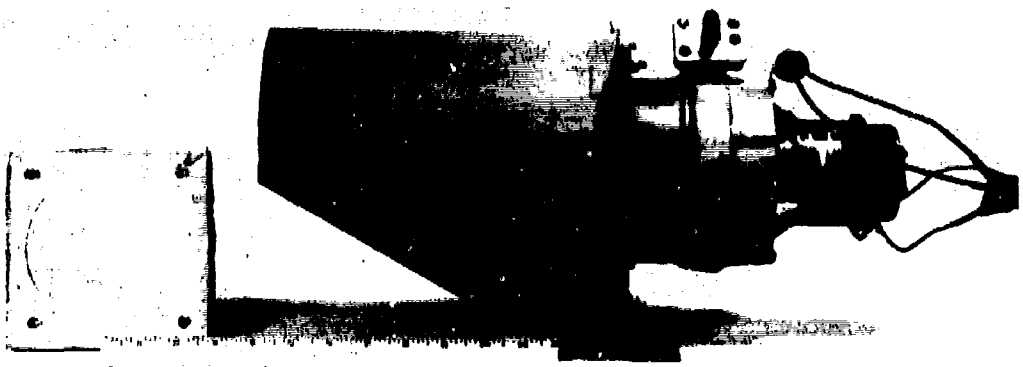


Fig. 2.1 Chemical Corps Filter Sampler

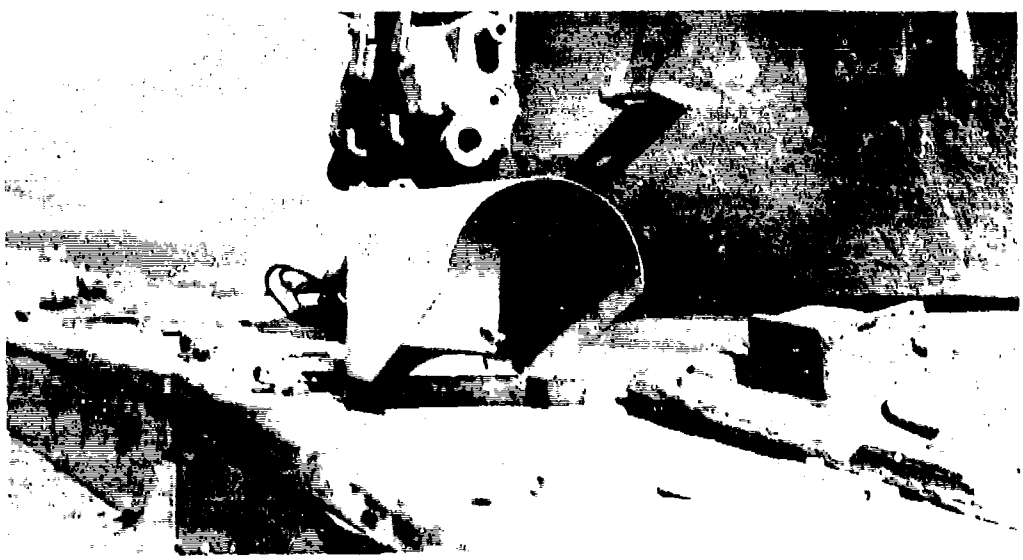


Fig. 2.2 Chemical Corps Filter Sampler Installations on M26 Tanks

[redacted]

to a level of 550 roentgens/hr at H-hr + 1/2 hr. One tank was located head-on, one tank side-on, and the Personnel Carrier, T18E1, Pilot Model No. 5, was located head-on to ground zero. The hatches were open on the head-on tank, closed on the side-on tank and the commander's and driver's hatches open on the Personnel Carrier, T18E1.

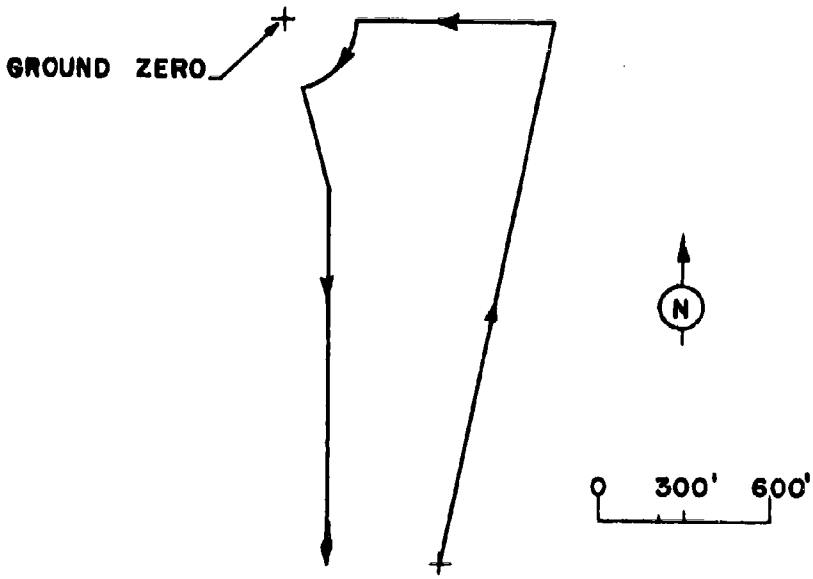
2.3.2 Areas of Operation Following Shots

The routes of operation of the vehicles through the contaminated area created by the two shots are shown in Fig. 2.4. The route shown for the surface shot was traversed at H-hr + 25 hrs, and the route shown for the underground shot was traversed at H-hr + 50 hrs. On the underground shot, the M-26 Tank 424-S was the lead vehicle, hatches open, followed by the M-26 tank 418-S and the Personnel Carrier, T18E1, hatches closed.

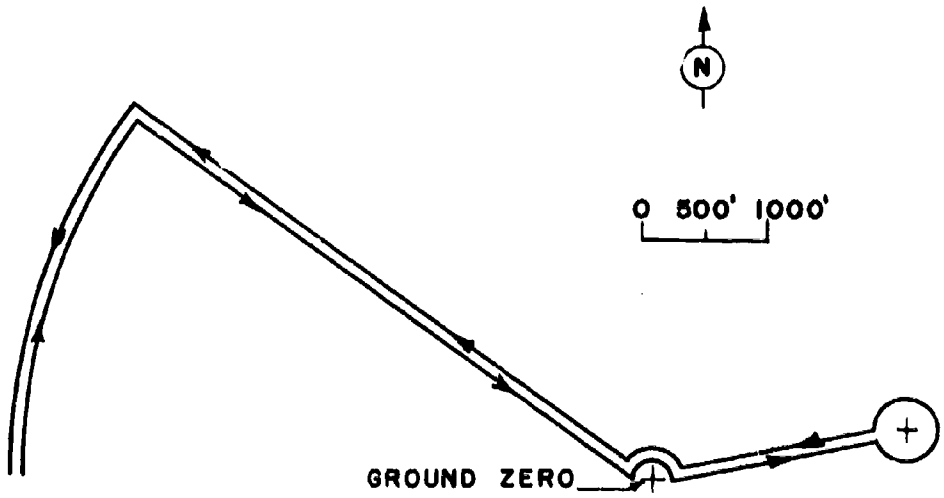
Fig. 2.3 Chemical Corps Filter Sampler Installation in M26 Tank

[redacted]

PROJECT 6.3-2



TANK ROUTE FOLLOWING SURFACE DETONATION



ARMORED VEHICLE ROUTE FOLLOWING UNDERGROUND DETONATION

Fig. 2.4 Areas of Operation of Vehicles in Contaminated Areas

[redacted]

[redacted]

CHAPTER 3

RESULTS

3.1 AIRBORNE ACTIVITY LEVEL IN VEHICLES DURING UNDERGROUND SHOT

The data on airborne beta activity level in vehicles are given in Table 3.1. The samples were taken for 55 minutes following the shot and the counting data were arbitrarily corrected to H-hr + 1 hr by means of the decay equation for gross fission products, $A = A_0 t^{-n}$, where the decay exponent was taken as 1.48. This was the experimentally determined value on the samples. Activity levels collected by the samples varied randomly with location within the vehicles from 0.17 to 0.45 millicuries per liter of air. The following averaged concentrations were obtained for the three vehicles:

Vehicle	Millicuries/Liter
M26 Tank - Hatches Closed	0.23
M26 Tank - Hatches Open	0.27
T18E1 Personnel Carrier	0.28

3.2 AIRBORNE ACTIVITY LEVEL IN VEHICLES DURING TEST RUN FOLLOWING THE UNDERGROUND SHOT

The data shown in Table 3.2 were obtained during the test run following the underground shot through the contaminated area to the crater lip and beyond, and return, as shown in Fig. 2.3.

[redacted] [redacted]

[redacted]

PROJECT 6.3-2

TABLE 3.1

Airborne Activity Level In Armored Vehicles

Vehicle	Location	Activity (mc)	Sampling Time (min)	Sampling Volume (l/min)	Activity/Liter (mc/liter)
M-26 Tank 424-S	Turret	12.2	60	1.23	0.17
M-26 Tank 424-S	Hull	21.2	60	1.08	0.33
M-26 Tank 424-S	Outside	11.0	60	0.95	0.19
Average Concentration					0.23
M-26 Tank 418-S*	Turret	30.6	60	1.12	0.45
M-26 Tank 418-S*	Hull	13.0	60	1.23	0.18
M-26 Tank 418-S*	Outside	14.0	60	1.28	0.18
Average Concentration					0.27
Personnel Carrier T18E1	Personnel Comp't	19.4	60	1.15	0.28

*Hatches Open

[redacted]

[redacted]

[redacted]

PROJECT 6.3-2

TABLE 3.2

Airborne Activity Level During Armored Vehicle Test Run*

Vehicle	Location	Activity (mc)	Sampling Time (min)	Sampling Volume (l/min)	Activity/Liter (mc/liter)
M-26 Tank 418-S	Turret	2.63	23	1.12	0.102
M-26 Tank 418-S	Hull	1.0	23	1.23	0.035
M-26 Tank 418-S	Outside	0.12	23	1.28	0.004
Average Concentration					0.068
M-26 Tank 424-S	Turret	0.48	23	1.23	0.017
M-26 Tank 424-S	Hull	9.0	23	1.08	0.362
M-26 Tank 424-S	Outside	1.2	23	0.95	0.055
Average Concentration					0.18
Personnel Carrier T18E1	Personnel Comp't	1.0	23	1.15	0.038

*M-26 Tank 424-S was the lead vehicle, hatches open, followed by the M-26 Tank 418-S, and the Personnel Carrier, T18E1, hatches closed.

[redacted] [redacted]

[redacted]

CHAPTER 4

DISCUSSION

4.1 VARIATION OF AIRBORNE ACTIVITY

It is considered significant that the airborne activity does not appear to vary markedly with the operational condition of the tanks; that is, whether the vehicle hatches are open or closed during the period of exposure. This is clearly indicated by the data given in Section 3.1. It was further indicated immediately after removal of the sampling papers from the test samplers when the papers were monitored by survey meters at H-hr + 70 hrs before shipment to the Army Chemical Center for detailed analysis. The measured activity on the papers at that time varied from 7 to 35 mr/hr at 6 in. from the samples.

During the test run through the contaminated area following the underground shot it is to be noted that there was no significant difference in activity in the lead vehicle as opposed to the two following "buttoned-up" vehicles, with ventilating system operating. This is strong indication that the major portion of the airborne material within the vehicle was a secondary aerosol created from contamination within the vehicle itself.

4.2 FACTORS AFFECTING APPLICATION OF DATA

Before applying the results of this investigation to an assessment of inhalation hazard associated with airborne radioactive material to armored vehicle personnel three additional factors should be considered. First it should be emphasized that no effort was made to limit the spectrum of particle size sampled by the filter samplers to that which is in the specific size range for lung retention. The particle size for retention has an upper limit of 10 microns, and more probably 3 microns. Data developed by Operation JANGLE Project 2.5a, Airborne Cloud Studies, indicate that less than 10 per cent of the total airborne activity is in the inhalation hazard size range of 0.5 to 5.0 microns[5].

Second, the protective measures available to personnel must be considered. The gas mask, or more specifically for armored vehicle crews,

[5]Letter to, Office of the Director, Effects Test, c/o Technical Operations Squadron (Prov), Washington 13, D.C., from CO, Cml C Chemical and Radiological Laboratories, Army Chemical Center, Md., dated 18 April 1952.

[redacted] [redacted]

the Tank Collective Protector, E26, has an extremely high efficiency for the removal of gross fission product contaminant associated with the cloud and base surge created by an underground detonation[6]. The average penetration of these units by radioactive particles was measured at 0.018 per cent, that is, 1.8 parts in 10,000 pass through the tank collective protector filter unit.

Third, the time of exposure must be considered. For short-term exposure, if one accepts the assumptions as outlined in Appendices A and B which provide the basis for calculation of short-term exposure to gross fission products, 8 hr exposure to 0.1 to 0.0035 microcuries per liter of gross fission products can be tolerated during the period of H + 1 hr to H + 1 day. This time of exposure was the shortest considered in the analysis and, since tank crews generally could be expected to be exposed for even shorter periods than 8 hrs during operations within contaminated areas, they could tolerate slightly higher levels of airborne contamination.

4.3 FACTORS BY WHICH MEASURED AIRBORNE CONCENTRATION EXCEED MAXIMUM ALLOWABLE CONCENTRATIONS

The concentrations given in Table 3.1 and 3.2, allowing for the 10 per cent size range factor, exceed the maximum allowable concentrations given in Appendices A and B, as given in Table 4.1.

TABLE 4.1

Factors by which Measured Airborne Concentration Exceed Maximum Allowable Concentrations

Time of Exposure	Maximum Allowable Concentration µc/l (for 8 hr Exposure)[1]	Measured Concentration		Factor by which Measured value exceeds Max. Allowable Conc.	
		Maximum µc/l	Minimum µc/l	Maximum	Minimum
H + 24 hr	0.0035	0.252	0.034	72	10
H + 1 hr	0.1	28.	3.8	280	38

[1] Appendices A and B

[6] "Evaluation of Protective Equipment", Operation Jangle Project 6.3, John R. Hendrickson, Army Chemical Center, Maryland.

[redacted]

4.4 EVALUATION OF THE POTENTIAL HAZARD

Thus, unprotected personnel would be exposed to concentrations exceeding the maximum allowable concentration for 8 hr exposure by a factor of 10 to 280, and there is thus a requirement for tank personnel to wear protective masks when operating within contaminated areas. Such protective masks would probably be worn for comfort purposes under any conditions, if available, under dusty conditions such as were encountered at the Nevada Proving Ground.

Wearing protective masks, with a penetration of 2 parts in 10,000, and considering that 10 per cent of the activity is in the respiratory size range, the concentrations inhaled are well below the maximum allowable concentration for eight hour exposure as outlined in Appendices A and B. There thus appears to be little hazard to tank crews wearing protective masks.

Without more definitive respiratory retention data, and the results of such exposure, it is not possible to determine the magnitude of the hazard to unprotected personnel. By comparison of the measured activity levels with U. S. Atomic Energy Commission and military standards for maximum permissible concentrations of radioactive isotopes in the air for lifetime exposures (which offer substantial safety factors), and by comparison with the short-term exposure limits for negligible hazard, there is an exposure problem to avoid all hazard. However, the degree of the hazard present in exposure which exceeds the maximum allowable concentrations has not been established to date and therefore the magnitude of the exposure to unprotected tank personnel cannot be firmly established.

[redacted]

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

1. Based on the data developed by this study there is a potential respiratory hazard during the initial 24 hr period to armored vehicle crews not wearing protective masks from the airborne fission product activity associated with the base surge and during the operation of armored vehicles through contaminated areas.

2. Satisfactory respiratory protection can be provided to armored vehicle crews operating in contaminated areas through the use of protective masks, and/or, tank collective protectors.

5.2 RECOMMENDATIONS

1. In developing the overall personnel hazard it is recommended that the results of these studies be applied only after adequate consideration for the external dose to which personnel would also be exposed.

2. It is recommended that protective masks, and/or tank collective protectors, be used in situations similar to that presented by the Operation JANGLE tests.

3. It is recommended that these data be extrapolated to the condition encountered during detonations of nominal or operational atomic weapons.

[redacted] [redacted]

[redacted]

PROJECT 6.3-2

APPENDIX A

MAXIMUM ALLOWABLE CONCENTRATIONS OF FISSION PRODUCTS IN THE AIR AS A FUNCTION OF EXPOSURE TIME AND TIME AFTER DETONATION

and

APPENDIX B

MAXIMUM ALLOWABLE CONCENTRATIONS OF FISSION PRODUCTS IN THE AIR AS A FUNCTION OF EXPOSURE TIME AND TIME AFTER DETONATION
(Continued)

by

ROBERT L. HARVEY
Lt, U. S. Navy

Radiological Division
Chemical Corps
Chemical and Radiological Laboratories
Army Chemical Center, Maryland

[redacted] [redacted]

[redacted]

PROJECT 6.3-2

APPENDIX A

MAXIMUM ALLOWABLE CONCENTRATIONS OF FISSION PRODUCTS IN THE AIR AS A FUNCTION OF EXPOSURE TIME AND TIME AFTER DETONATION

A.1 INTRODUCTION

During the planning of a decontamination project at the Radiological Division, Chemical and Radiological Laboratory, Army Chemical Center, Md., it was observed that the procedures to be employed might cause the formation of secondary aerosols, and that these might well pose an internal health hazard. Provision was then made to make beta activity determinations in microcuries per liter of air in the vicinity of the exposed personnel. It was then observed that the determination would be of little value unless there were some criterion for determining whether or not the measured activity were actually an hazard. Unfortunately, the figures in the literature, some of which were listed in Table A.1, were all set for steady state conditions, that is to say, for continual exposures for long periods of time. These figures it was felt might well be unrealistic for short-term exposures, that is to say, that permissible concentrations might be higher.

A.2 OBJECTIVE

It was decided that to be of genuine utility to the military a graph would have to be prepared with maximum permissible fission product concentration in microcuries per liter of air as the ordinate and time after detonation of an atomic bomb as the abscissa, showing a family of curves corresponding to given lengths of exposure time.

A.3 METHOD OF ATTACK

It was first assumed that the activities resulting from the slow-neutron fission of U^{235}, as reported by Hunter and Ballou (6), were close enough to those arising from fast fission to serve as a guide for the contributions of the nuclides under consideration. Then the further assumption was made that any airborne fission product mixture would have the same composition.

Sr^{90} was selected as the base, or reference activity since it is the most persistent, though not the most serious hazard (1), (3), (4), (5), (7), (8), after having been metabolized into the human body. Not only that, but during the period of time under consideration, its activity could be

[redacted] [redacted]

TABLE A.1

Maximum Permissible Concentrations of Various Elements in the Atmosphere for Continual Exposure

Element	β-ν Act. in μc/l	El.	α Act. in μc/l	Ref.	Remarks
I, Sr, Ba	10^{-4}	Pu	3×10^{-8}	1	Alpha exposure for an 8-hr day, 6-day week for 1 yr
Fission Product	2×10^{-7}	Pu	1.5×10^{-9}	2	Continual exposure
I, Sr, Ba	10^{-4}	Pu	3×10^{-8}	3 p.26	Alpha exposure for an 8-hr day, 6-day week for 1 yr
Long-lived beta-gamma emitter	10^{-5}	(Pu) α	3×10^{-8}	3 p.86	- - - - - - -
I	3×10^{-6}	Pu	2×10^{-9}	4 p.71	Continual exposure
Beta or gamma emitter	10^{-6}	Pu	2×10^{-9}	5	Continual exposure

considered constant. Now it is known that the standard man breathes 10 cu.m. of air during an 8-hr working period, and a total of 20 cu.m. of air during a 24-hr period which includes an 8-hr working period (8). The maximum permissible amount of Sr^{90} in the human body is 1 microcurie (4). If the assumption is then made that 25 per cent of the airborne Sr^{90} which is breathed in (4), (5) is retained permanently, the maximum permissible amounts of this nuclide in the atmosphere may be calculated. Twenty-five per cent retention, of course, is too high an estimate by a factor of four, as reported by ICRP (4), and neglects biological decay.

The calculation is as follows:

Let Y = the number of liters of air breathed in during the time in question, and

Z = maximum permissible amount of Sr^{90} retained in the body (1 microcurie), then to determine

X = maximum permissible concentration of Sr^{90} in microcuries per liter of air breathed during the time in question

Formula A.1

$$Z = (XY) \times .25$$

Table A.2 shows several values of X.

TABLE A.2

Concentration of Sr^{90} in air necessary to cause retention in the human body of 1 microvurie (or 2 microcuries of Sr^{90}-Y^{90}, since they are parent and daughter in stable equilibrium) during the following periods of time, based on the absorption and permanent retention of 25 per cent of the activity.

Time of Exposure	Concentration μc/liter
8-hr work day	4×10^{-4}
24-hr including an 8-hr work day	2×10^{-4}
7 days including an 8-hr work day each day	2.8×10^{-5}

Now having evaluated the maximum permissible concentrations of Sr^{90} in the air for several exposure times, the gross fission product activity required to provide such concentrations was calculated (see the sample calculation at the bottom of Table A.3). The figures in Table A.3 were plotted on Figs. A.1 and A.2. Thus looking at Figs. A.1 and A.2, we can enter the graph at any time, from 1 hr to 1 yr after detonation, and find the gross fission product activity which, if the assumptions be sound, will cause the deposition and retention of no more than 1 μc of the Sr^{90} in the body. For example, if it is desired to enter a contaminated area 10 hrs after detonation and to stay for 8-hrs, take the abscissa as 10 + 8 hrs, or 18-hrs, run a vertical line up to the 8-hr line, and from the point of intersection, read the maximum permissible concentration, at the left margin, of 34 μc/l. Eighteen hours was used as the entry figure, since the total beta activity decays appreciably during the period, but the Sr^{90} activity does not. It is further noted that although the curves in Fig. A.2 tail downwind, it is expected that they will level off (see p. 73 of ref. 6) toward a partial asymptote.

[redacted] [redacted]

It is plain, however, that Sr^{90} is not the only hazardous fission product. Hamilton (7) indicates that several members of the rare earth group are indeed deserving of consideration. Those considered significant are listed in Table A.4. Each of these nuclides was evaluated as having associated hazards which were so many multiples of Sr^{90}, on the basis of equal activities - than that associated with Sr^{90}.

To arrive at these relative values the following factors were considered: (a) maximum permissible concentration of each nuclide in the body (5) (see second column, Table A.4) and (b) relative activities at various times. The ratios of the various significant fission product activities were roughly estimated by the author by using Hunter and Ballou's plots of activity (6). It then followed that at a given time so many equivalent Sr^{90} activities existed in the presence of 1 unit of actual Sr^{90} activity. Therefore the gross fission product activities listed in Table A.3 were divided by the total Sr^{90} equivalents existing at each time, and the results were plotted in Figs. A.3 and A.4. Thus, a plot of the maximum permissible gross fission product activity vs. time after detonation for various times of exposure was achieved. It is well to emphasize that according to the assumptions drawn here, the maximum deposition and retention is 1 μc of equivalent Sr^{90} activity.

A.5 DISCUSSION

It is recognized that this whole report is largely qualitative in nature and is therefore subject to modification. Several of the questionable aspects of this report will be discussed here by way of amplification.

For simplification the activity of Sr^{90} was considered constant. This is essentially so during the period in question (6). The assumption that 25 per cent of all material inhaled is absorbed and retained permanently, as previously observed, was a high estimate and presents the worst possible picture (4,5,7). In addition particle size distribution has not been considered at all, nor has the accumulation of material in the lungs. Thus it is highly questionable whether the body will have an equivalent of 1 μc of Sr^{90} activity at any time under the stated conditions.

It will be noted further that the assumptions regarding Sr^{90} have been applied to all the other elements considered in Table A.4. The Sr^{90} equivalents - or weighting factors - for each nuclide were arrived at by considering their maximum permissible concentration in the body, their relative activity to that of Sr^{90} at given times.

Iodine was included as the only nonbone seeker, inasmuch as it was determined that a hazard would develop in the thyroid before it existed in the bone, because of rapidity of uptake (the hazard to the rest of the body

[redacted]

PROJECT 6.3-2

TABLE A.3

Maximum Permissible Fission Product Concentration

Time after detonation	Sr^{90} Act. as % of total beta activity[a]	Gross fission product beta activity in μc/l required to cause retention of 1 μc of Sr^{90} in the human body during the following exposure times		
(6)	(6)	8-hr. work day	24-hr[b]	7 days[b]
1 hr	4.35×10^{-5}	920.	460.	66.
3.5 hr	1.82×10^{-4}	220.	110.	16.
12 hr	7.11×10^{-4}	0.56	0.28	3.9
24 hr	1.55×10^{-3}	26.	13.0	1.8
2 days	3.50×10^{-3}	11.5	5.65	0.81
4 days	8.0×10^{-3}	5.0	2.6	0.37
7 days	1.5×10^{-2}	2.7	1.35	0.2
14 days	3.2×10^{-2}	1.25	0.63	0.099
28 days	7.7×10^{-2}	0.52	0.26	0.04
105 days	2.86×10^{-1}	0.14	0.07	0.01
210 days	7.3×10^{-1}	0.055	0.028	0.004
1 yr	1.96	0.020	0.01	0.001

[a] These figures were adjusted slightly to give smooth curves.

[b] Each 24-hr period includes an 8-hr working period.

SAMPLE CALCULATION

At 1 hr Hunter and Ballou (6) give the Sr^{90} activity as 4.35×10^{-5} per cent of the total beta activity. From Table A.2 the concentration of Sr^{90} in the air necessary to cause the deposition and retention of 1 μc at the end of an 8-hr work day is 4×10^{-4} μc/l. Therefore:

$$\frac{4 \times 10^{-4}}{4.35 \times 10^{-5}} \times 100 = 920 \text{ μc/l}$$

[redacted]

[redacted]

PROJECT 6.3-2

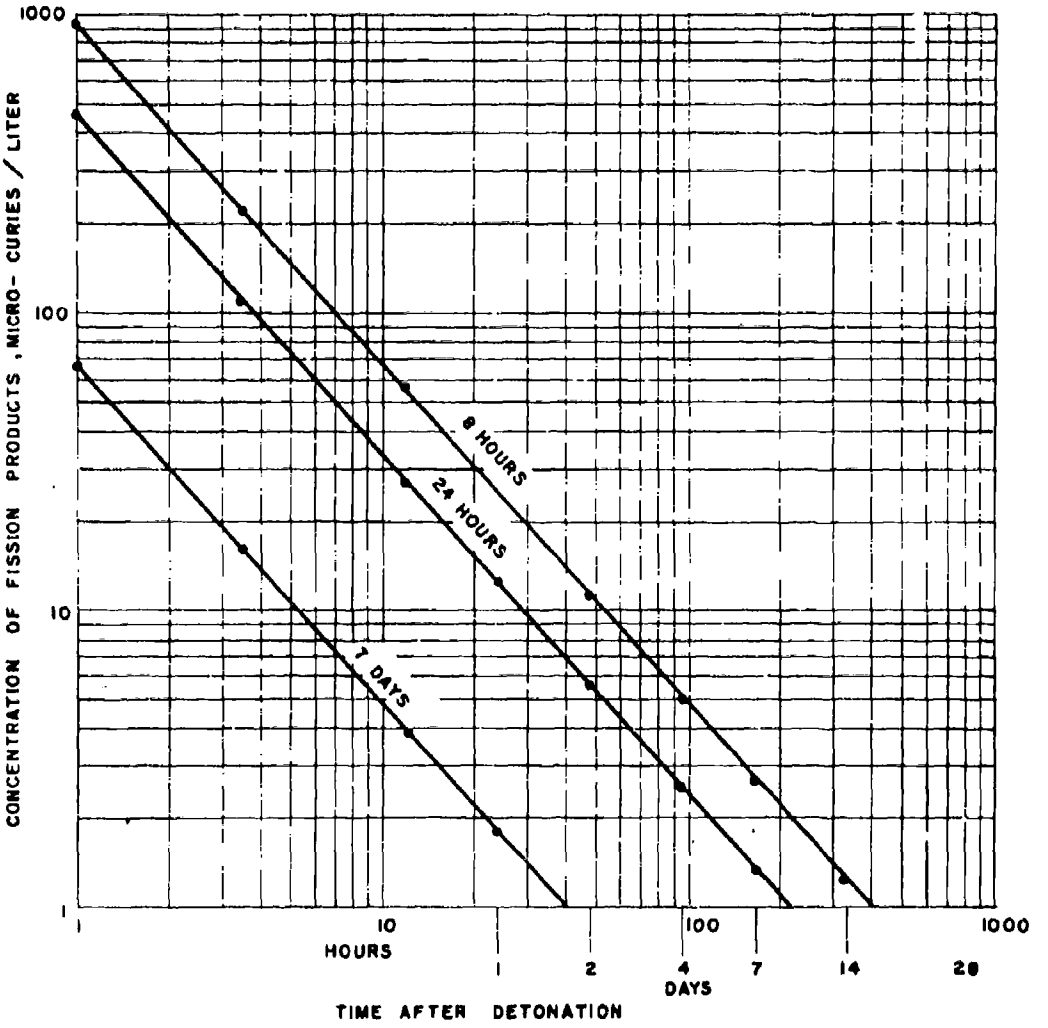


Fig. A.1 Maximum Permissible Concentrations of Fission Products in the Air - 1 hr to 1000 hr (So that not more than 1 microcurie of Sr^{90} is retained in the body)

[redacted]

[redacted]

PROJECT 6.3-2

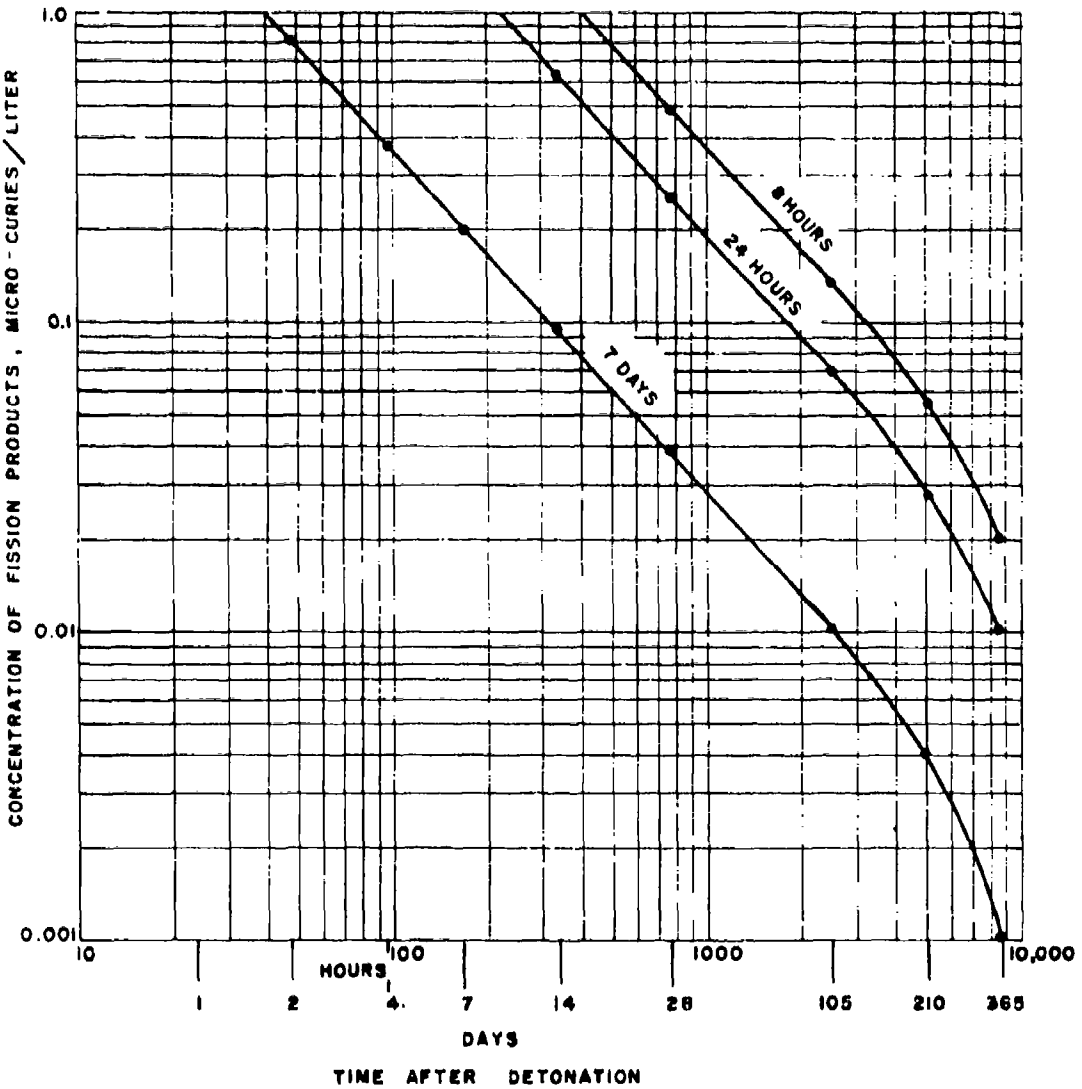


Fig. A.2 Maximum Permissible Concentrations of Fission Products in the Air - 10 hr to 1 yr (So that not more than 1 microcurie of Sr^{90} is retained in the body)

[redacted]

TABLE A.4

Analysis Sheet

Listed below are those fission products which constitute internal hazard. Their beta activities and Sr equivalents are given for various times.

1	2	3		4		5		6		7		8	
Nuclide	Maximum Permissible Concentration in the body in microcuries	1 hr		12 hr		24 hr		1-10 days(d)		10-100 days(d)		100-1000 days(d)	
		Per cent of total activity	Sr^{90} equivalents	Per cent of total activity	Sr^{90} equivalents	Per cent of total activity	Sr^{90} equivalents	Per cent of total activity	Sr^{90} equivalents	Per cent of total activity	Sr^{90} equivalents	Per cent of total activity	Sr^{90} equivalents
(7)	(5)	(6)		(6)		(6)		(6)		(6)		(6)	
I^{131} (a)	0.3	0.02	1530	0.4	1880	1.	2150	3.	1000	3.	67	0	0
Sr^{90}-Y^{90} (b,f)	2.0	4.35×10^{-5}	2	7.4×10^{-4}	2	1.55×10^{-3}	2	0.01	2	0.15	2	8.0	2
Sr^{89} (b)	2.0	0.006	140	0.1	140	0.24	150	2.	200	7.	47	2.5	0.31
Ba^{140}-La^{140} (b)	5.8	0.037	150	0.66	160	1.73	110	10.	175	16.	8	0	0
Y^{91} (c)	0.3	0.17	13000	2.9	13600	3.00	845	2.	670	6.5	145	3.0	1.25
Zr^{95}-Cb^{95} (c)	0.3	0.006	460	0.12	560	0.26	560	2.	670	16.	360	16.0	6.7
Ce^{144}-Pr^{144} (c)	0.3	0.0024	185	0.04	190	0.51	240	0.7	240	7.	155	50.0	21.0
Ce^{143}-Pr^{143} (c)	0.3	0.27	20700	4.4	20600	8.6	18500	16.5	5500	7.	155	0	0
Nd^{147}-Pr^{147} (c)	0.3	0.8	13800	2.7	12700	6.3	12200	3.5	1170	3.	67	10.0	4.2
Total Sr^{90} equivalents			44437		47952		32457		8627		939		35.46
Equivalents used in figures A.3 and A.4			5×10^5		5×10^5		3.5×10^5		9×10^4		1×10^4		3.6×10^2

(a) The figures given under the columns "Sr^{90} equivalents" for I^{131} indicate only the multiples of maximum permissible iodine activity present when the maximum permissible concentration of Sr^{90} is present (8).

(b) Metabolism of this nuclide is similar to that of Radium (7).

(c) Metabolism of this nuclide is similar to that of Plutonium (7) (8).

(d) Estimated mean beta activity (6).

(e) Figures in column 2 for Sr^{90}-Y^{90}, Ba^{140}-La^{140}, Zr^{95}-Cb^{95}, and Ce^{144}-Pr^{144} etc. are based on the assumption that the maximum permissible concentration in the body for a parent-daughter pair is equal to the maximum permissible concentration of the parent. The per cent of total activity figures in columns 3 through 8 represent the sum of the activities of the parent and daughter.

(f) Y^{90} activity grows into equilibrium with Sr^{90} between 1-10 days. Prior to 1 day Sr^{90} is predominant.

(g) The figures in columns 6, 7, and 8 were arrived by estimating a mean value of the activity for each nuclide during the period in question using Hunter and Sallen's figures (6). The total Sr^{90} equivalents were therefore multiplied by 10 to provide a factor of safety should an entry be made in figures A.3 and A.4 on the high side of the means.

[redacted]

PROJECT 6.3-2

TABLE A.5

Maximum Permissible Fission Product Concentrations

Time after detonation	Sr^{90} Equivalents(a)	Gross fission product beta activity in μc/l required to cause retention of 1 Sr^{90} equivalent in the body during the following exposure times(b)		
		8-hr work day	24-hr (c)	7 days (c)
1 hr	5×10^{5}	1.84×10^{-3}	9.2×10^{-4}	1.31×10^{-4}
3.5 hr	5.5×10^{5}	4.0×10^{-4}	2.0×10^{-4}	2.86×10^{-5}
12 hr	4.65×10^{5}	1.2×10^{-4}	6×10^{-5}	8.6×10^{-6}
24 hr	3.24×10^{5}	8.0×10^{-5}	4×10^{-5}	5.7×10^{-6}
2 days	1.8×10^{5}	6.4×10^{-5}	3.2×10^{-5}	4.6×10^{-6}
4 days	9×10^{4}	5.5×10^{-5}	2.75×10^{-5}	3.93×10^{-6}
7 days	5.6×10^{4}	5.3×10^{-5}	2.65×10^{-5}	3.78×10^{-6}
14 days	2.4×10^{4}	5.2×10^{-5}	2.60×10^{-5}	3.72×10^{-6}
28 days	1×10^{4}	5.2×10^{-5}	2.6×10^{-5}	3.72×10^{-6}
105 days	2.7×10^{3}	5.3×10^{-5}	2.65×10^{-5}	3.78×10^{-6}
210 days	9.65×10^{2}	5.4×10^{-5}	2.7×10^{-5}	3.86×10^{-6}
1 yr	3.6×10^{2}	5.6×10^{-5}	2.8×10^{-5}	4.0×10^{-6}

(a) These figures were taken from the last row of figures on Table A.4 and were adjusted to give a smooth set of curves.

(b) The figures in these three columns were determined by dividing the figures in the corresponding columns of Table A.3 by the respective numbers of Sr^{90} equivalents (the last row of figures in Table A.4). The quotients were plotted and adjusted to give a smooth curve.

(c) Indludes an 8-hr work day.

[redacted]

[redacted]

[redacted]

PROJECT 6.3-2

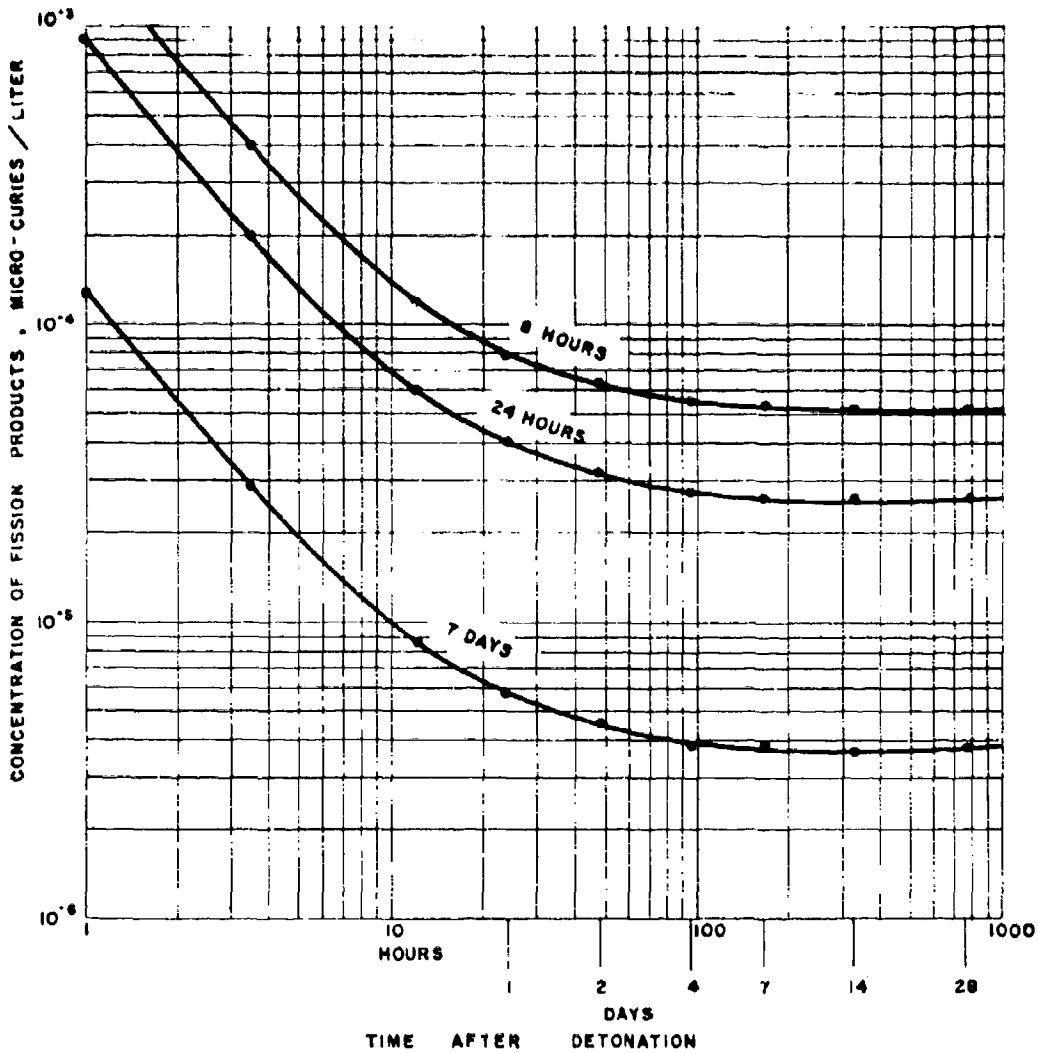


Fig. A.3 Maximum Permissible Concentrations of Fission Products in Air - 1 hr to 1000 hr (So that not more than 1 microcurie of equivalent Sr^{90} are retained in the body).

[redacted]

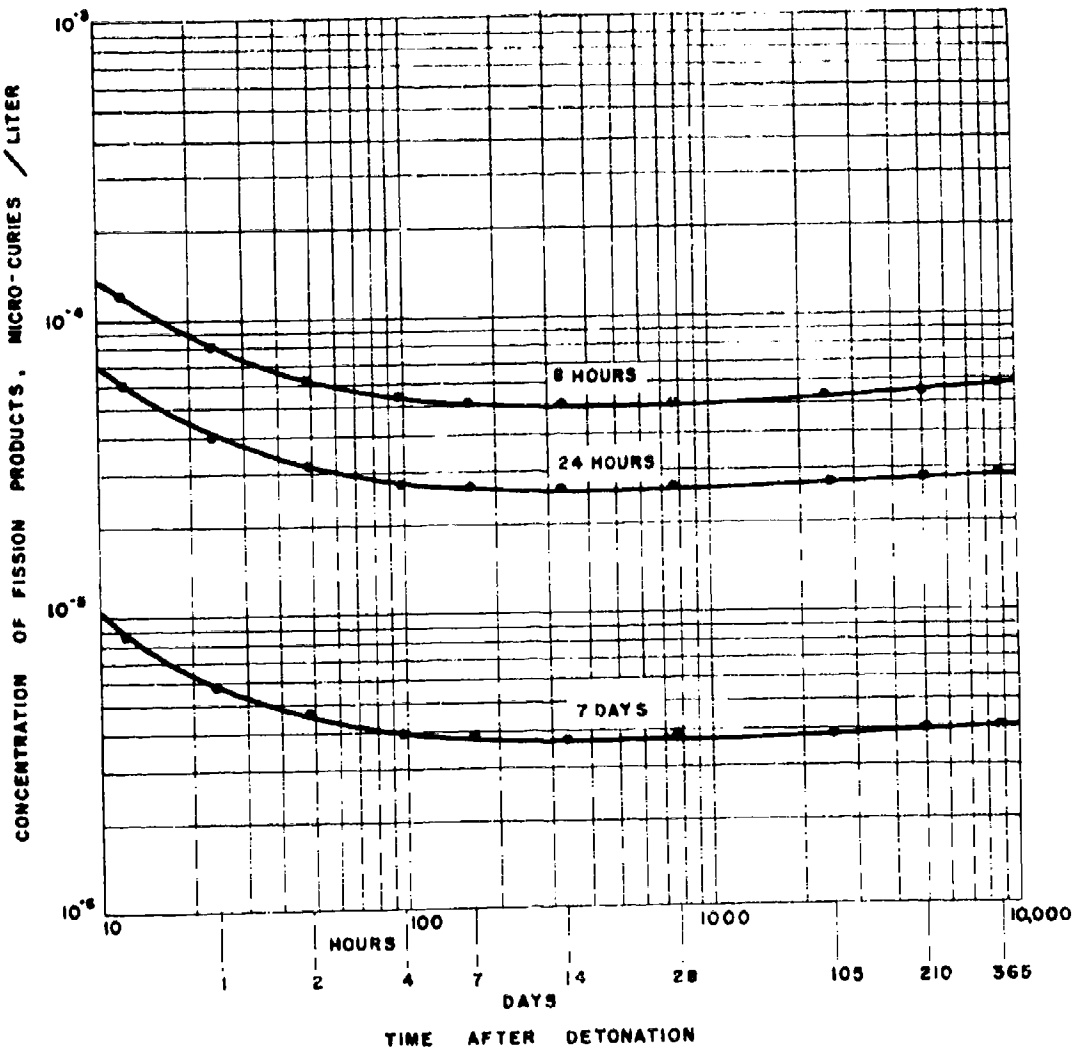


Fig. A.4 Maximum Permissible Concentrations of Fission Products in Air - 10 hr to 1 yr (So that not more than 1 microcurie of equivalent Sr^{90} are retained in the body).

was considered negligible in comparison). To be more explicit, Table A.3 shows for several times, the number of multiples of the maximum permissible quantity of iodine present when the maximum permissible concentration of Sr^{90} or one Sr equivalent is present. Thus, the total Sr^{90} equivalents was set high enough so that iodine could at no time present a hazard.

Finally, it will be noted in Fig. A.4 that a trend upward is indicated, commencing at 28 days after detonation. This trend is not unreasonable, if the 8-hr curve in Fig. A.4 is considered. It is noted from Hunter and Ballou activity plots that all the nuclides considered except Sr^{90}-Y^{90}, Pm^{147}, and Ce^{144}-Pr^{144} decay below 1 per cent of the total activity within 2 yr. Ce^{144}-Pr^{144} reach their peak activity at 1.5 yr, Pm^{147} at 5 yr. It follows therefore, that as the more hazardous nuclides decay, the 8-hr curve will tend to rise toward the figure given in Table A.1 for maximum permissible concentration in air of Sr^{90} for an 8-hr day.

A.5 SUMMARY

An attempt has been made to evaluate the inhalation hazard associated with fission products based on Sr^{90} equivalents of the various "bad actors". This has led to construction of graphs relating the maximum permissible concentration of fission product in air to time after detonation for exposure times of 8 hr, 24 hr, and 7 days.

[redacted]

PROJECT 6.3-2

A.6 BIBLIOGRAPHY

1. J. E.Wirth, General Rules and Procedures Concerning Activity Hazards - MDDC247 (1946).

2. The Effects of Atomic Weapons - Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

3. Lecture Notes: Health Physics Training Lectures, 1948-1949. AECU 817.

4. ICRP Supplement on Maximum Permissible Amounts of Radioisotopes, Nucleonics 8, no. 2 (1951).

5. Subcommittee on Internal Dose of the National Committee on Radiation Protection -- Maximum Permissible Concentrations of Radioisotopes in the Air, Water, and in the Human Body (1951).

6. Hunter and Ballou, Simultaneous Slow Neutron Fission of U^{235} Atoms I -- Individual and Total Rates of Decay of the Fission Products. NRDL, ADC 65.

7. J. G. Hamilton, The Metabolic Properties of the Fission Products, Rev, of Mod. Phys. 20, no. 4, pp. 718-728 (1948).

8. J. Schubert, Estimating Radioelements in Exposed Individual II Nucleonics 8, no. 3, p. 66 (1951).

9. W. Siri, Isotopic Tracers and Nuclear Radiations, McGraw Hill Book Co., New York, 1949.

10. AFSWP, Radiological Defense, Vol. I.

11. J. G. Hamilton, Deposition and Fate of Plutonium, Uranium, and the Fission Products Inhaled as Aerosols by Rats and Man, Arch. of Path., 48, p. 31 (1949).

[redacted] [redacted]

[redacted]

PROJECT 6.3-2
APPENDIX B

MAXIMUM ALLOWABLE CONCENTRATIONS OF FISSION PRODUCTS IN THE AIR AS A FUNCTION OF EXPOSURE TIME AND TIME AFTER DETONATION (Continued)

B.1 INTRODUCTION

Comment received by the author has indicated that the conditions assumed to exist in the preparation of reference (1) were unnecessarily pessimistic, and that much higher maximum permissible concentrations could be realized if less conservative, albeit equally supportable, assumptions were made. In addition it was indicated that the possibility of a plutonium hazard should not have been neglected. This paper then is an attempt to satisfy that criticism. In addition, the evaluation of the hazards of the various nuclides considered, relative to Sr^{90}, or their "Sr^{90} equivalents", (1) has been done in considerably more detail.

Although it has not been deemed necessary to repeat some of the detail in reference (1), it has been considered necessary to restate the basic assumptions, and the calculations presented so that to preserve continuity the reader would not be required to refer continually to reference (1).

B.2 ASSUMPTIONS

The assumptions, briefly stated, are as follows:

(a) The relative activities of fission products resulting from fast fission are essentially the same as those reported for slow neutron fission of U^{235} (2).

(b) The activity of Sr^{90} is constant from 1 hr to 1 yr after fast fission, and is in stable equilibrium with Y^{90} (2).

(c) The maximum permissible amount of Sr^{90} in the human body is 1 microcurie (3). This presupposes that 1 microcurie of Y^{90} is also present. Also, when 1 microcurie of Sr^{90} exists in the human body, no more than .3r/week will be delivered to the man site of deposition, which, in this instance, is the skeleton. This dose rate may not be exceeded since the factor of safety associated with it may be very low (4).

(d) For Sr^{90} in air, 25 per cent of the inhaled amount is absorbed, and 25 per cent of the absorbed amount is retained permanently (3).*

*Assumption modified from that in ref. (1).

[redacted] [redacted]

All nuclides discussed in this paper are considered to behave similarly with the exception of I^{131} and Pu^{239}.

(e) All particles in a fission product mixture are considered to be of small enough size for them to reach the alveolar space and there to enter the blood stream, or the lymphatic system.

(f) The maximum permissible concentration in the body of a parent-daughter pair such as Zr^{95}-Cb^{95} is considered to be the same as that of the parent alone.**

(g) The standard man breathes 10 cu.m. or 10^4l., of air during an 8-hr working period, and 20 cu.m., or 2×10^4l., of air during a 24-hr day which includes an 8-hr working period (4).

(h) With the exception of iodine (3), the bone seeking elements are considered to be the most serious radioactive hazards.

(i) The maximum permissible amount of I^{131} in the body is .3 μc, 100 per cent of airborne I^{131} can be inhaled and 20 per cent is retained permanently (3).

(j) For the purpose of this paper, the following assumptions are considered to apply to the fissionable material:

(aa) The fissionable material is Pu^{239}.

(bb) Fission efficiency is one per cent.

(cc) The unfissioned Pu^{239} is uniformly mixed with the fission products.

(dd) 100 per cent of the unfissioned Pu^{239} in the air may be inhaled.

(ee) 100 per cent of the inhaled Pu^{239} is absorbed and retained permanently (3).

(ff) U^{235} is not considered a radioactive hazard at all (5).

B.3 CALCULATIONS

The foregoing assumptions comprised all those necessary to compute the relative hazards of the fission products to Sr^{90}.

**Except for Sr^{90}-Y^{90}.

First Step

The concentrations of Sr^{90} in the air necessary to cause the absorption and retention of 1 microcurie were calculated (see Table B.1) from the following formula:

$$X = Z/Y \times 1/.25 \times 1/.25$$

Where X = Conc. of Sr^{90} in μc/l of air,

Y = Liters of inhaled air, and

Z = 1 μc of Sr^{90}, the maximum permissible concentration of Sr^{90} in the body.

TABLE B.1

Concentrations in the Air Necessary for Retention in the Human Body of 1 Microcurie of Sr^{90} (or 2 microcuries of Sr^{90}-Y^{90}) Based on 100 per cent Inhalation, 25 per cent Absorption of the Material Inhaled, and 25 per cent Retention of the Absorbed Material.

Period of Exposure	Conc. of Sr^{90} in μc/l of air
8-hr work day	1.6×10^{-3}
24-hrs*	8×10^{-4}
7-days*	1.14×10^{-4}

Second Step

It was then possible to calculate the concentrations of fission products necessary to cause the retention of 1 microcurie of Sr^{90} during three exposure periods.

Sample Calculation

Hunter and Ballou (2) report the Sr^{90} activity as 4.35×10^{-5} per cent of the gross fission product beta activity at 1-hr after fission. From Table B.1 the Sr^{90} concentration in the air necessary to cause the absorption and retention of 1 μc by the end of an 8-hr work day is 1.6×10^{-3}

*Includes 8-hr work period for each 24-hr period.

μc/l. Therefore, the gross fission-product activity required to provide such a concentration is found as follows:

$$1.6 \times 10^{-3}/4.35 \times 10^{-5} \times 100 = 3680 \ \mu c/l$$

In the light of the foregoing, Table B.2 is self-explanatory.

TABLE B.2

Maximum Permissible Fission Product Concentrations

1	2	3	4	5
Time after detonation	Sr^{90} Act. as % of total beta activity	Gross fission product beta activity in μc/l required to cause retention of 1 μc of Sr^{90} in the human body during the following exposure times		
(2)	(2)	8-hr work day	24-hrs (a)	7 days (a)
1 hr	4.35×10^{-5}	3680.	1840.	262.
3.5 hrs	1.82×10^{-4}	880	440	62.8
12 hrs	6.56×10^{-4}	244	122	17.4
24 hrs	1.55×10^{-3}	103	51.5	7.35
2 days	3.86×10^{-3}	41.5	20.7	2.96
4 days	8.8×10^{-3}	18.2	9.1	1.30
7 days	1.52×10^{-2}	10.5	5.25	.75
14 days	2.96×10^{-2}	5.4	2.7	.39
28 days	5.95×10^{-2}	2.69	1.35	.193
105 days	2.67×10^{-1}	.60	.30	.043
210 days	7.3×10^{-1}	.22	.11	.0157
1 yr	1.96	.082	.041	.00585

(a) Each 24-hr period includes an 8-hr working period.

[redacted] [redacted]

Third Step

Having calculated the gross fission product beta activity necessary to cause the retention of 1 μc of Sr^{90} during three periods of exposure at various times after detonation, the corresponding activities of the nuclides considered hazardous (see Table B.3) were determined (2). Each of these nuclides was considered to have an associated hazard which, for equal activities, is certain multiples of Sr^{90} hazard, determined on the basis of maximum permissible concentrations. This number was then multiplied by the ratio of the activity of the nuclide to the activity of Sr^{90} present in the fission product mixture. The resulting figure was called the "Sr^{90} equivalent".

Sample Calculation

At 1-hr the Sr^{90} activity is 4.35×10^{-5} per cent of the gross fission product beta activity, and the total beta activity of Zr^{95}-Cb^{95} = 6×10^{-3} per cent of the gross fission product beta activity.

$$6. \times 10^{-3} / 4.35 \times 10^{-5} = 137$$

Now the maximum permissible concentration or Sr^{90} in the body is 1 μc, and that of the Zr^{95}-Cb^{95} pair, 3 μc (4). The toxicity of Zr^{95}-Cb^{95} to Sr^{90} is therefore 1/.3. Consequently, there exist 137 x 1.0/.3 = 460 "Sr^{90} equivalents" of Zr^{95}-Cb^{95} at 1 hr. Table B.3 was constructed in this way.

One might inquire at this point about the effect of the presence of Y^{90} which is in stable equilibrium with Sr^{90}. If the Y^{90} activity is considered as essentially that of Sr^{90}, then the Sr^{90} activity is effectively doubled, and the relative activity of Zr^{95}-Cb^{95} is halved. But the maximum permissible concentration of Y^{90} must be added to that of Sr^{90}, which is then effectively doubled. Thus while the activity of Zr^{95}-Cb^{95} relative to Sr^{90} (plus the Y^{90} increment) is halved, its relative toxicity is doubled. The net result is that there is no difference if Zr^{95}-Cb^{95} is compared to Sr^{90} or to Sr^{90}-Y^{90}.

Fourth Step

The "Sr^{90} equivalents" in Table B.3 were divided into the corresponding figures in columns 3, 4, 5 of Table B.2. The results were tabulated in Table B.4. Thus Table B.4 is a compilation of the fission product concentrations necessary to cause the retention of 1 microcurie of "equivalent Sr^{90}" activity at various times after an atomic bomb detonation for three different times of exposure.

Fifth Step

Now finally it is necessary to calculate the effect of Pu^{239}. The calculations of Hunter and Ballou (2) are based on the simultaneous

TABLE B.3

Analysis Sheet

Listed below are those fission products which constitute internal hazards. Their beta activities and "Sr equivalents" are given for various times.

1	2	3		4		5		6		7		8		9		10		11		12		13		14	
Nuclides	Max. Per. con. in the body in micro-curies	1 hr		3.5 hrs		12 hrs		24 hrs		2 days		4 days		7 days		14 days		28 days		105 days		210 days		1 yr	
		Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents	Per cent of total activity	Sr^{90} equiva-lents
(4)	(3)(4)(6)	(2)		(2)		(2)		(2)		(2)		(2)		(2)		(2)		(2)		(2)		(2)		(2)	
I^{131} (a)	0.3	0.823	5650	0.132	6000	0.12	6650	0.98	6700	2.29	6350	4.56	5550	6.28	4300	6.68	2400	3.97	705	.0000	0	0	0	0	0
Sr^{90}-Y^{90} (b)	2.0	4.35×10^{-5}	2	1.8×10^{-4}	2	6.56×10^{-4}	2	1.55×10^{-3}	2	3.84×10^{-3}	2	8.8×10^{-3}	2	1.52×10^{-2}	2	2.96×10^{-2}	2	5.95×10^{-2}	2	0.267	2	0.73	2	1.96	2
Sr^{89}	2.0	0.006	69	0.029	80	0.1	76	0.24	77	0.587	76	1.30	74	2.13	70	3.83	64	6.39	54	10.9	26	7.31	5	2.60	0.7
Ba^{140}-La^{140}	5.6	0.037	147	0.16	153	0.66	173	1.73	192	4.71	210	11.4	224	18.4	208	25.3	147	23.8	69	1.66	1.0	0.002	0	0	0
I^{133}	0.3	0.177	13600	1.35	25000	2.9	11800	3.20	6900	1.9	1640	1.53	580	2.36	520	4.25	244	7.20	140	12.9	160	9.75	44.5	4.00	6.8
Zr^{95}-Cb^{95}	0.3	0.006	460	0.031	570	0.11	505	0.27	580	0.68	587	1.47	556	2.52	555	5.5	326	11.5	645	35.0	437	38.8	177	32.1	38.6
Ce^{144}-Pr^{144}	0.3	0.0027	207	0.012	276	0.043	218	0.10	215	0.25	216	0.58	220	0.99	207	1.88	138	3.68	206	13.7	171	28.7	131	32.3	89
Ce^{143}-Pr^{143}	0.3	0.27	20700	1.20	22000	3.65	18500	7.5	16100	11.6	10000	12.7	4820	11.3	2480	11.5	660	11.5	645	1.08	13	0	0	0	0
Nd^{147}-Pm^{147}	0.3	0.018	1380	0.074	1350	2.7	13500	6.3	13600	1.43	1240	2.86	1080	4.10	900	5.15	294	4.17	234	1.02	13	2.28	12.6	5.66	9.6
Total Sr^{90} equivalents			36566		49375		47774		37666		13971		7556		4942		1845		2759		817		389.5		175.7

(a) The figures given under the column "Sr^{90} equivalents" for I^{131} indicate only the multiples of maximum permissible I^{131} activity when the maximum permissible concentration of Sr^{90} is present. These figures are not included in the totals.

(b) Only Sr^{90} activity is given in this row. The total activity of Sr^{90}-Y^{90} may be considered as being double the figures given.

TABLE B.4

Maximum Permissible Fission Product Concentrations

Time after detonation	Sr^{90} Equivalents*	Gross fission product beta activity in μc/l required to cause retention of 1 μc of "equivalent" Sr^{90} in the body during the following exposure times**		
		8-hr work day	24-hrs***	7 days***
1 hr	36,600	.10	.05	.0072
3.5 hrs	49,400	.0178	.0089	.00127
12 hrs	47,800	.0051	.00255	.00036
24 hrs	29,400	.0035	.00175	.00025
2 days	16,000	.0026	.0013	.000185
4 days	9,100	.0020	.001	.00014
7 days	6,550	.0016	.0008	.00011
14 days	4,320	.00125	.00062	.000098
28 days	2,690	.00100	.00050	.000072
105 days	835	.00072	.00036	.000052
210 days	366	.00060	.00030	.000043
1 yr	150	.000540	.00026	.000037

*These figures were taken from the last row of figures in Table B.3, and were adjusted to give a smooth set of curves.

**The figures in these three columns were determined by dividing the figures in the corresponding columns of Table B.2, by the corresponding number of "Sr^{90} equivalents".

***Includes an 8-hr work day each 24 hrs.

NOTE: The author has felt free to adjust the figures in this table to get a smooth curve, since it is reasonable to expect that 100 per cent inhalation will not occur,

fission of 10,000 atoms of U^{235}. If it is assumed that Pu^{239} has fissioned, the calculation of the residual Pu^{239} activity is straightforward. With a fission efficiency of 1 per cent 9.9×10^5 atoms of Pu^{239} remain unfissioned. The residual Pu activity is calculated as follows:

Given; λ, the decay constant = $.693/T_{1/2}$, the half-life

$T_{1/2} = 2.41 \times 10^4$ yrs

$N = 9.9 \times 10^5$ Pu^{239} atoms

Therefore:

Activity = λN

$= .693 \times 9.9 \times 10^5 / 2.41 \times 10^4$ dis./yr.

$\lambda N = .693 \times 9.9 \times 10^5 / 2.41 \times 10^4 \times 365 \times 24 \times 60$ dis/min.

Activity = 5.4×10^5 disintegrations per minute

The activity of Sr^{90} is 2.7×10^5 disintegrations per minute. The ratio of Pu^{239} activity to that of Sr^{90} is therefore 2. The maximum permissible concentration in the body of Pu^{239} is .031 μc (1). The "Sr^{90} equivalent" of Pu^{239} is $2 \times 1/.031 = 64.5$. But the portion of inhaled Pu^{239} which is absorbed and retained permanently is 10 per cent* rather than 25 per cent of 25 per cent, or 6.25 per cent. Therefore 64.5 must be multiplied by 10/6.25, or 1.6. Thus the effective "Sr^{90} equivalent" of Pu^{239} is 103.

The figure may be considered constant due to the long half-life of Pu^{239}. Thus, the "Sr^{90} equivalents" of the fission products become smaller--- 145.7 at 1 year after detonation--- while the "Sr^{90} equivalent" of Pu^{239} remains unchanged. A brief glance then at Table B.3 shows that the Pu^{239} hazard becomes significant at 105 days after fission.

B.4 DISCUSSION

As was stressed in the preceding report (1), this study is largely qualitative, and consequently subject to modification. It should be noted that this report has served simply to reduce the estimated percentage of absorbed and retained Sr^{90} for a given concentration in the air, to refine the calculations of the percent activity of fission products at various times, and to consider the plutonium hazard.

*For Iodine it is 20 per cent (3).

I^{131} was included as a check in the discussion because of its low maximum permissible concentration, and its high percentage of absorption of the body (3).

It will be noted that the contribution of Pu^{239} to the internal hazard has not been considered in the construction of figures B.1 and B.2. It must be emphasized therefore that after 1 year the curves will tend to approach asymptotes which are about 100 times the magnitude of the figures in Table B.1. This is obvious since Pu^{239} is about 50 times as hazardous as Sr^{90} for equal activities.

In closing, some of the questionable aspects of this report will be noted briefly. Particle size distribution (5), as an added safety factor, has only been considered roughly, and then only to smooth the curves. Neither the chemical nor physical state has been mentioned. Of course, the factor which may serve to upset all these calculations may be the dose received from material accumulated in the lungs. The computation of such a dose is beyond the scope of this paper.

B.5 SUMMARY

A graph of the maximum permissible concentrations of fission products as a function of time of exposure and time after detonation has been prepared using Sr^{90} as a basis for comparison for several fission products and plutonium.

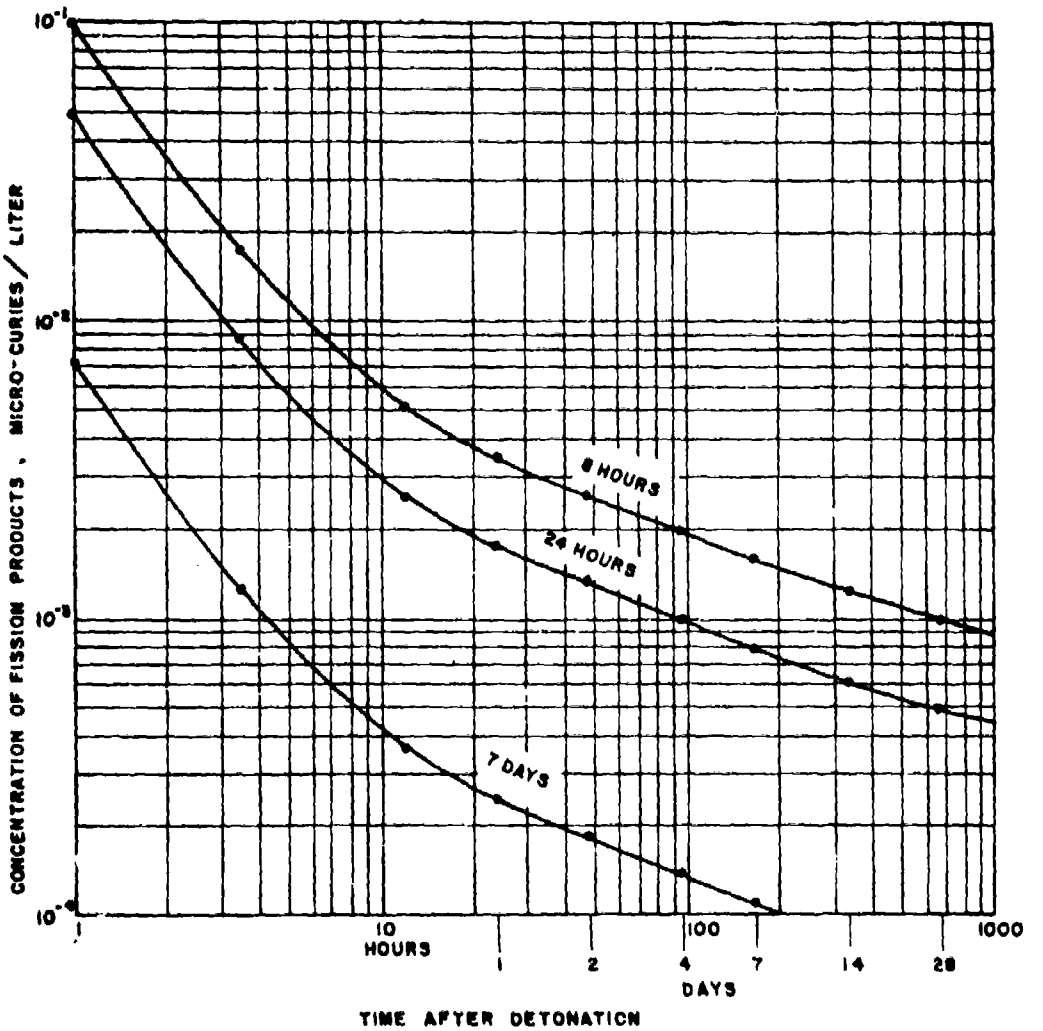


Fig. B.1 Maximum Permissible Concentrations of Fission Products in Air .. 1 hr to 1000 hr (So that not more than 1 microcurie of equivalent Sr^{90} is retained in the body).

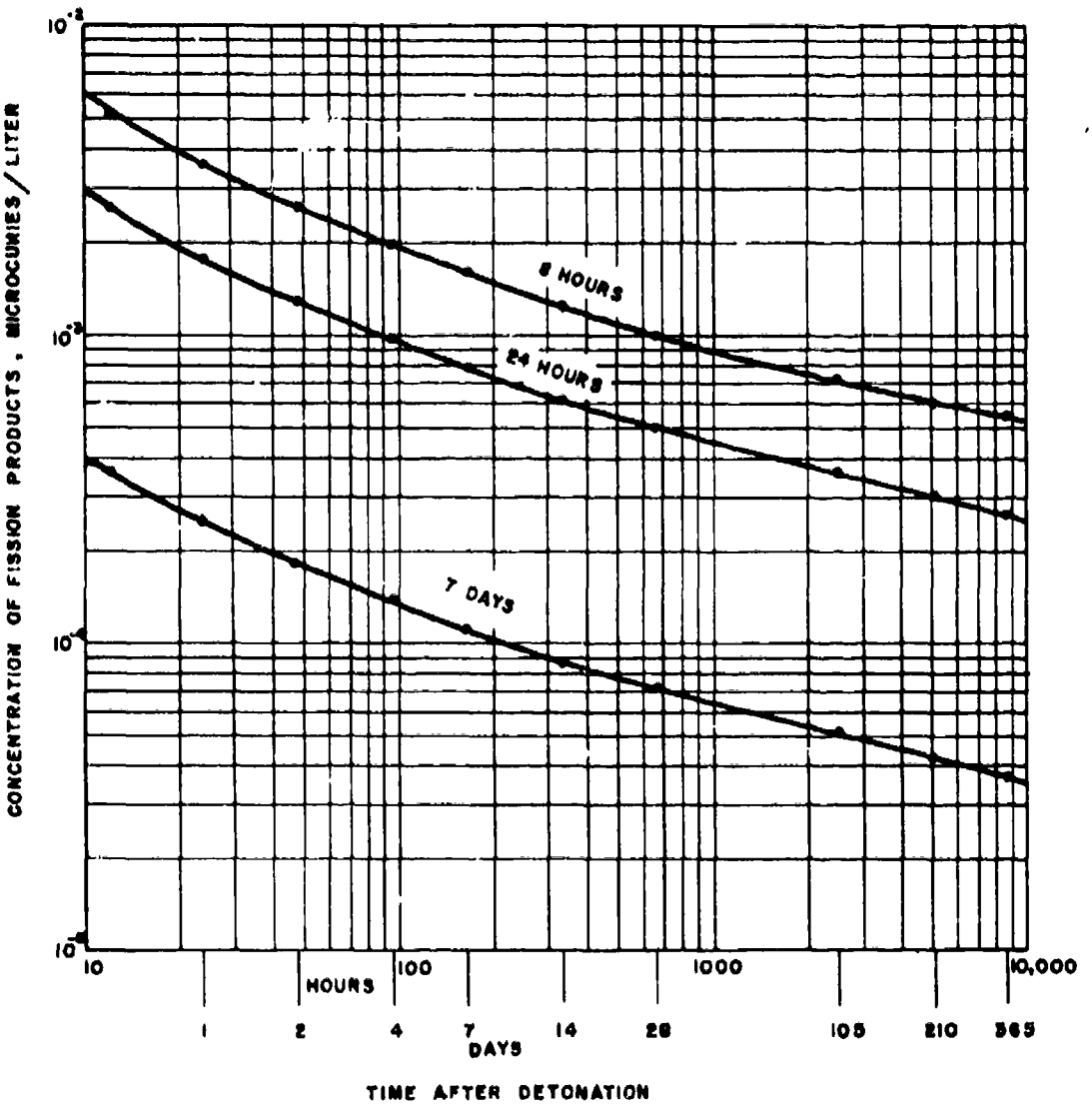


Fig. B.2 Maximum Permissible Concentrations of Fission Products in Air - 10 hr to 1 yr (So that not more than 1 microcurie of equivalent Sr^{90} is retained in the body).

[redacted]

PROJECT 6.3-2

B.5 BIBLIOGRAPHY

1. R. L. Harvey, Chemical and Radiological Laboratories Interim Report, Appendix A.

2. N. F. Hunter, N. E. Ballou, Naval Radiological Defense Laboratory. Report ADC 65 (1949).

3. Maximum Permissible Amounts of Radioisotopes, Nucleonics 8, no. 2, 70 (1951).

4. J. Schubert, Nucleonics 8, No. 3, 66 (1951).

5. The Effects of Atomic Weapons -- Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

6. J. G. Hamilton, Revs. Mod. Phys. 20, no. 4, 718 (1948).

[redacted] [redacted]

[redacted]

OPERATION JANGLE

PROJECT 6.7

CLOTHING DECONTAMINATION AND EVALUATION OF LAUNDRY METHODS

By

DONALD C. HUGHES
Lt. Colonel QMC

ALFRED H. PARTHUM, JR.
Major QMC

HOWARD JAMES
Major QMC

JOHN C. MCWHORTER, JR.
Captain QMC

and

Staff of QM Det. 7, 9135th T. S. U., Ft. Lee, Va.

1 April 1952

Office of The Quartermaster General

Washington 25, D. C.

[redacted]

[redacted]

PROJECT 6.7

ACKNOWLEDGMENTS

It is desired to acknowledge and commend the project personnel for their untiring efforts and full cooperation throughout the JANGLE Operation. Personnel of this project consisted principally of the members of Detachment 7, 9135th T. S. U., Fort Lee, Virginia, who were as follows:

Lt. Col. Donald C. Hughes
Major Howard James
Major Robert B. Bennett
Capt. John C. McWhorter, Jr.
2nd Lt. William W. Goozee
M/Sgt. Glenn E. Michael
M/Sgt. Cecil McCaulley
Sfc. William H. McConnell
Sfc. Donald C. Allgeier, Sr.
Sfc. Donald J. Petri
Sgt. David M. Arnold
Pfc. Bert S. Gorton

Other project personnel were Major Alfred H. Parthum, Jr., ABC&R Liaison Officer, Research and Development Division, Office of the Quartermaster General, who was the Project Officer, and Captain Joseph F. Nahan, Memorial Division, Office of the Quartermaster General.

The assistance of Mr. John M. Davies and Mr. Frank Rizzo of the Philadelphia Quartermaster Depot in the preparation of the experimental fabrics materially advanced the program and it is desired to acknowledge their contribution.

The assistance of Mr. Robert H. Sugarman of Evans Signal Laboratory, Signal Corps Engineering Laboratories, Belmar, N. J., with clothing monitoring instrumentation is also gratefully acknowledged.

[redacted]

[redacted]

PROJECT 6.7

CONTENTS

[redacted]

[redacted]

PROJECT 6.7

ILLUSTRATIONS

[redacted]

TABLES

[redacted]

PROJECT 6.7

ABSTRACT

The over-all objectives of this project encompassed testing the suitability of standard and special laundering methods and standard equipment for field decontamination of clothing; evaluating the contaminability and decontaminability of selected fabrics; and testing of experimental clothing monitoring instruments.

Garments and fabrics contaminated by controlled methods were used during the operation for testing the equipment and evaluating fabrics and formulae.

Standard Army laundering methods and equipment, including wooden washers, were effective for decontaminating clothing in the field.

A decontaminating laundry formula employing citric acid and tartaric acid followed by either an organic or inorganic chelating agent results in a higher degree of decontamination than other formulae tested. The standard Quartermaster Corps mobile field laundry formula resulted in satisfactory decontamination with the type of soil and activity encountered and the cost of supplies is approximately one-tenth as much as the special formulae. Woolen garments and fabric swatches decontaminated by laundering as readily as cotton or synthetic fabrics.

Clothing monitoring instruments, under development by the Signal Corps, appear suitable for monitoring clothing under field conditions to determine the degree of contamination both before and after processing.

[redacted]

[redacted]

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The objectives of this project were:

1. To test the suitability of decontamination laundering formulae developed during Operation GREENHOUSE for the removal of contaminants resulting from surface and sub-surface atomic explosions.

2. To test the suitability of a wooden laundry washer for clothing decontamination.

3. To evaluate the susceptibility of selected materials to contamination and to determine their subsequent decontaminability.

4. To compare the clothing contamination resulting from surface and sub-surface bursts with that previously encountered after tower shots.

5. To field test experimental clothing monitoring instruments.

1.2 HISTORICAL BACKGROUND

Initial work on this project was conducted at Oak Ridge National Laboratory in the summer of 1950. This phase of the work was concerned primarily with training of personnel in the handling, monitoring, and decontaminating of radioactively contaminated clothing, and the development of a satisfactory formula for decontaminating clothing which had been artificially contaminated by immersion in dilute iodine dissolver solution.[1]

Since the Oak Ridge phase of the project was concerned with clothing which had been contaminated by dipping into a solution, a second phase was conducted to check results on clothing which had become contaminated by other means. This second phase was conducted at Dugway Proving Ground, Utah, in September, 1950. A study was made there of the effectiveness of the formula developed at Oak Ridge upon clothing contaminated by RN-type contaminants.

---

[1] Laundering Decontamination Test Conducted at Oak Ridge National Laboratory, Research and Development Division, Office of the Quartermaster General, Washington 25, D. C., Chapter III, B.

[redacted]

The third phase of the project took place at Eniwetok where the training and data from the first two phases were tested under field conditions on contamination resulting from actual bomb bursts.[2] The tests conducted in Operation GREENHOUSE permitted the development of a promising field decontamination laundering formula, but inadequate contaminated materials were available to permit its full evaluation and further simplification, or the investigation of possible substitutions of less critical supplies.

1.3 BASIC THEORY:

Contamination of clothing is caused by the deposition of radioactive particulate matter on, in, or around the fibers and yarns of the fabrics. The degree to which the particles penetrate into the fabric and yarns will depend upon the surface characteristics of the fabric, the closeness of weave, the twist of the yarns, and the nature and physical characteristics of the fibers. The adhesion of the contaminating materials will depend, to some extent, on the chemical nature of the fibers and upon special finishes which may have been applied to the fibers and fabrics.

Decontamination of the clothing by laundry methods presents the problem of removal of the particulate matter by emulsification and suspension, and/or conversion of radioactive contaminants into soluble compounds and their removal in solution.

---

[2] Protective Clothing and Clothing and Personnel Decontamination. Operation GREENHOUSE, Project 6.9, Part II.

[redacted]

CHAPTER 2

EQUIPMENT, INSTRUMENTATION, AND MATERIALS

2.1 LAUNDRY EQUIPMENT

The laundry equipment used in this project consisted of two basic types encountered in military and commercial laundries.

2.1.1 Quartermaster Corps Mobile Field Laundry, 10-Ton Van Type

A Quartermaster Corps mobile field laundry unit (Fig. 2.1), a standard World War II type, was used for all decontamination studies.[1] The unit consisted of a 10-ton semi-trailer type van equipped with standard corrosion resistant machinery, including a 30 x 30 inch stainless steel washer rated at 60 pounds per load. A petcock had been installed in the bottom of the washer shell in order to withdraw samples of solutions without interrupting the operation. The van was fitted with a vinyl floor covering to minimize contamination.

2.1.2 Wooden Washer

In addition, a 36 x 36 inch wooden washer (Fig. 2.2) was used to decontaminate eight loads of clothing. This was a standard commercial washer. Hot and cold water connections were made from the mobile laundry unit to the wooden washer which was placed adjacent to the 10-ton laundry trailer.

2.2 CLOTHING MONITORING INSTRUMENTS

Six instruments, as described below, were evaluated for use as clothing monitors and the experimental items were compared with standard survey meters.

---

[1] Operating Instructions and Parts List, Mobile Laundry Unit, W-950-QM-3270, War Department TM 10-351, 21 Sept. 1942

[redacted]

Fig. 2.1 Quartermaster Corps Mobile Field Laundry, 10-Ton Van Type

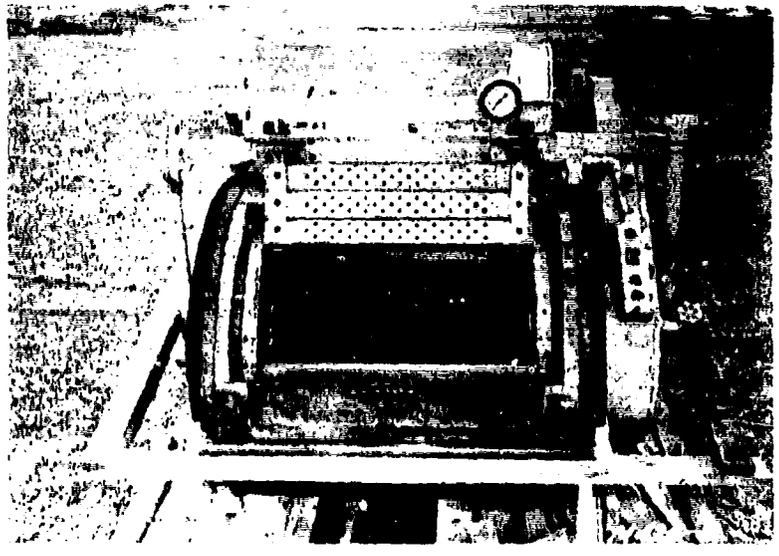


Fig. 2.2 A 36 x 36 inch Wooden Washer

2.2.1 Chemical Corps Clothing Checker (Experimental)[2]

The Chemical Corps Clothing Checker (Fig. 2.3) consists of a wooden box with a hinged lid. The dimensions of the top of the box are 27 x 29 inches. Mounted within the lower portion of the box are five, 12-inch, thin walled GM tubes whose active length is 7 inches. Five GM tubes are also mounted in the lid, but their position is such that, when the lid is closed, the long axes of the tubes in the lid are perpendicular to those in the box. All tubes are protected by 16-mesh copper screen. This clothing checker was operated in conjunction with a Berkeley Model 2000 Scaler. Counting was accomplished with the lid closed.

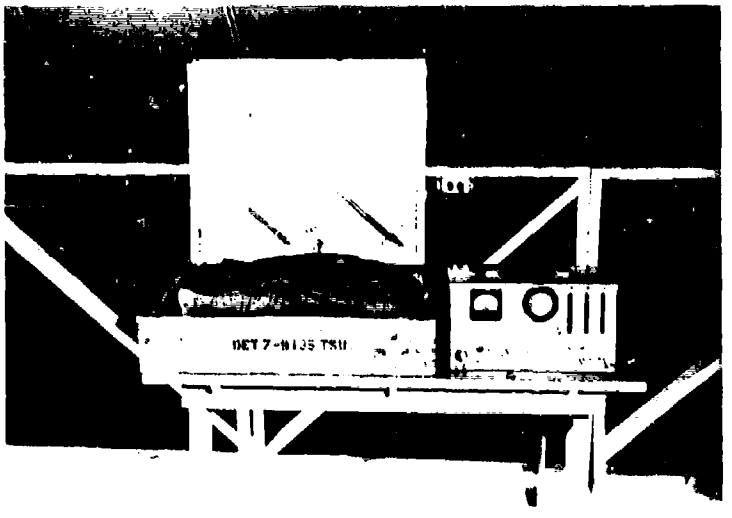


Fig. 2.3 Chemical Corps Clothing Checker

---

[2] TCIR 606, Radiological Clothing Monitor, Technical Command, Army Chemical Center, Maryland, 27 November 1951.

2.2.2 Modified Chemical Corps Checker (Experimental)

The Modified Chemical Corps Checker (Fig. 2.4) consists of the bottom half of the Chemical Corps Clothing Checker described in paragraph 2.2.1. The board to which the five tubes are mounted is adjustable from one to eight inches below the screen. These adjustments are accomplished by means of a screw at each of two sides. The tubes were operated at a distance of six inches below the screen during the test. This checker was also used in conjunction with a Berkeley Model 2000 Scaler.

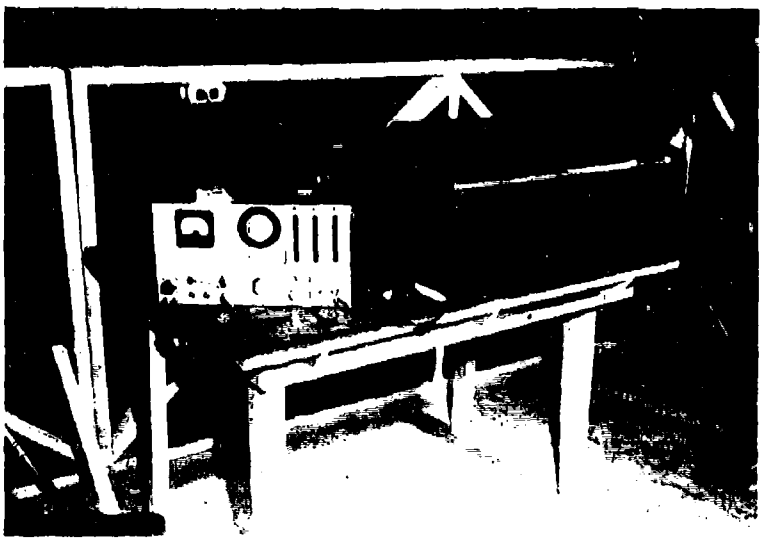


Fig. 2.4 Modified Chemical Corps Checker

2.2.3 Signal Corps Table Top Laundry Monitor (Experimental)

The Signal Corps Table Top Laundry Monitor consists of a table top of expanded metal 54 inches long by 34 inches wide supported by four legs. Beneath the expanded metal top is mounted a channel support upon which eight halogen type tubes are mounted. These tubes are placed to give the best geometric results for a source placed at any point on the table top. When comparing readings with other type monitors, a Berkeley Model 2000 Scaler was employed to record counts. A count rate meter was employed when the instrument was used for more rapid measurement of garment activity.

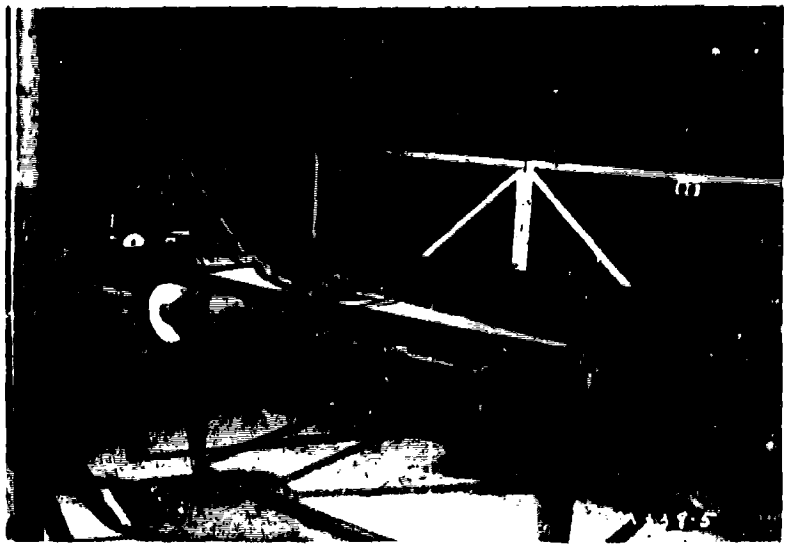


Fig. 2.5 Signal Corps Table Top Laundry Monitor

2.2.4 Signal Corps Scanning Arm Laundry Monitor (Experimental)

The Signal Corps Scanning Arm Laundry Monitor (Fig. 2.6) consists of a table top of expanded metal 54 inches long by 34 inches wide supported by four legs. Three halogen type tubes are mounted in a carrier along the width of the instrument underneath the expanded metal top. The tube assembly is motor powered and moves from one end of the device to the other at a constant rate of speed; the tubes being connected to a Berkeley Model 2000 Scaler. Counting begins when the tube assembly starts its traverse and stops when the tubes reach the opposite end of the device.

2.2.5 Radiac Meter from Radiac Set - AN/PDR 27A

This instrument has a halogen-filled, mica end-window tube for detection of beta-gamma activity from 0 to 5.0 mr/hr. The beta window has a thickness of 3 to 4 mg/cm^2. The instrument is a military portable Geiger-Mueller detector. It is rectangular in shape (9 1/4 x 5 3/16 x 4 1/2 inches) and weighs 10.2 pounds. The probe is equipped with a

beta shield which may be moved aside when measuring beta and gamma radiations together. Clothing monitoring with this meter was accomplished by placing the clothing flat on a table and passing the end-window of the probe over the garment at a constant height of six inches. Activity was recorded in mr/hr beta-gamma.

The 27A was not used primarily as an experimental clothing checker, but was used as a guide in determining the activity level in contaminated clothing. Its use was necessitated by clothing tolerance information which states that the tolerance is based on an end-window tube held six inches over the garment.

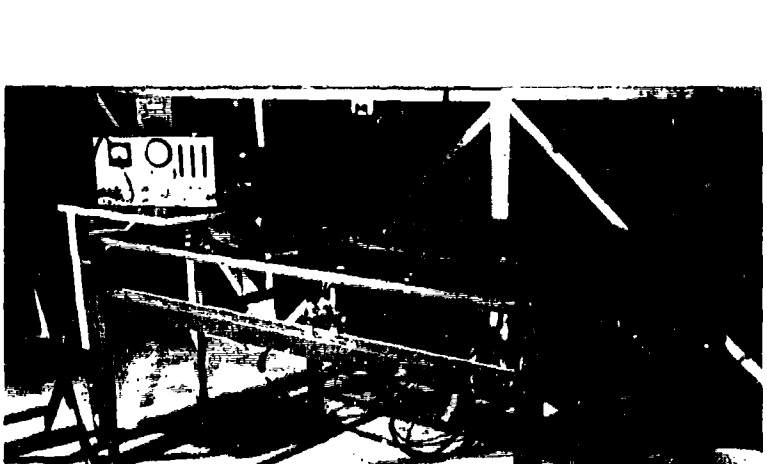


Fig. 2.6 Signal Corps Scanning Arm Laundry Monitor

2.2.6 Portable Geiger-Mueller Survey Meter - AN/PDR T-2A

This instrument has a glass GM tube for detection of beta-gamma activity from 0 to 50.0 mr/hr. Beta indication is by means of a perforated shield around the side of the tube. The beta window has a thickness of 30 mg/cm^2. The instrument is a military, portable Geiger-Mueller detector used chiefly for training. It is rectangular in shape (10 x 6 x 7 inches) and weighs 9.5 pounds. Monitoring of clothing with this instrument was accomplished in the same manner as with the 27A and its use was also made necessary by tolerance specifications.

[redacted]

2.3 LIQUID CONTAMINATION COUNTING DEVICE

For the measurement of the activity of the laundry solutions a device (Fig. 2.7) was built using a single Geiger-Mueller tube connected to a Berkeley Model 2000 Scaler. A Victoreen 1B85 Thyrode Aluminum Counter Tube and a Tracerlab TGC-5, Geiger Counter Tube, were both used in this process. Equal volumes of solution samples were drawn and counted in every case.

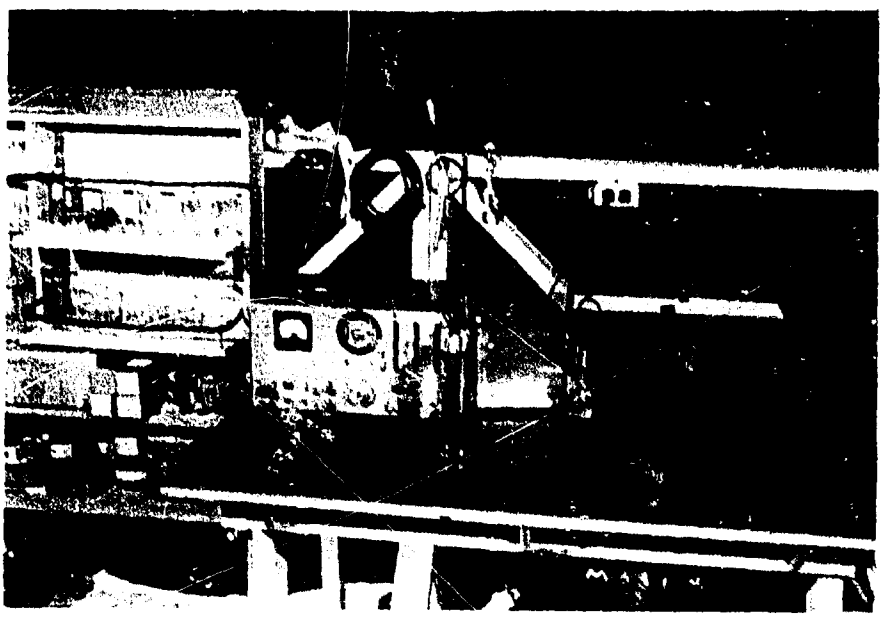


Fig. 2.7 Liquid Contamination Counting Device

2.4 FILM

Double emulsion X-ray film, 14 x 17 inches, was placed in X-ray exposure holders and positioned over contaminated garments and swatches for photographing the distribution of contamination. Film, X-ray type K, Eastman Kodak Co., Code #5135 and holder, X-ray exposure, General Electric catalog #E0019F, size 14 x 17 inches were used for this purpose

2.5 CONTROLLED CONTAMINATION TUMBLER

The drying tumbler from a air-portable, skid mounted, laundry unit was modified for deliberately contaminating test items (Fig. 2.8). A

[redacted]

[redacted]

PROJECT 6.7

TABLE 2.1

Clothing for Controlled Contamination

Trousers, nylon, Oxford, 5 oz., OD	112 pair
Trousers, rayon, satin lining, 5.5 oz., blue . . .	112 pair
Trousers, carded cotton sateen, 8.5 oz., OD 7. . .	254 pair
Trousers, field, cotton sateen, 9 oz., ...	34 pair
Trousers, wool serge, 18 oz., OD 33	24 pair
Shirts, field, wool, 16 oz., OG 108	27 each
Trousers, HBT, (greasy)	35 pair

TABLE 2.2

Fabric Swatches for Controlled Contamination

Code	Type	Number of Swatches
A	Cloth, cotton, 9 oz., sateen, dyed (untreated) - Control	31
B	Cloth, cotton, 9 oz., sateen, dyed (Zelan AP Base)*	31
C	Cloth, cotton, 9 oz., sateen, dyed (Norane)*	31
D	Cloth, cotton, 9 oz., sateen dyed (Aluminum, soap and wax)*	31
E	Cloth, cotton, 9 oz., sateen, dyed (Permel)*	29
F	Cloth, cotton, 9 oz., sateen, dyed (Treated with Inorganic Pigments)*	31
G	Cloth, cotton, 9 oz., sateen, dyed (Treated with Inorganic Pigments, Permel)*	31
	*Water Repellent Finishes	
H	Cloth, wool serge, 18 oz., OD 33	39
J	Cloth, wool, shirting, 16 oz., OG 108	39
K	Cloth, nylon, Oxford, 5 oz., OD	100
L	Cloth, rayon, satin lining, 5.5 oz., blue (Viscose)	100
M	Cloth, cotton, HBT, OD 7	100
N	Cloth, cotton, carded sateen, 8.5 oz., OD 7	98

[redacted]

Thirty suits each of herringbone twill clothing and field clothing were issued to personnel of Project 6.2 for wear in the "Land Reclamation Program."

A number of Project 6.3-1 test garments worn by persons entering the shot area were decontaminated and returned to that project for their evaluation. (See report of Project 6.3-1 for details and results.)

2.7 OPERATING SUPPLIES

The following detergents and chemicals were used during the decontamination operation:

Citric Acid (commercial crystals)		84 lbs.
Tartaric Acid (commercial crystals)		18 lbs.
EDTA (tetra sodium salt of ethylene-diamine-tetra-acetic acid)		45 lbs.
Oxalic Acid (technical crystals)		15 lbs.
Laundry Sour (mixture of equal parts of sodium-silico-flouride and sodium-acid-flouride		20 lbs.
Armour Detergent		23 lbs.
Chemical Composition:		
Renex	45.0%	
Carboxymethyl Cellulose	4.5%	
Urea	50.5%	
General Aniline and Film Detergent		5 lbs.
Chemical Composition:		
Antarox (non-ionic)	20.0%	
Borax	50.0%	
Carboxymethyl Cellulose	3.0%	
Sodium Sulfate	26.0%	
Tamol	1.0%	
Sodium Hexameta-phosphate		8 lbs.

2.8 WATER

Water used in the laundry was taken from the normal water supply at Indian Springs Air Force Base. An analysis of a sample of this water, drawn in September, 1951, made by the U. S. Bureau of Standards, is given in Table 2.3

[redacted]

PROJECT 6.7

TABLE 2.3

Water Analysis

Calcium Hardness (as $CaCO_3$)	131 ppm
Magnesium Hardness (as $CaCO_3$)	118 ppm
Alkalinity (as HCO_3)	387 ppm
Chloride (as Cl)	11 ppm
Sulfate (as SO_4)	38 ppm
Sediment	19 ppm
CO_2	Not detected

[redacted]

[redacted]

CHAPTER 3

EVALUATION OF LAUNDRY EQUIPMENT AND METHODS

3.1 OPERATIONAL PROCEDURES

In evaluating laundry equipment and materials for their suitability and effectiveness for clothing decontamination, fabrics and clothing were first contaminated by controlled methods, then decontaminated. The efficiency of the operation was then determined by use of the monitoring instruments described in Chapter 2.

3.1.1 Controlled Contamination Procedure

Contaminated soil taken from near the surface shot zero point was sifted through a 16 mesh screen to obtain as uniform a contaminant as practicable.

Approximately 20 pounds of dry clothing or swatches were put into the contaminating tumbler and one pound of sifted contaminated soil was introduced into the system. As the clothes were tumbled, the contaminant was circulated through the clothing for five minutes. An exhaust duct was then opened while the machine continued to run for five minutes, thus exhausting loose dust into a cloth collecting bag.

3.1.2 Laundry Formula Evaluation

The laundry formula evaluation phase consisted of testing two general type formulae and modifications of these formulae by the substitution of supplies. The two general type formulae are given in Table 3.1.

Six special 60 pound loads of trousers were deliberately contaminated as outlined in paragraph 3.1.1 above. Each of the loads was identical, consisting of 30 carded cotton sateen trousers, 16 nylon trousers, and 16 rayon trousers. These loads were numbered one through six. After each load was contaminated, it was monitored with the Table Top Laundry Monitor and then decontaminated with the process as indicated:

Load No.	Decontamination Process
1.	Mobile field formula (Armour Detergent)
2.	Mobile field formula (General Aniline Detergent)

[redacted]

[redacted]

PROJECT 6.7

Load No.	Decontamination Process
3.	Formula 77A
4.	Formula 77A - Tartaric Acid sub. for Citric Acid
5.	Formula 77A - $(NaPO_3)_6$ sub. for EDTA
6.	Formula 77A - Laundry Sour sub. for Citric Acid

Preliminary tests conducted using the contaminating tumbler indicated that one pound of the sifted dirt per one-third of a laundry load resulted in an adequate level of contamination, for evaluation

TABLE 3.1

Decontaminating Laundry Formulae

Step	Operation	Water Level (in)	Temperature °F	Time (min)	Supplies
		STANDARD QUARTERMASTER MOBILE FIELD FORMULA[1]			
1.	Suds	5	90-100	5	6 oz. Detergent
2.	Suds	5	130	5	3 oz. Detergent
3.	Suds	5	140	5	2 oz. Detergent
4.	Rinse	8	140	3	None
5.	Rinse	8	120	3	None
6.	Rinse	8	100	3	None
		FORMULA 77A			
1.	Suds	6	90-100	5	6 Oz. Armour Det.
2.	Acid	12	140	5	4 lbs. Citric Acid
3.	Acid	12	140	5	2 lbs. Citric Acid
4.	EDTA	8	140	5	1 1/2 lbs. EDTA*
5.	EDTA	8	140	5	1 lb EDTA*
6.	Rinse	12	140	3	None
7.	Rinse	12	120	3	None
8.	Sour	12	Tap	5	1 oz. Sour

*Tetra sodium salt of ethylene-diamine-tetra-acetic acid.

[1] Source, War Department Technical Bulletin 10-352-2, dtd 26 February 1946; however FM 10-16 "Quartermaster Laundry Company Semimobile" Department of the Army dtd June 1950 has eliminated the third suds in the above formula. The three suds formula has been tested during previous tests and results have indicated that three suds are imperative.

[redacted]

purposes. Therefore, the first cycle of six laundry formulae, which will be referred to a "A" laundry runs, was contaminated using one pound of contaminated dust to approximately 20 pounds of clothing.

Due to the rapid rate of decay of the contaminated soil collected on the first day following the surface shot, it was necessary to double the amount of contaminant the second time the six laundry loads were contaminated ("B" laundry runs). Also, the order of processing the numbered loads was reversed.

For the third cycle of the laundry formula evaluation phase ("C" laundry runs) contamination was accomplished by using one pound of contaminated dust per 20 pounds of garments. This new dirt was collected from nearer the surface shot crater on the third day following the shot and produced the highest level of clothing contamination of the three cycles. The processing order of this third cycle was as follows: Laundry loads number 3,4,5,2,1, and 6.

In order to obtain a more complete evaluation of the effect of the laundry supplies, one laundry run was made to determine the amount of contamination that would be removed by clear water alone. To accomplish this, formula 77A was used complete with regard to running time, temperature, and water level; but no supplies were added. Thus, it was possible to credit the laundry supplies with only the amount of decontamination actually accomplished by their use.

The monitoring of each garment before and after each decontaminating process provided a means of evaluating the over-all efficiency of the process. All loads were remonitored immediately after decontamination. The complete time span for monitoring, laundering, and remonitoring was approximately two hours, therefore no corrections were made for the decay occurring during the time required for processing.

In order to evaluate each step of a particular formula, a 4-ounce sample of the wash water solution was withdrawn from the washer at the end of each step of each formula. A special petcock installed near the bottom of the washer facilitated the withdrawal of these samples. After the samples from each step of a formula were collected, the activity of a controlled amount of each (approx. 4-oz.) was counted by means of the special solution activity counter described in paragraph 2.3. These readings in counts per minute were corrected for background before being recorded. Since each step in a particular laundry formula contained different amounts of waste water, it was necessary to adjust the counts per minute recorded, as the same amount of sample was withdrawn each time. Based on the amount of water in the washer filled to 8 inches versus the amount for the various washer levels encountered, the solution activities recorded were corrected to correspond to the concentration of activity which would have been present had each step had an 8

inch water level. The resulting data gave an indication of the percent of the activity transferred from the clothing to the wash solution during each step of each formula.

One 60 pound load of greasy HBT fatigue trousers, previously worn by mechanics at Fort Lee, Virginia, motor pool, was contaminated in the controlled contaminating device. These trousers had been worn by motor and shop mechanics for a period of one work week and were quite soiled by grease and shop dirt. This load of clothing was decontaminated with Formula 77A.

To investigate the need for a special laundry decontamination formula, fifteen pair of Rad-Safe coveralls worn in the underground shot area by monitors and scientific personnel were processed. This processing consisted of monitoring with the Table Top Laundry Monitor, then ordinary laundering with the mobile field formula and remonitoring.

3.1.3 Decay of Contamination and of Washing Solution Waste Water

Four controlled contaminated swatches (two before laundering and two after) were set aside after the surface shot for decay studies. Also one pair of Rad-Safe coveralls worn on underground shot plus one day were set aside for decay studies. Readings were taken periodically measuring both beta-gamma and gamma activity with the Table Top Laundry Monitor.

During the laundry formula evaluation phase, decay readings were taken on the waste water from one run of the mobile field formula and one run of formula 77A. This was accomplished by withdrawing an aliquot sample from each step of the laundry formula and combining all samples in order to get the over-all decay rate of the activity removed by each formula.

3.1.4 Suitability of Wooden Washer

Two 75 pound loads of mixed types of trousers (cotton sateen, cotton field, nylon, and rayon) were set aside for processing in the wooden washer. These loads of trousers were contaminated in the controlled contamination tumbler as outlined in Paragraph 3.1.1, monitored, and then laundered in the wooden washer. Prior to and after each laundering, the interior of the washer was monitored with an AN/PDR-T-2A hand survey GM meter to determine the extent of washer contamination. Each of the two loads were processed with the mobile field formula and were then recontaminated. Before and after laundering, 15 pair of trousers from each load were monitored on the Table Top Laundry Monitor to provide

a measure of the effectiveness of decontamination. After being recontaminated, the two loads were each processed with formula 77A. This entire procedure was then repeated, making a total of eight laundry loads processed with the wooden washer.

Upon determination of the extent of contamination of the machine at the completion of the eight runs, decontamination was performed by running the washer unloaded but containing a solution of hot water and oxalic acid. Then pressure hosing with a solution of ethylene-diamine-tetra-acetic acid followed with a clear water rinse also applied by hose. The washer was monitored before and after each of the foregoing baths to determine the degree of decontamination accomplished.

3.1.5 Transfer of Contamination

Four uncontaminated garments, two pair each of field and carded sateen trousers, were placed in the washer with each load of contaminated clothing processed during the formula evaluation phase. These test trousers were monitored after being processed with the hot loads to indicate the amount of contamination transferred to uncontaminated clothing when it is processed with contaminated items.

3.1.6 Inhalation Hazard to Laundry Monitoring Personnel

Air samples were taken inside the monitoring tent to evaluate the health hazard from inhaling radioactive dust while handling contaminated clothing. The air samples were taken by representatives from the Radiological Safety Group. The air sampling instrument was operated adjacent to the laundry monitoring device where the air would be the most highly contaminated.

3.2 RESULTS

Results of the evaluation of laundry equipment and methods are included in the following paragraphs.

3.2.1 Laundry Formula Evaluation

Table 3.2 shows the effectiveness of the six laundry formulae based on the percent of contamination removed as measured by the Table Top Laundry Monitor. These figures represent the over-all average of a load of 62 garments consisting of sateen, rayon, and nylon trousers.

In addition to the total percent decontamination for a laundry run, as based on the measure of activity before and after

TABLE 3.2

Evaluation of Decontamination Formula

	"A" Laundry Runs Decontamination			"B" Laundry Runs Decontamination			"C" Laundry Runs Decontamination		
	10^3 c/m			10^3 c/m			10^3 c/m		
	Before	After	Percent	Before	After	Percent	Before	After	Percent
Standard Field (Armour)	21.1	3.7	82.6	12.0	2.1	82.8	288.4	62.8	78.2
Standard Field (General Aniline)	23.3	3.9	83.2	9.4	1.9	80.2	207.6	47.7	77.0
77A (Alone)	14.3	1.5	89.6	9.1	1.1	88.3	213.0	27.1	87.3
77A (with $(NaPO_3)_6$	14.5	1.6	89.0	12.4	1.3	89.9	234.0	36.0	84.6
77A (with Tartaric)	16.1	1.2	92.5	9.9	0.6	93.5	239.7	33.1	86.2
77A (with Sour)	14.2	0.7	95.3	13.0	1.6	88.0	257.8	65.5	74.6
77A (Water Only)	___	___	___	___	___	___	69.5	24.5	64.7

laundering, it was possible to evaluate the relative amount of activity removed during each step of any laundry formula. (See paragraph 3.1.2). The sum of these corrected scaler counts for all steps of a formula were considered to represent the activity removed by the complete laundry process. As the amount of activity present is reduced after each step, the figures representing percent removal are based on the contamination removed by each step relative to the amount present at the beginning of that step. (Table 3.3).

The "A" laundry runs were made up of new garments and it may be seen from the analysis of the percent of activity removed in the first suds that the average was 43.3 percent as compared to an average of 32.9 percent for the first suds in the "B" and "C" runs. The tendency for a greater amount of activity to be removed from new fabric continues through the first few steps, then appears to decrease, so that the overall decontamination produced is about the same for both new and used fabrics. Apparently, the new fabric additives that are readily soluble, are removed early in the first laundering, but this has little effect on the total decontamination.

In order to better evaluate the decontamination formulae, comparison was made by considering laundered garments of the "B" and "C" runs only. These two groups of laundry runs represent both high and low degrees of contamination.

The order of efficiency of the six laundry formulae tested, based upon the percent decontamination of the average "B" and "C" runs, is presented graphically in figure 3.1.

A method of comparing formula efficiency is by use of the "Indices of Washing Efficiency" from the following equation:

$$\text{Index of Washing Efficiency} = \frac{10 \times (\%\ \text{removed by agent} - \%\ \text{removed by } H_2O)^2}{(100 - \%\ \text{removed by } H_2O)} \qquad (3.1)$$

The index of washing efficiency is equal to one-tenth of the percentage removal of the contamination which is not removed by water alone. The maximum index of efficiency possible is 10, in which case all or practically all of the contamination is removed from the cloth. If

---

[2] A. B. Carlson and William F. Neuman, The Removal of Uranium Compounds from Cloth, University of Rochester, Technical Information Div., ORE, Oak Ridge, Tennessee, p 7.

[redacted]

PROJECT 6.7

TABLE 3.3

Efficiency of Each Step of Laundry Formula

Step Operation	Laundry Runs		
STANDARD FIELD FORMULA (ARMOUR DETERGENT)			
	"A"	"B"	"C"
1. Suds	41.0%	31.6%	31.8%
2. Suds	29.1	31.0	27.4
3. Suds	20.8	27.7	24.8
4. Rinse	23.7	26.7	21.5
5. Rinse	20.0	19.5	15.3
6. Rinse	13.8	14.5	12.0
STANDARD FIELD FORMULA (GENERAL ANILINE)			
	"A"	"B"	"C"
1. Suds	40.6%	35.1%	32.3%
2. Suds	36.2	34.5	28.2
3. Suds	28.8	27.0	25.2
4. Rinse	19.5	19.5	18.3
5. Rinse	16.6	13.4	13.7
6. Rinse	7.2	8.3	10.2
FORMULA 77A			
	"A"	"B"	"C"
1. Suds	44.6%	28.9%	33.2%
2. Citric	41.5	27.8	33.9
3. Citric	19.8	16.7	19.5
4. EDTA	26.5	15.7	16.5
5. EDTA	24.2	16.8	20.0
6. Rinse	21.4	22.4	24.7
7. Rinse	6.5	24.7	19.9
8. Rinse	2.5	29.7	11.3

This Table is Continued on Next Page

[redacted]

[redacted]

PROJECT 6.7

TABLE 3.3 (Cont'd)

Efficiency of Each Step of Laundry Formula

Step	Operation	Laundry Runs		
		FORMULA 77A with $(NaPO_3)_6$		
		"A"	"B"	"C"
1.	Suds	41.5%	35.0%	33.2%
2.	Citric	39.3	30.3	28.5
3.	Citric	27.3	14.4	16.4
4.	$(NaPO_3)_6$	24.7	23.7	17.8
5.	$(NaPO_3)_6$	18.5	38.0	18.3
6.	Rinse	16.5	29.6	21.7
7.	Rinse	14.3	15.8	19.2
8.	Rinse	2.8	7.0	9.3
		FORMULA 77A with TARTARIC ACID		
		"A"	"B"	"C"
1.	Suds	47.7%	36.5%	36.0%
2.	Tartaric	52.3	45.0	31.9
3.	Tartaric	23.5	23.0	19.8
4.	EDTA	21.4	27.6	15.3
5.	EDTA	28.8	38.8	19.7
6.	Rinse	27.5	26.4	24.3
7.	Rinse	9.8	13.4	14.9
8.	Sour	3.7	14.5	10.1
		FORMULA 77A with SOUR		
		"A"	"B"	"C"
1.	Suds	44.3%	29.9%	30.9%
2.	Sour	40.8	24.5	19.5
3.	Sour	22.7	15.3	11.6
4.	EDTA	34.9	17.2	14.3
5.	EDTA	40.3	34.0	16.0
6.	Rinse	37.2	33.4	16.1
7.	Rinse	24.6	20.5	9.8
8.	Sour	___	7.5	5.0

This Table is continued on Next Page

[redacted]

[redacted]

PROJECT 6.7

TABLE 3.3 (Cont'd)

Efficiency of Each Step of Laundry Formula

Step Operation	Laundry Runs		
FORMULA 77A with WATER RINSES			
	"A"	"B"	"C"
1. Rinse	———	———	27.3%
2. Rinse	———	———	18.9
3. Rinse	———	———	11.6
4. Rinse	———	———	10.8
5. Rinse	———	———	9.0
6. Rinse	———	———	7.3
7. Rinse	———	———	4.9
8. Rinse	———	———	6.7

the decontaminating agent had removed no more contamination than did water alone, the index of washing efficiency would be zero. Also, if the agent would result in less decontamination than water alone, the index of washing efficiency would be between -1 and -10. The relative effectiveness of the various formulae tested, as evaluated by this method, is shown in Table 3.4

TABLE 3.4

Index of Washing Efficiency

Formula	Laundry Runs "A"	"B"	"C"
Standard Field (Armour)	5	5	4
Standard Field (Gen. Aniline)	5	4	3
77A (Alone)	7	7	6
77A (with $(NaPO_3)_6$	7	7	6
77A (with Tartaric)	8	8	6
77A (with Sour)	9	7	3

[redacted]

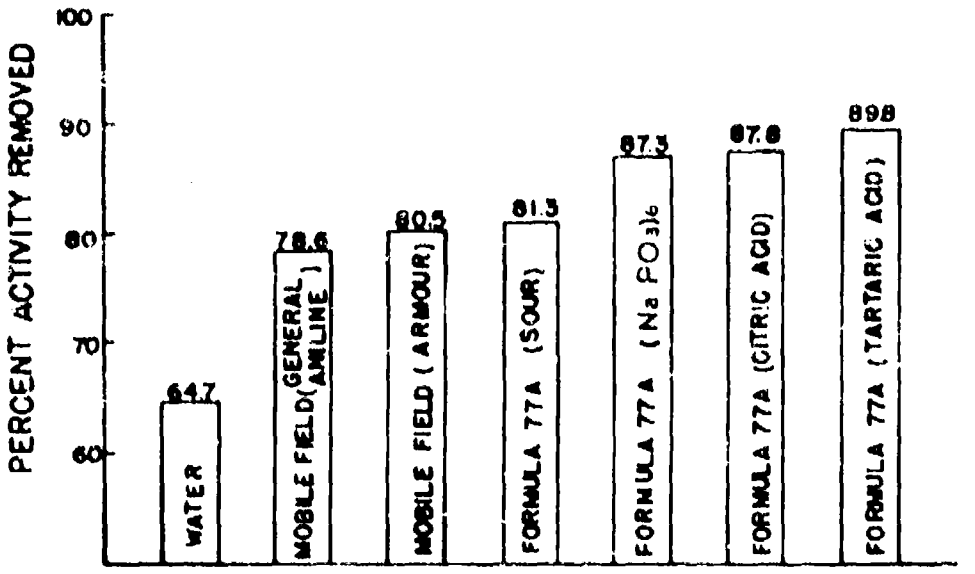


Fig. 3.1 Efficiency of Laundry Formula

The 60-pound load of greasy, cotton, herringbone twill trousers were contaminated to an average level of 102 thousand counts per minute per garment as measured by the Table Top Laundry Monitor. Decontamination by use of Formula 77A reduced the level of activity to an average of 8000 counts. This represents 92 percent decontamination achieved on greasy trousers.

The 15 pairs of Rad-Safe coveralls which had become contaminated by being worn near the underground shot on underground plus one and underground plus two days were decontaminated by laundering with the mobile field formula. The average decontamination resulting from this procedure was over 90 percent.

3.2.2 Decay and Beta-Gamma Ratio

Surface Shot: Decay readings were taken on nylon and rayon swatches before and after laundering. These swatches were contaminated with dirt which had been picked up from near the surface shot on surface shot plus six days. Since the decay slope for nylon and rayon were the same; i.e. -1.3, only the curve for nylon has been given in figure 3.2 to show the relationship between laundered and unlaundered fabrics. These curves represent beta-gamma activity only.

Underground Shot: Figure 3.3 shows the beta-gamma, and gamma decay for one pair of Rad-Safe coveralls worn in the underground shot area on underground plus one day.

Figure 3.4 shows the beta-gamma decay rate for an aliquot sample of water from the first group of laundry evaluation runs. One curve represents the decay rate for the waste water from the mobile field formula with Armour detergent and the other curve represents the decay rate for the waste water from the formula 77A. The slope for each is approximately -1.7.

The scaler count for garments contaminated following both the surface and the underground shots was reduced by approximately 90 percent when an aluminum Beta shield was placed between the tubes and the garment on the Table Top Laundry Monitor.

3.2.3 Suitability of Wooden Washer

The wooden washer was as effective when used for laundry decontamination as the stainless steel washer, using the same laundry formulas and processing the same type garments, contaminated under the same conditions. The average percent decontamination achieved by four

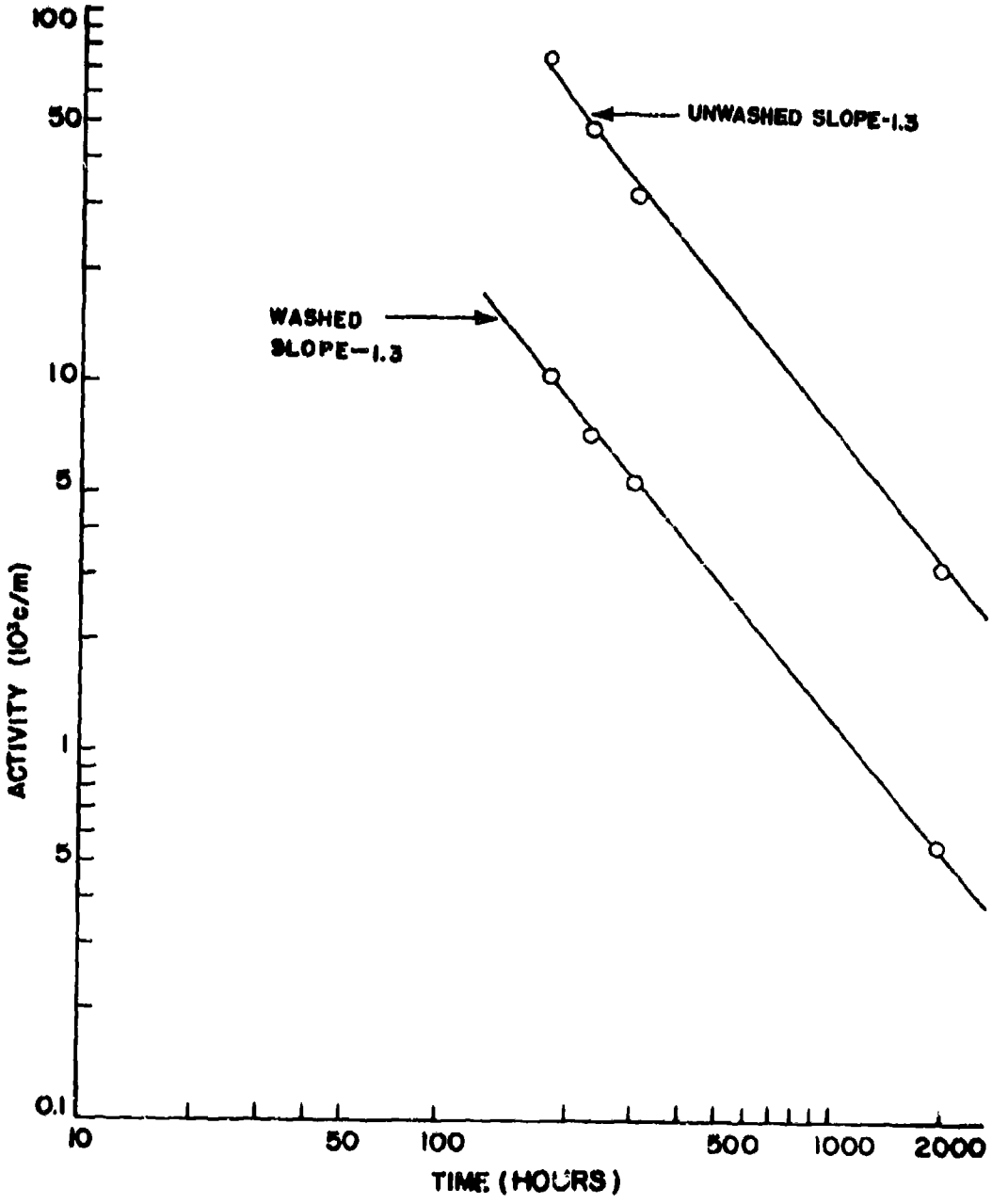


Fig. 3.2 Logarithmic Plot of the Beta, Gamma Activity Decay of Nylon Swatches Surface Shot

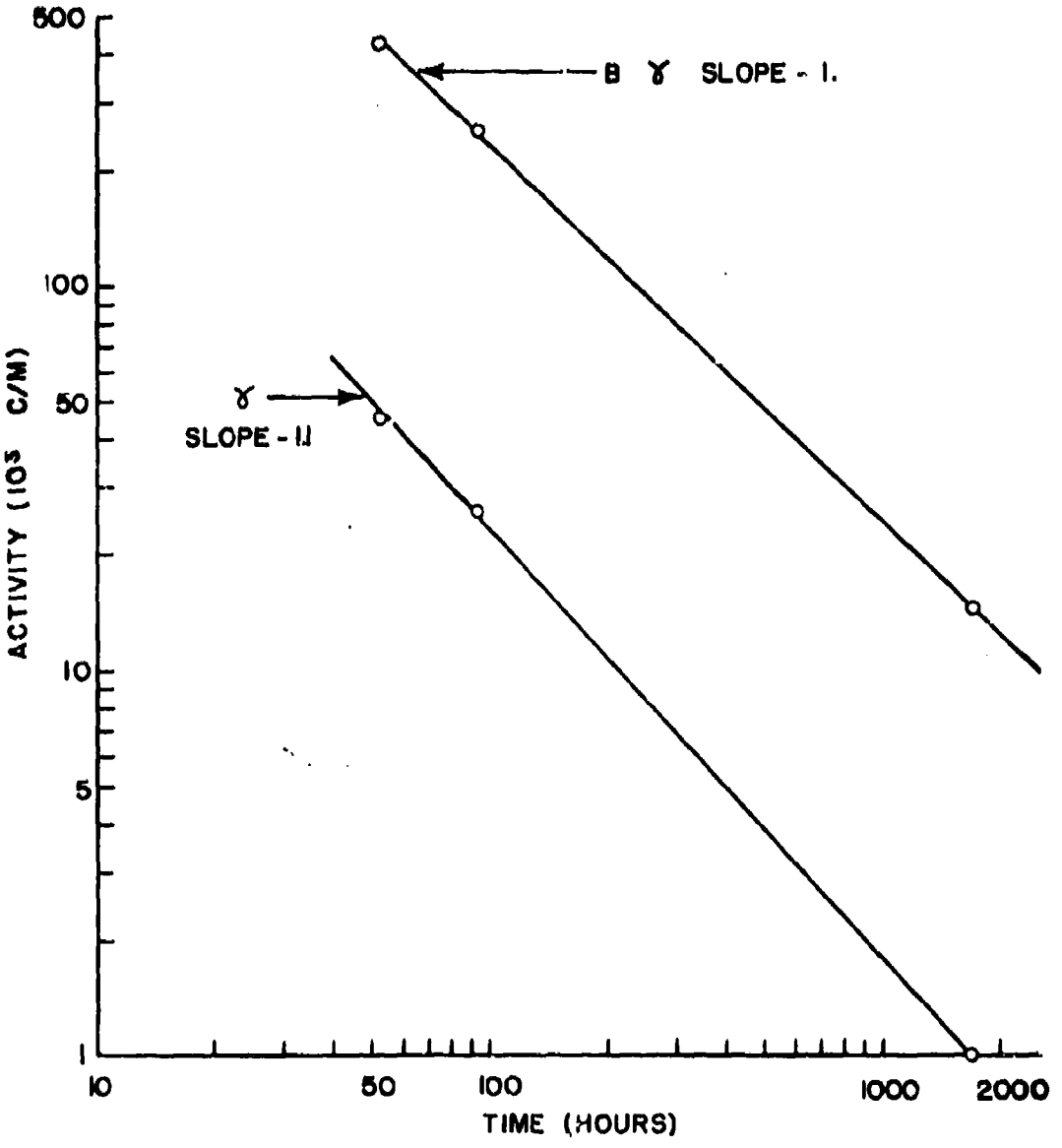


Fig. 3.3 Logarithmic Plot of the Activity Decay of Coveralls Contaminated in Underground Shot Area

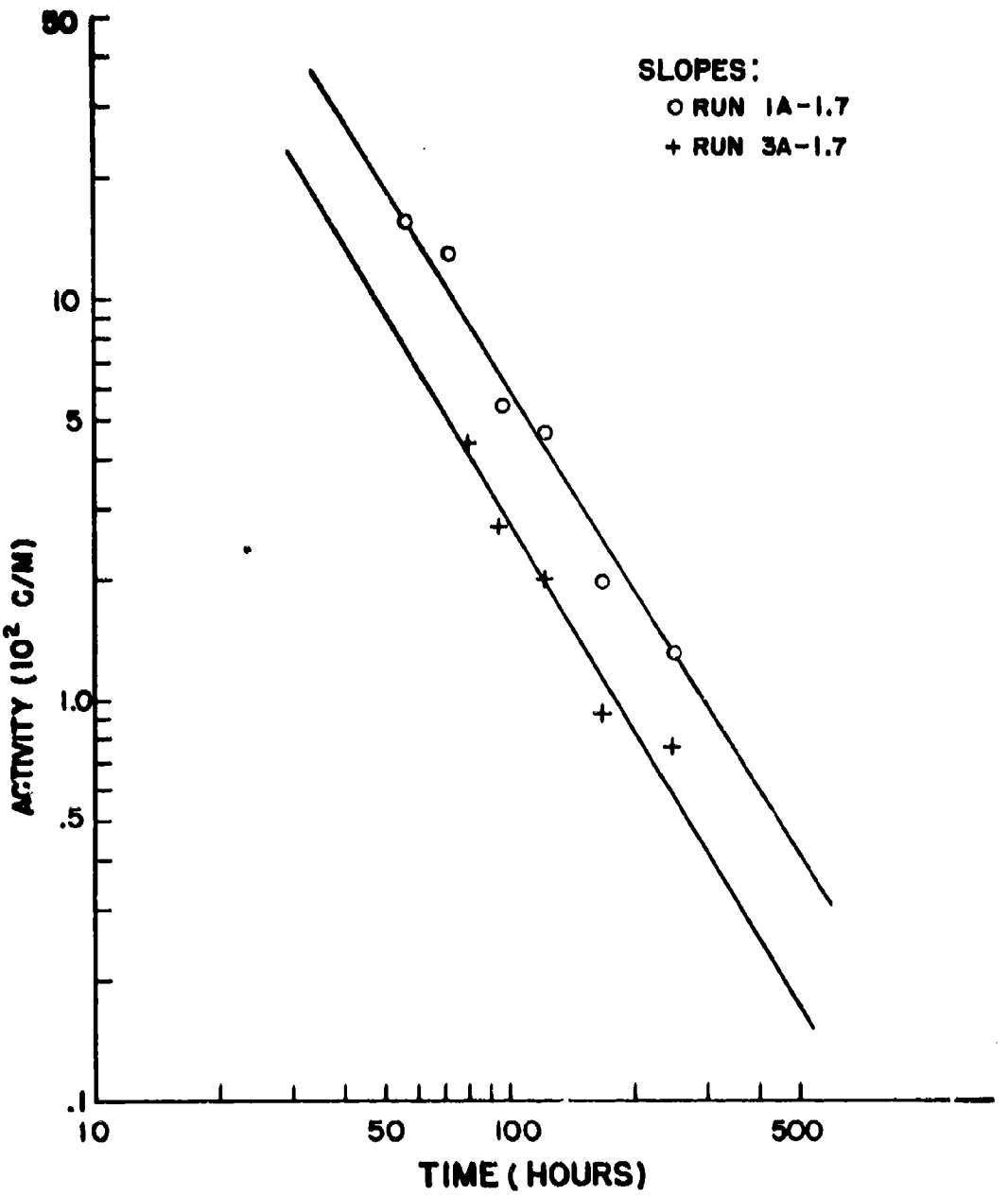


Fig. 3.4 Logarithmic Plot of the Beta, Gamma Decay Rate for Laundry Evaluation Runs

laundry runs with the wooden washer and three laundry runs with the stainless steel washer for each of two laundry formula is shown in Table 3.5.

The wooden washer did not become contaminated to the extent that it would be impractical to use. The contamination did not continue to build up throughout the several runs. After the level of activity reached approximately 10 mr/hr during the fourth laundry run, it remained at this level throughout four more runs. These data are shown in Table 3.6.

TABLE 3.5

Comparison of Decontamination Performed in Steel and Wooden Washers (Sateen Trousers)

Type Washer	Laundry Formula	
	Mobile Field Formula (Armour)	77A
Wooden Washer	86.7%	89.4%
Stainless Steel	80.1	90.9

TABLE 3.6

Activity in Wooden Washer (mr/hr)

Run No.	Formula	Inside Washer (Highest Reading)	Waste Water Dump Value
1.	Mobile Field	4.5	11.0
2.	Mobile Field	5.0	11.0
3.	77A	4.5	10.0
4.	77A	11.0	12.0
5.	Mobile Field	10.0	11.0
6.	Mobile Field	10.0	12.0
7.	77A	7.0	12.0
8.	77A	10.0	11.0

Four pounds of oxalic acid were put into the washer and run for ten minutes in ten inches of water at 140°F. This did not materially lower the activity of the washer. Pressure hosing with an organic chelating agent following the oxalic acid treatment brought the level of activity down only slightly. This was followed by a clear water rinse to remove any of the decontaminating chemicals which would tend to cause corrosion of the metal parts.

3.2.4 Transfer of Contamination

Four uncontaminated garments, two pair each of field and carded sateen trousers, were placed in the washer with each of the 18 laundry runs during the formula evaluation phase of the work.

In every case, activity was picked up by the uncontaminated garment during the laundering process. In no case did the activity of the carded sateen trousers exceed that of the contaminated carded sateen trousers when both were compared after laundering. Transfer of contamination resulted in the residual activity of uncontaminated carded sateen trousers being in the order of 60 to 70 percent of the activity of the contaminated trousers. No field trousers were contaminated during the laundry formula evaluation phase; however, the two pair of uncontaminated field trousers which were laundered with each of these 18 laundry runs picked up considerable activity as compared to other type trousers. In every case, these field trousers were more radioactive than the original contaminated sateen trousers after laundering. In comparing the two types of trousers tested for transfer of contamination, the field trousers were in the order of two to four times as radioactive after laundering as were the carded sateen trousers.

3.2.5 Inhalation Hazard to Laundry Monitoring Personnel

On the second day following the surface shot during the period of time when contaminated garments were being monitored, the air sampling device indicated that the air in the vicinity of the clothing checker contained approximately 1.4 micro curies per cubic meter.

During the period between the second and the seventh day following the surface shot the air was filtered from near the clothing monitor for a total of 16.8 hours while contaminated garments were being monitored. The activity of this air averaged approximately 0.8 micro curies per cubic meter.

3.3 DISCUSSION

This discussion includes statistical evaluation of results as well as the implications that may result from considerations of economy and availability of supplies and equipment.

3.3.1 Laundry Formula Evaluation

The data concerning percent decontamination was evaluated for significance by use of the following formula for the ratio of the observed difference to the standard error of the difference.[3]

$$\frac{X}{\sigma} = \frac{\bar{x}_1 - \bar{x}_2}{\sigma_{\bar{x}_1 - \bar{x}_2}} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(\frac{SD_1}{\sqrt{N_1}}\right)^2 + \left(\frac{SD_2}{\sqrt{N_2}}\right)^2}} \qquad (3.3)$$

X = Observed Difference
σ = Standard error of the Difference
$\bar{x}$ = Average Percent Decontamination

SD = Standard Deviation
N = Number of Samples

There was no significant difference between Armour Detergent and General Aniline Detergent when used for decontamination. In every case the difference between results obtained with the Mobile Field Formula and Decontamination Formula 77A is significant.

In two cases the use of tartaric acid was significantly better than citric acid when substituted for citric acid in Formula 77A; in the third case, while the tartaric acid appeared slightly more efficient, the difference was not significant. There was so much variation in the results obtained by the substitution of laundry sour for citric acid that no definite statement can be made as to its effectiveness.

Due to the large number of samples in each laundry load, the statistical significance of some of the data was greater than the practical difference occurring as the result of using different supplies.

---

[3] Croxton and Cowden, Applied General Statistics, p 319.

For example, the first cycle of the formula evaluation (Runs "A") indicated that there was no significant difference between using the tetra sodium salt of ethylene-diamine-acetic acid and sodium hexameta-phosphate; however, for the second cycle (Runs "B") the sodium meta-phosphate was significantly better and during the third cycle, (Runs "C") the ethylene-diamine-tetra-acetic acid was significantly better. The practical difference was only 1.6 percent in one case and 2.7 percent in the other. Therefore, the results indicate that either of these two supplies may be used with the same over-all results.

While there is a difference between the decontaminating efficiency of the various laundry formulae, there is also a difference in the cost of running each formula. For example, if two laundry formulae meet the requirements of decontaminating clothing to a safe level, then a matter of one being slightly more efficient is not too important. Therefore, consideration should be given to the cost of performing a laundry run before it is adopted for general use. A comparison of prices is shown in Table 3.7. The price for detergent is based on the Army Pricing Guide for 1952. The price for the other chemicals is approximate and is based on commercial bulk purchase estimates.

TABLE 3.7

Cost of Supplies for One Run
of Each Laundry Formula

Formula 77A	$3.55
Formula 77A with Tartaric Acid	4.45
Formula 77A with $(NaPO_3)_6$	2.42
Formula 77A with Laundry Sour	2.37
Mobile Field Formula (Armour or General Aniline Detergent)	.20

Since atomic tests are conducted in the open and the personnel entering contaminated areas normally wear clean clothing, the question arose as to the amount of decontamination that might be expected for clothing soiled with grease and grime. One load of contaminated greasy clothing decontaminated quite well with Formula 77A and did not present an additional problem because of grease and other soil.

In evaluating the effectiveness of the decontamination process, consideration was also given to the need for such a process. The degree of contamination encountered is discussed more fully in Chapter IV, "Evaluation of Fabrics." It is, however, interesting to note that

the only information available with regard to allowable degree of contamination on clothing, is that published in D/A Pamphlet, "Handbook of Atomic Weapons for Medical Officers" which is quoted below.[4] This tolerance level is for peacetime, industrial application and includes a substantial factor of safety.

For fission product contamination, the following are considered as limits for a 24-hour working day:

a. Thin side-wall GM tube (30-40 mg/cm^2 such as the AN/PDR-5)-7 mr/hr indicated beta plus gamma when measured with the tube parallel and not more than 6" from the contaminated surface.

b. Thin end wall GM tube (2-4 mg/cm^2 such as the AM/PDR-27)-2 mr/hr indicated beta plus gamma with the thin window parallel and not over 6" from the contaminated surface.

It is interesting to note that the personnel of this project received no information of any clothing becoming radioactively contaminated to a measureable degree through wear following the surface shot. Also, after the underground shot, the total of seventeen coveralls obtained were the result of screening approximately one-hundred coveralls in an effort to obtain some which were highly contaminated. Of these seventeen Rad-Safe coveralls, only four were contaminated above tolerance.

The most highly contaminated pair of coveralls encountered was twice tolerance. If it is assumed that the decay rate has a slope of -1.2 (log log scale), a garment which was twice tolerance at 24 hours after the underground shot, would decay to below tolerance one day later.

The decay curves for the waste water solutions indicate that there was no difference in the type of contaminant removed by the two laundry formulae.

The decay slope did not differ materially from that encountered during Operation GREENHOUSE; however, the reduction in scaler counts due to shielding with an aluminum shield was approximately 90 percent on Operation JANGLE as compared to approximately 80 percent at Operation GREENHOUSE.

4D/A Pamphlet #8-11, Handbook of Atomic Weapons for Medical Officers, 26 June 1951, p 44.

3.3.2 Suitability of Wooden Washer

The wooden washer used during this test was a new washer and thus required a considerable amount of soaking before it would swell sufficiently to hold water. The wood appeared to have been coated with a preservative finish, therefore the cylinder and shell were cleaned by use of caustic soda and oxalic acid.[5]

The wooden washer was as effective in decontaminating clothing as was the stainless steel washer; however, the wood did accumulate contamination to a limited extent which was not easily removed. It may be that the washer continued to swell during the first few laundry runs resulting in some contamination becoming entrapped in the cracks. In any event the degree to which the wooden washer became contaminated is considered to be so low as not to present a problem. This may not hold true for an old used washer. It is believed that a used wooden washer should be thoroughly cleaned of soap scum prior to its being used for decontaminating radioactively contaminated clothing. Also fatty-acid soaps, which precipitate in hard water, should not be used in the decontaminating formula.

3.3.3 Inhalation Hazard to Laundry Monitoring Personnel

The dry condition of the contamination on clothing contaminated in the tumbling device could be expected to create more of an inhalation hazard than garments contaminated by wear. Although there was an activity in the air of 1.4 microcuries per cubic meter, the monitoring personnel were breathing this contaminated air only during the time of monitoring. If one breathed this air for eight hours, his average for the day would be less than one-half microcurie per cubic meter of the total air inhaled. Although contaminated garments should not be deliberately shaken or handled in such a way as to create a dust hazard, there appears to be no necessity for wearing dust respirators during the monitoring operation.

---

[5] TM 10-354 Quartermaster Fixed Laundry Organization, Operation, and Equipment, War Department Technical Manual, September 1947, p 78.

[redacted]

CHAPTER 4

EVALUATION OF FABRICS

4.1 OPERATIONAL PROCEDURES

This study consisted of an evaluation of both synthetic and natural fabrics as well as special fabric finishes as to their comparative contaminability and decontaminability under controlled conditions.

4.1.1 Clothing Contaminated Through Wear in Shot Areas

On surface shot plus two days, nine persons wearing cotton herringbone twill clothing entered an area reading between 80 and 150 mr/hr. These persons were members of Project 6.2 (Land Reclamation) and worked with bulldozers and road graders. Upon completion of their work, the group turned their clothing over to Project 6.7 and were issued cotton field jackets and field trousers for the following day. On surface shot plus three days, the nine persons again entered areas reading between 80 and 150 mr/hr doing work similar to that of the previous day. This clothing was also turned over to Project 6.7 at the end of the day. No further issue of clothing was made to personnel of Project 6.2.

Personnel of Project 6.3 entered the surface shot area wearing their own test clothing. This clothing was also turned over to Project 6.7 for processing.

4.1.2 Swatches and Clothing Contaminated by Controlled Methods

The fabric swatches and the woolen shirts and trousers listed in paragraph 2.6 were subjected to controlled contamination as described in paragraph 3.1.1. The contaminant used in this case was picked up from the lip of the crater on surface shot plus six days. In instances where one fabric type did not contain enough swatches to make a 60 pound laundry load, two similar types were combined or other material was added to bring the weight up to 60 pounds. The rayon, Code L, and nylon, Code K, swatches were processed together; and the wool trouser material, Code H, and the wool shirting, Code J, swatches were processed together. The woolen shirts and trousers were also combined into a single load. Since the number of each type of swatch, Code A through G, was relatively small, each of these code types was built up to 60 pound loads by the addition of cotton sateen trousers.

[redacted]

After contaminating the combined and built up loads, they were all monitored on the Table Top Laundry Monitor, laundered with the mobile field formula, and then remonitored.

4.1.3 Radiographs of Contamination

Radiographs were taken of two suits of coveralls which were worn in the contaminated area following the underground shot. Also, radiographs were taken of deliberately contaminated swatches both before and after laundering. Type K, X-ray film was placed inside the X-ray exposure holder and placed in direct contact with the contaminated material for the period of time necessary to produce exposure. Preliminary experimenting indicated that approximately 35 milliroentgens of radiation (intensity being measured with AN/PDR-T-2) would produce considerable blackening of this type of film.

In making the radiograph of coveralls, eight pieces of the film were fastened to a sheet of plywood in order to provide complete coverage of the coveralls.

4.2 RESULTS

The results of the fabric evaluation phase of the project together with radiographs of some contaminated materials are presented in the following paragraphs.

4.2.1 Clothing Contaminated Through Wear in the Shot Area (Surface Shot)

The clothing worn by Project 6.2 personnel was not contaminated to an extent discernible above background.

The garment contamination resulting from wear by Project 6.3 personnel after the surface shot was very low, less than 1 mr/hr. For a complete report on the levels of contamination encountered, reference is made to the report of Project 6.3.

4.2.2 Swatches Contaminated by Controlled Methods

The 22 x 26 inch pillowcase type swatches were divided into four categories. Code letters A and G represented a control group and six special finishes. Code letters H and J were woolens. Code letters K and L were assigned to synthetics, and Code letters M and N represented cottons. These codes listed in Table 2.2 are together with a complete description of the fabrics.

[redacted]

PROJECT 6.7

The contaminability of each type swatch and the decontaminability of each type in percent removal of the contaminant originally present is shown in Table 4.1 and graphically in figure 4.1. Each figure represents the average of the readings on all swatches of a given type. The percent decontamination represents the action of the mobile field formula in every case.

TABLE 4.1

Relative Contaminability and Decontaminability of Fabric Swatches.

Code	Activity 10^3 c/m		Per cent Decontamination
	Before Laundering	After Laundering	
A	106.9	27.2	74.6%
B	150.1	35.7	76.2
C	167.4	108.5	35.2
D	131.9	34.6	73.8
E	145.5	25.9	82.2
F	156.6	50.4	67.8
G	126.4	46.6	63.1
H	131.1	15.5	88.2
J	140.4	10.2	92.7
K	110.5	8.5	92.3
L	95.4	26.5	72.2
M	126.9	42.2	66.7
N	125.0	20.6	83.5

4.2.3 Clothing Contaminated by Controlled Methods

The 27 wool field shirts, and 24 wool serge trousers, showed the following degrees of contaminability and decontaminability. All processed with the mobile field formula, as were the swatches. Data regarding these items are shown in Table 4.2.

[redacted]

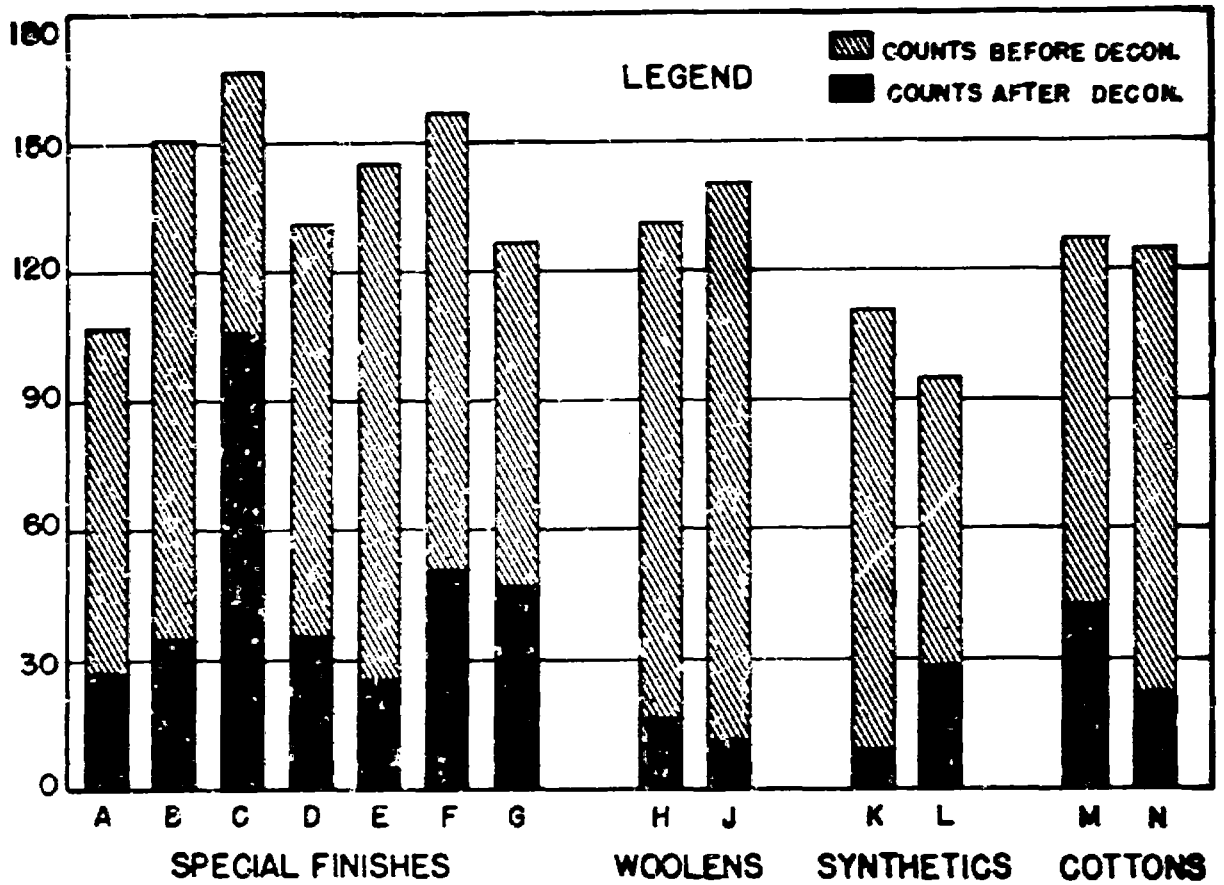


Fig. 4.1 Graph of Relative Contaminability and Decontaminability of Fabric Swatches

PROJECT 6.7

TABLE 4.2

Woolens Processed with Mobile Field Formula

Type	Activity 10^3 c/m		Per cent Decontamination
	Before Laundering	After Laundering	
Shirts	261.1	32.9	87.4%
Trousers	196.9	23.2	88.2

For the purposes of fabric study, an evaluation was made of the data from the laundry formulae evaluation phase of the test that concerned contaminability and decontaminability of nylon, rayon, and cotton sateen trousers when processed with the mobile field formula. These data were further broken down into new and laundered trousers. The level of activity in the dirt with which the new trousers were contaminated was much lower than that with which the laundered trousers were contaminated, hence they received less contamination. These data are shown in tables 4.3 and 4.4.

TABLE 4.3

New Trousers Processed with Mobile Field Formula

Number	Trouser Type	Activity 10^3 c/m		Per cent Decontamination
		Before Laundering	After Laundering	
32	Nylon, oxford, 5 oz.	27.7	1.9	93.1%
32	Rayon, satin, 5.5 oz.	20.3	5.1	74.5
60	Cotton sateen, 8.5 oz.	20.1	3.6	81.9

TABLE 4.4

Laundered Trousers Processed with Mobile Field Formula

Number	Trouser Type	Activity 10^3 c/m		Per cent Decontamination
		Before Laundering	After Laundering	
32	Nylon, oxford, 5 oz.	183.9	28.7	84.4%
32	Rayon, satin, 5.5 oz.	277.8	67.5	75.7
60	Cotton sateen, 8.5 oz.	266.2	67.3	74.7

[redacted]

PROJECT 6.7

Further fabric evaluation studies were made on the cotton field and sateen trousers which were processed in the wooden washer. This included both new and laundered trousers. Table 4.5 gives the data for new trousers while Table 4.6 shows the results for trousers laundered three times.

TABLE 4.5

New Trousers Processed in the Wooden Washer

Number	Trouser Type	Activity 10^3 c/m		Per cent Decontamination
		Before Laundering	After Laundering	
10	Cotton sateen, 8.5 oz.	102.5	19.0	81.5%
20	Cotton, field, 9 oz.	65.8	21.1	67.9

TABLE 4.6

Laundered Trousers Processed in the Wooden Washer

Number	Trouser Type	Activity 10^3 c/m		Per cent Decontamination
		Before Laundering	After Laundering	
10	Cotton sateen, 8.5 oz.	98.4	6.5	93.5%
20	Cotton, field, 9 oz.	110.1	15.6	85.8

4.2.4 Radiographs of Contamination

Figure 4.2 is a picture of the distribution of contamination on a pair of AEC coveralls which was worn in the vicinity of the underground shot on the first day following this shot. The film was exposed to the garment for one hour. The activity as measured with the AN/PDR-T-2A with the tube held six inches from the garment was approximately 40 mr/hr over the waist area and approximately 30 mr/hr over the shoulder area. Note: The two white blotches are undeveloped areas on the film.

Figure 4.3 is a picture of the distribution of contamination on a pair of AEC coveralls which was worn in the vicinity of the underground shot on the second day following this shot. The film was exposed to this garment for three hours. The activity as measured with the AN/PDR-T-2A with the tube held six inches from the garment was

[redacted]

PROJECT 6.7

Fig. 4.2 Radiograph of Coveralls Worn in the Underground Shot Area on Underground plus One Day

[redacted]

PROJECT 6.7

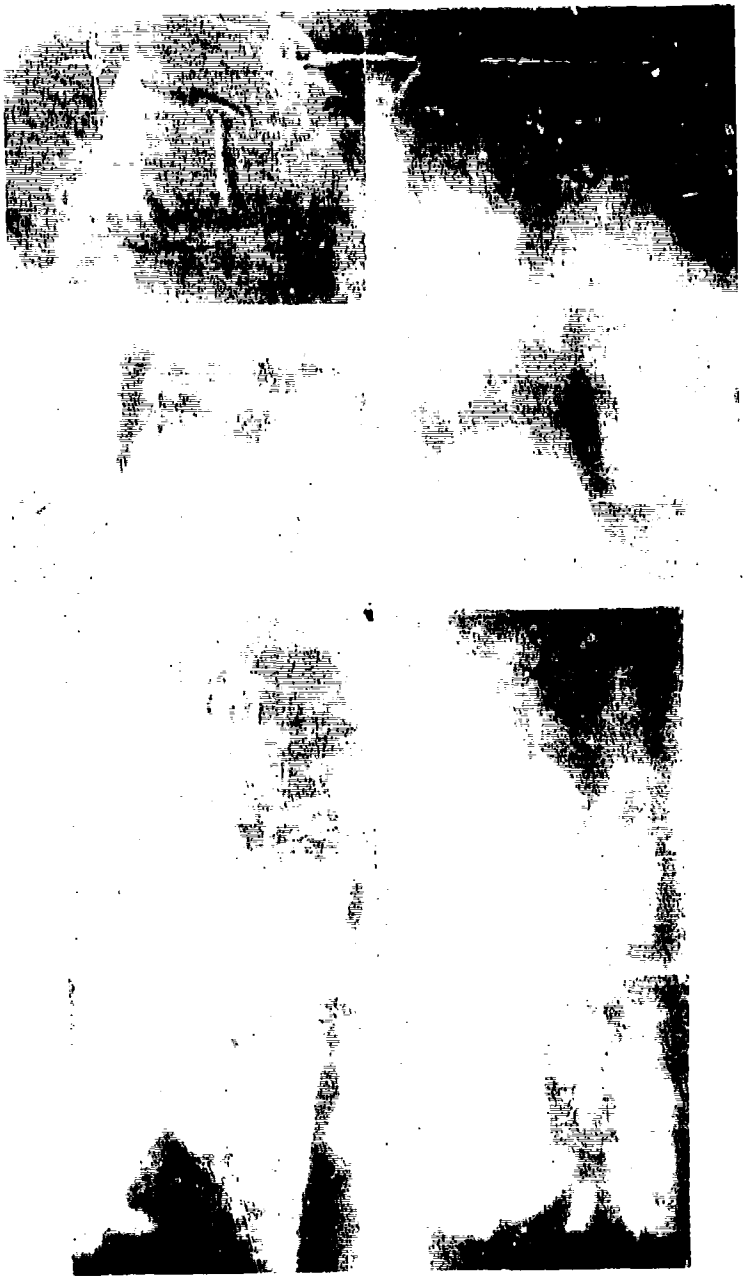


Fig. 4.3 Radiograph of Coveralls Worn in the Underground Shot Area on Underground plus two Days

[redacted]

approximately 30 mr/hr for the left knee area, 20 mr/hr for the right knee area, and 10 mr/hr in the chest and shoulder area. One should keep in mind that the picture is a mirror image of the garment.

Figures 4.4 through 4.7 are the results of exposing film to contaminated fabric swatches. Information included with each figure indicates the type of fabric, washed or unwashed material, the intensity of radiation as measured with the GM tube of the AN/PDR-T-2A held six inches from the material, and the length of time of film exposure.

4.3 DISCUSSION

An examination of the data and observations regarding the susceptibility of various fabrics to contamination and decontamination as well as the dispersion of contamination on the fabrics is presented in this section.

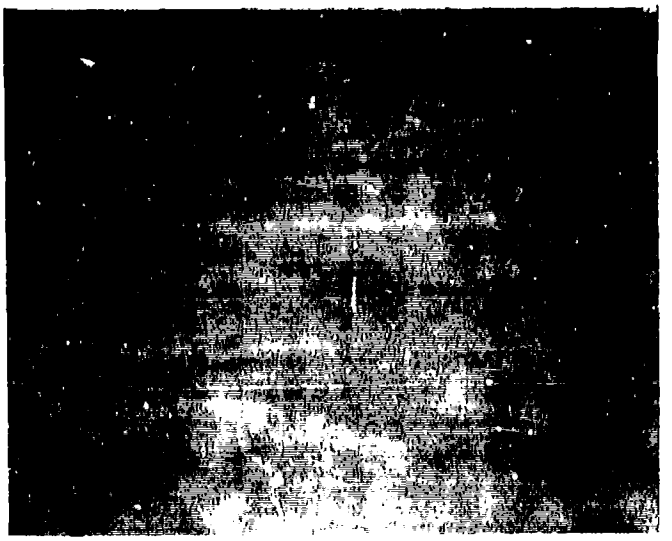
4.3.1 Clothing Contaminated Through Wear in the Shot Area (Surface Shot)

The wearing of clothing in the surface shot area did not produce any amount of contaminated items. This was well demonstrated by Project 6.2 personnel who worked on bulldozers and road graders. Even with the tremendous amount of dust generated, their clothing showed no contamination above background. As a result of this lack of contamination, no attempt was made to evaluate the fabrics put out on this wear phase of the test.

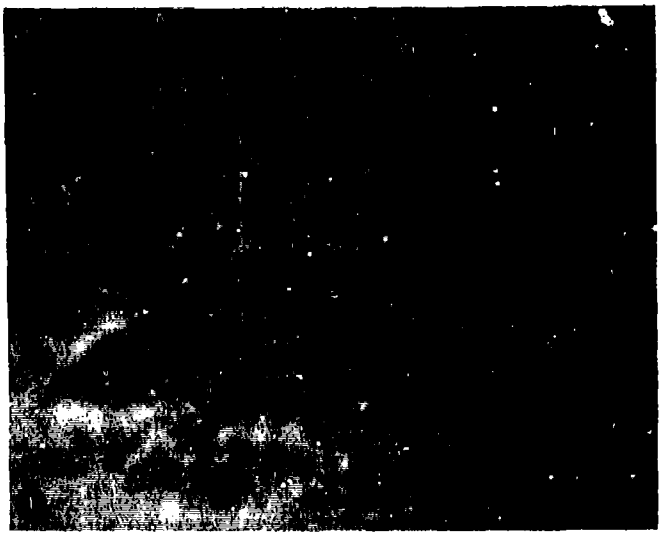
4.3.2 Swatches Contaminated by Controlled Methods (Special Finishes)

The testing of water repellent finishes originated at Operation GREENHOUSE where water repellent field trousers appeared to be more susceptible to contamination and less so to decontamination than other fabric types. On Operation JANGLE the various water repellent finishes, Codes B through G, showed a greater pick-up of contamination than the untreated control, Code A.

Table 4.7 indicates the relative order that the finishes contribute to pick-up of contamination. It is difficult to say definitely that any one finish has greater susceptibility than another, because the method of controlled contamination was a field method and did not permit complete control of all factors. One major factor that could very easily have affected the degree of pick-up of contamination was the humidity which could not be controlled. Also there is no certainty that one pound of finely sifted dirt was enough to saturate the contents of the tumbler,

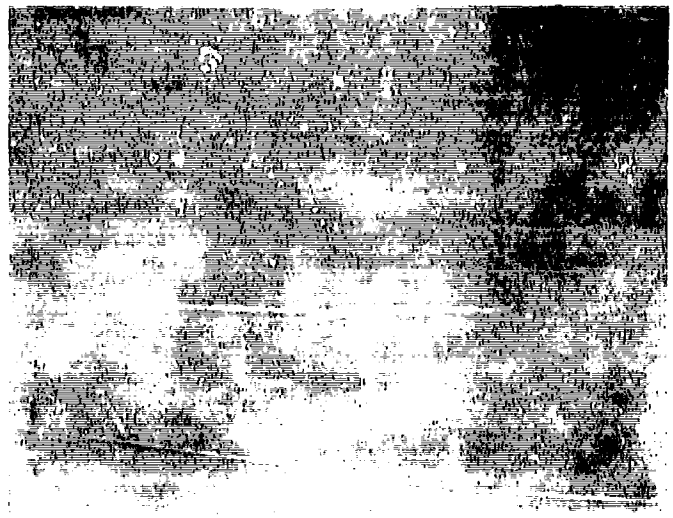


Contaminated Rayon: AN/PDR-T-2A - 6 mr/hr - Exposed 6 hrs.

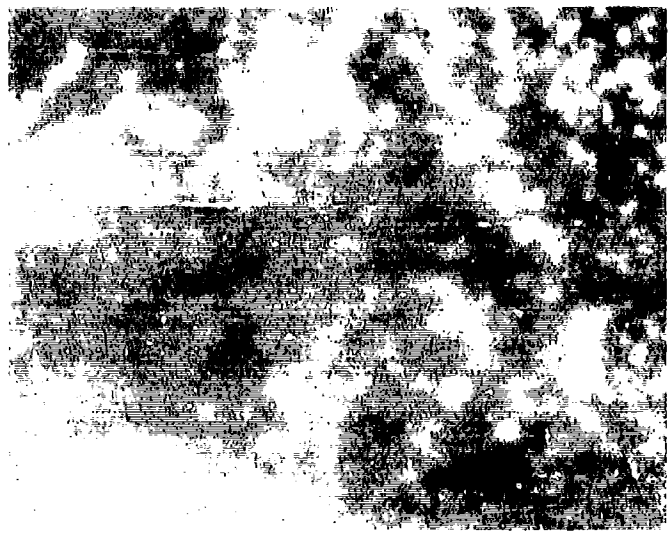


Decontaminated Rayon: AN/PDR-T-2A - 4.5 mr/hr - Exposed 11 hrs.

Fig. 4.4 Radiographs of Rayon Before and After Laundering.

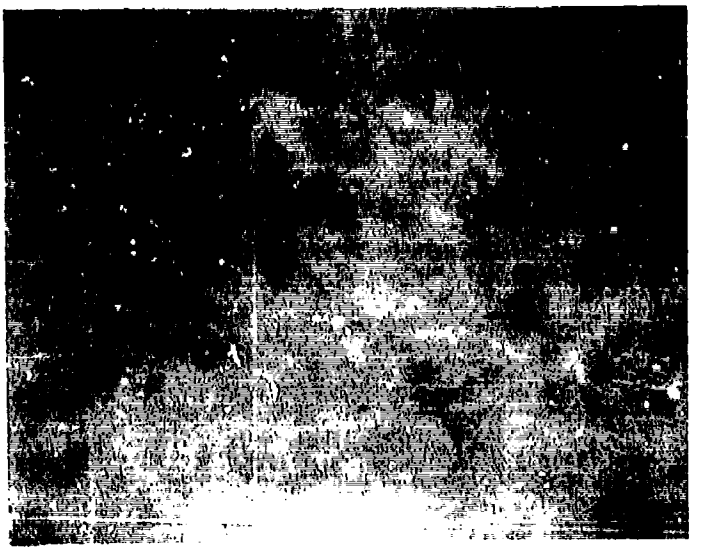


Contaminated Nylon: AN/PDR-T-2A - 6 mr/hr - Exposed 6 hrs.



Decontaminated Nylon: AN/PDR-T-2A - 2.5 mr/hr - Exposed 9 hrs.

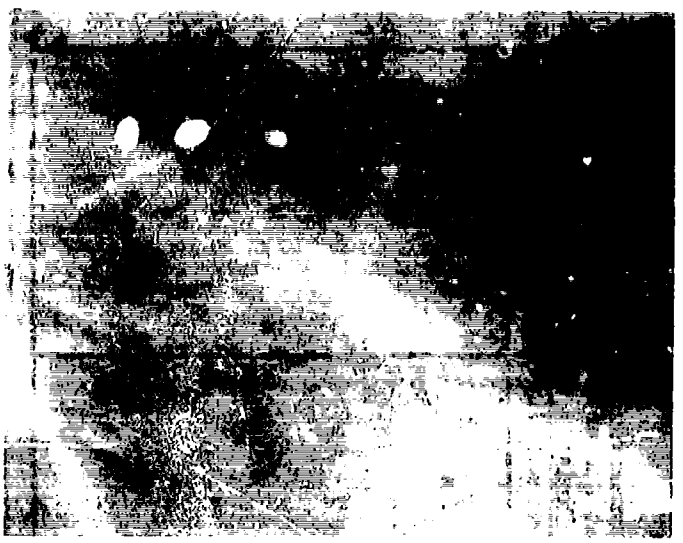
Fig. 4.5 Radiographs of Nylon Before and After Laundering.



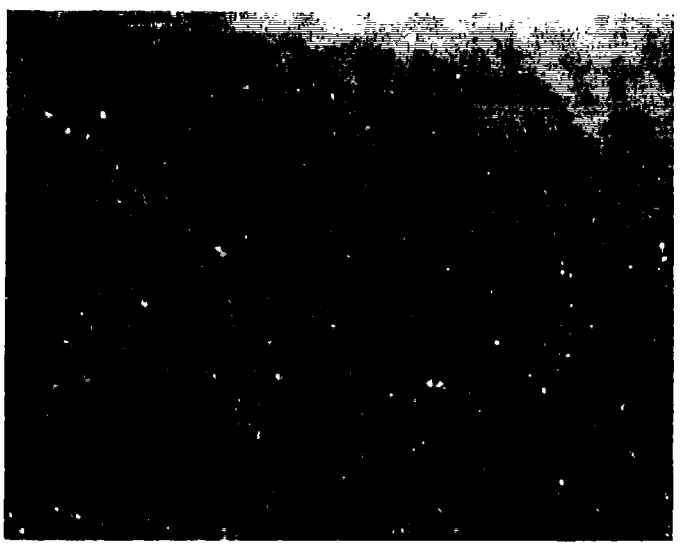
Contaminated Sateen: AN/PDR-T-2A - 12 mr/hr - Exposed 3 hrs.

Decontaminated Sateen: AN/PDR-T-2A - 2 mr/hr - Exposed 12 hrs.

Fig. 4.6 Radiographs of Sateen Before and After Laundering.



Contaminated HBT: AN/PDR-T-2A - 9 mr/hr - Exposed 4 hrs.



Decontaminated HBT: AN/PDR-T-2A - 3.5 mr/hr - Exposed 12 hrs.

Fig. 4.7 Radiographs of HBT Before and After Laundering.

TABLE 4.7

Special Finishes Rated in Order of Desirability

Code	Type	Lowest Numbers Represent Most Desirable Finishes from a Standpoint of:	
		Contaminability	Decontaminability
A	Cloth, cotton, 9 oz., sateen, dyed (untreated) - Control	1	3
B	Cloth, cotton, 9 oz., sateen, dyed (Zelan AP Base)	5	2
C	Cloth, cotton, 9 oz., sateen, dyed (Norane)	7	7
D	Cloth, cotton, 9 oz., sateen, dyed (Aluminum, soap and wax)	3	4
E	Cloth, cotton, 9 oz., sateen, dyed (Permel)	4	1
F	Cloth, cotton, 9 oz., sateen, dyed (Treated with Inorganic Pigments)	6	5
G	Cloth, cotton, 9 oz., sateen, dyed (Treated with Inorganic Pigments, Permel)	2	6

thus limiting the opportunity to determine the amount of contamination that would adhere to each type of fabric. One final point to be considered is the action inside the tumbler during the contamination process. The action of each swatch within the tumbler should have been the same, but there is no way of knowing that with one type of swatch, perhaps, the action was radically different than for the other types. These points make it difficult to say with certainty that any one fabric type or finish is more or less susceptible to contamination than another. However, from the table it appears that, of the special finishes, all of which are more contaminable than the untreated control, Code C is more susceptible to contamination than the other types. It is felt that no other difference can be stated.

Table 4.7 also shows that in two cases, Codes B and E, the finishes decontaminated more than did the control; while in the other cases, a lesser degree of decontamination was performed. However, the difference above or below the control, Code A, is not great enough to warrant particular interest except in the case of Code C. (Table 4.1) Code C, decontaminated 35.2 per cent, and compared to the control and other finishes, appears to be undesirable as a finish for clothing which may be radioactively contaminated. This is further borne out by the fact that Code C also appears to be more readily contaminable than untreated or other finishes.

In comparing the two types of woolen swatches, 18 oz. serge and a 16 oz. felt shirting, the felt, although lighter than the serge, had more nap and consequently picked up slightly more contamination than did the smoother serge. The felt shirting decontaminated slightly more readily than did the serge trousers material which may be attributable to the fact that a felt has already been shrunk a great deal and probably will not shrink much more; especially since the laundering was done at less than 90°F. Since the felt material did not shrink as much as the serge there was not as much chance of its trapping contaminant in the fibers and yarns as the shrinkage took place, therefore permitting a greater degree of decontamination.

The two synthetic fabrics tested were rayon and nylon. The nylon appeared to pick up a bit more contamination than the rayon. However, the nylon decontaminated much more readily than did the rayon (92.5 per cent for nylon and 72.2 per cent for rayon).

Cotton sateen and herringbone twill both picked up very nearly the same amount of contamination. There is no explanation for herringbone twill decontaminating only 66.7 per cent while the sateen decontaminated 83.5 per cent. These fabrics were the same weight, color, and material. The only difference is probably one of those factors that cannot be eliminated in a field test where rigid laboratory controls cannot be applied.

When considering all the swatches together, three factors are apparent. First, in general, the special water repellent finishes show a greater degree of contaminability than the untreated, regardless of fabric type. Second, the woolen fabrics do not pick up any more contamination than cotton, and aside from the nylon, the woolens are as readily decontaminated as other fabrics. Third, the special finish, Code C (Norane), is less readily decontaminated than any of the fabrics tested by a very large margin of difference.

4.3.3 Clothing Contaminated by Controlled Methods (Special Finishes)

The wool felt shirts appeared to pick up more contamination than did the wool serge trousers. However, they both decontaminated the same amount. It appears therefore that there is very little difference between the two wools so far as contaminability and decontaminability are concerned.

The cotton and rayon trousers were very nearly alike in both contaminability and decontaminability, regardless of whether they were new or laundered. The new nylon trousers were more susceptible to contamination than either rayon or cotton; on the other hand, the laundered nylon trousers were much less susceptible to contamination than either rayon or cotton. This difference between new and laundered nylon trousers was further brought out in the decontamination; the new ones decontaminated 93.1 per cent while the laundered decontaminated only 84.4 per cent. It is noted that the three types of fabrics, cotton, rayon, and nylon, regardless of whether new or laundered, showed approximately the same per cent decontamination as the corresponding fabric in swatch form.

The new field trousers showed less susceptibility to contamination than new sateen trousers. However, after both types had been laundered, the field trousers showed slightly greater residual contamination than the sateen trousers, 67.9 per cent decontamination for field against 81.5 per cent for sateen. When both types were laundered three times, the per cent decontamination of sateen trousers rose to 93.5 per cent and field trousers to 85.8 per cent. In neither instance, new nor laundered, do the field trousers appear to be unacceptable compared to sateen on a basis of contaminability and decontaminability. The manufacturer of field trousers may treat the fabric with one of several water repellent finishes, and it is impossible to ascertain in the field which finish is on any one pair of trousers. Therefore, any test of field trousers from general stocks may vary greatly in the results depending upon the number of trousers which have been treated with each of the finishes listed in Table 4.7. In this connection,

since Code C falls considerably below all others insofar as qualities desirable in connection with radioactive contamination are concerned, it is believed that more extensive and specific tests may be in order.

4.3.4 Radiographs of Contamination

Since the study of methods for decontamination of clothing began, there has been the question of the general distribution pattern of contamination one might expect from a garment actually worn in a contaminated area, i.e. is the contamination localized in spots, or is it distributed fairly uniformly over the entire garment? Due to the lack of contaminated garments after the surface shot, no radiographs were made. Following the underground shot it was possible to expose film to two pair of coveralls. The film indicates that there is a certain amount of contamination fairly uniformly spread over the garment, but in addition, one or two careless moves by an individual can result in a concentration of contamination at specific locations.

Figure 4.2 indicates that the wearer of this garment used both of his left pockets. Also, it appears that he may have rubbed against something or carried some contaminated article across the front of his body below the waist.

Figure 4.3 clearly shows that the wearer of this garment used his right breast pocket several times, possibly he carried his notebook or cigarettes there. Also, he apparently was on his knees in the contaminated area.

In both figures, the outline of the masking tape is quite clear at the bottom of each of the coverall legs.

In exposing film to the different types of fabrics that had been contaminated in the tumbling device, it was not intended to prove or disprove any point. The film was available for use with garments contaminated by wearing and it was decided to expose the film to a few of these swatches to see how the contamination appeared. The pictures before and after laundering are not of the same piece of fabric, therefore comparison of change can only be made generally.

In several cases with fabric swatches the exposure appears concentrated at points, whereas the contamination on coveralls appears as shaded. In considering this difference, one must remember that it was possible for the film holder to make closer contact with the fabric swatch than with the pair of coveralls, and it is possible that this difference in distance could very well account for the difference in effects.

[redacted]

CHAPTER 5

EVALUATION OF MONITORING INSTRUMENTS

5.1 OPERATIONAL PROCEDURE

Observations were made by the operating personnel during operation JANGLE to determine the suitability of the various experimental clothing monitoring instruments for field use.

It was desirable to determine whether the scaler readings of the multiple tube instruments increased proportionately as the activity increased. Also, it was desired to know the comparative readings of the various instruments at different levels of activity; especially at the tolerance level.

A piece of cloth, 27 x 45 inches, was contaminated by sprinkling sifted dust uniformly over the swatch and then spraying on plastic adhesive to hold this contaminated dust in place. After each addition of contaminant, readings were taken with the different experimental instruments.

5.2 RESULTS

These results include an evaluation of each instrument and a comparison of the relative readings of each instrument to the Signal Corps Table Top Laundry Monitor in paragraph 5.2.6.

5.2.1 Chemical Corps Clothing Checker (Experimental) (Fig. 2.3)

Readings with this instrument varied considerably due to the criticality of the geometric position of the garment with respect to the tubes. Due to the large number of Geiger-Mueller tubes, i.e. ten tubes, the maximum reliable capacity of the instrument was below the point at which a garment would be classified as contaminated to an unsafe level. There is no satisfactory means of knowing if or when one of the tubes ceases to function properly. Too much time and physical effort is required to raise and lower the lid of the clothing checker.

[redacted]

5.2.2 Modified Chemical Corps Checker (Fig. 2.4)

This instrument gave more consistant readings than did the Chemical Corps Clothing Checker when the same garment was monitored several times. This may be explained by the fact that the tubes were six inches from the garment and were not affected so greatly by the geometric position of the garment with respect to the tubes. By eliminating the top or lid part the problem of raising and lowering it was overcome as well as permitting an increase in the maximum reliable range with respect to the level of contamination. The problem of not knowing when the individual tube had reached the end of its life span was the same as with the Chemical Corps Clothing Checker.

5.2.3 Signal Corps Table Top Laundry Monitor (Fig. 2.5)

After a considerable amount of preliminary checking of several experimental clothing monitors, it was decided to use this instrument for the laundry formula and fabric evaluation phases of the operation. This instrument most nearly filled the requirements for either a research type or a field type instrument. Although there was no way of knowing when a tube ceased functioning, no difficulty was encountered with the tubes during the operation. These halogen type tubes have an unlimited counting life, whereas the other GM tubes are limited to about 10^9 counts.

There were a few specific minor features about this instrument which can be improved from the standpoint of operating efficiency. However, the instrument is satisfactory for use as a research type instrument and can be adapted to serve as a field "screening" instrument.

5.2.4 Signal Corps Scanning Arm Laundry Monitor (Experimental) (Fig. 2.6)

This instrument was probably the most ingenious instrument tested; and, with the exception of a few mechanical difficulties, it functioned quite well and is satisfactory as a research type instrument. However, it was agreed that this instrument was not a practical field device because of the many mechanical parts.

5.2.5 Radiac Meter from Radiac Set AN/PDR 27A and Portable Geiger-Mueller Survey Meter AN/PDR-T-2A

Although these hand survey instruments were not intended for clothing monitoring and are not satisfactory for this purpose, two

such meters were used during the test. Their use was necessary to correlate the tolerance for contaminated clothing; i.e. 2 mr/hr with the 27A or 7 mr/hr with the T-2A, with the readings obtained on the experimental clothing checkers.

5.2.6 Comparison of Relative Readings Between Instruments

By uniformly spreading contaminated dust over a piece of cloth, 27 x 45 inches, it was possible to control the contamination at various levels. Thus, comparative readings of the various instruments was made possible. It was also possible to obtain the approximate instrument readings that a garment would give when the garment was contaminated at the tolerance level. The term tolerance level is used in this manuscript as described in paragraph 3.3.

As the Signal Corps Table Top Laundry Monitor was adopted as the standard instrument for experimental use during this operation, the graphic comparison of the relative instrument readings is made, in each case of this instrument. Comparison of the relative readings of the other instruments was made by using the readings of the Table Top Laundry Monitor as a standard.

A clothing monitoring instrument to be entirely efficient should indicate readings that increase in a direct straight-line ratio with an increase in radioactivity, i.e., if the radioactivity doubles, the instrument reading should double. Loss of efficiency in a multiple tube type instrument may be caused by coincidence loss within the tubes or by several tubes being activated at the same time. A third means of loss of efficiency is within the mechanical functioning of the scaler.

If it may be assumed that the AN/PDR-T-2A and the AN/PDR 27A are fairly reliable within the range indicated in figures 5.1 and 5.2 then it may be seen in these two figures that the Table Top Laundry Monitor is quite efficient. These two figures also clearly indicate that the readings of the T-2A and the 27A are in the ratio of 7 to 2.

The loss of efficiency in counting is plainly evident for the Chemical Corps type instruments in figure 5.3. This condition does not appear as pronounced as it actually is because the loss of counting efficiency within the Table Top Laundry Monitor tends to straighten the curve. Based on the results indicated in figures 5.1 and 5.2, the tolerance for clothing is approximately 200,000 c/m on the table top monitor. In referring to figure 5.3, curve 1, it may be seen that 200,000 c/m on the Table Top Laundry Monitor is comparable to approximately 700,000 c/m on the Chemical Corps Clothing Checker. As the maximum rated capacity of the Berkeley Decimal Scaler, Model 2000, is 600,000

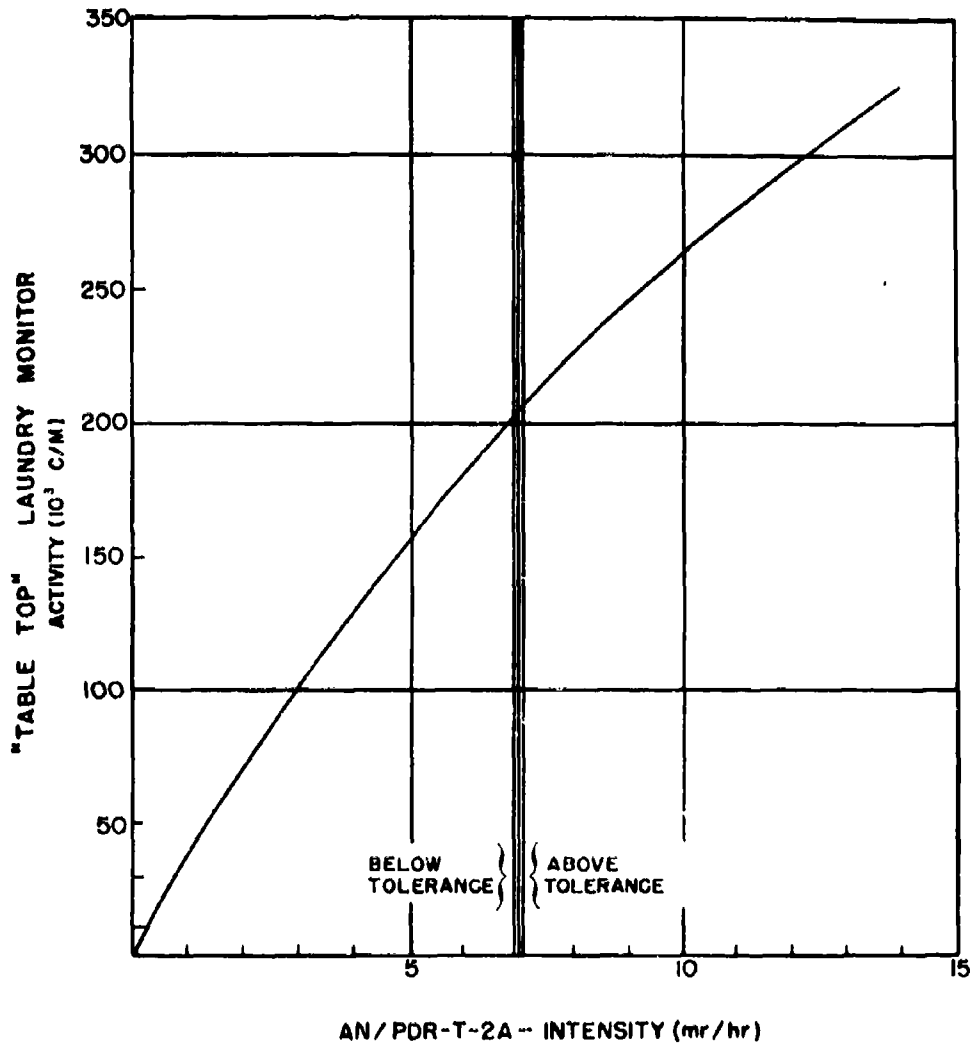


Fig. 5.1 Table Top vs AN/PDR T-2A

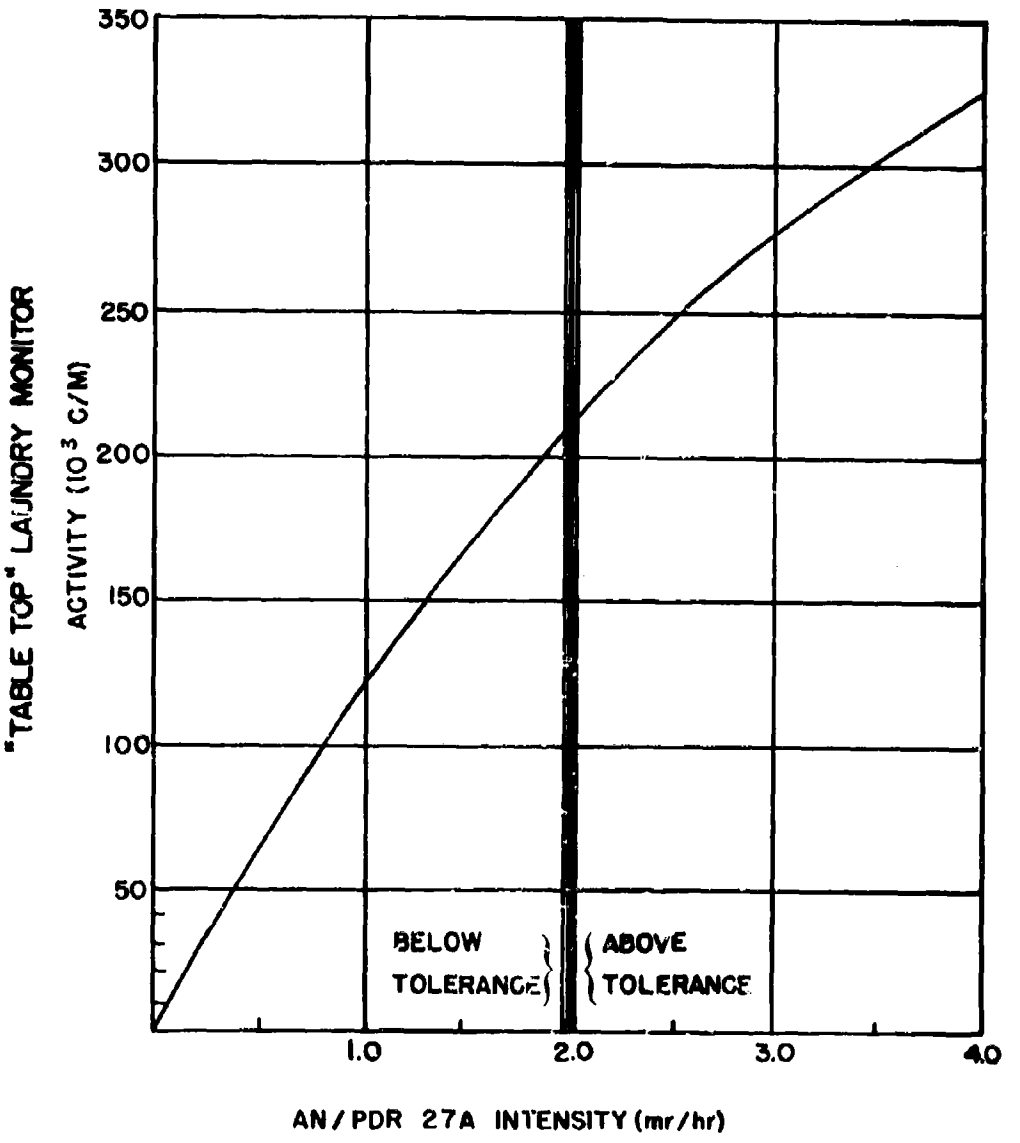


Fig. 5.2 Table Top vs AN/PDR 27A

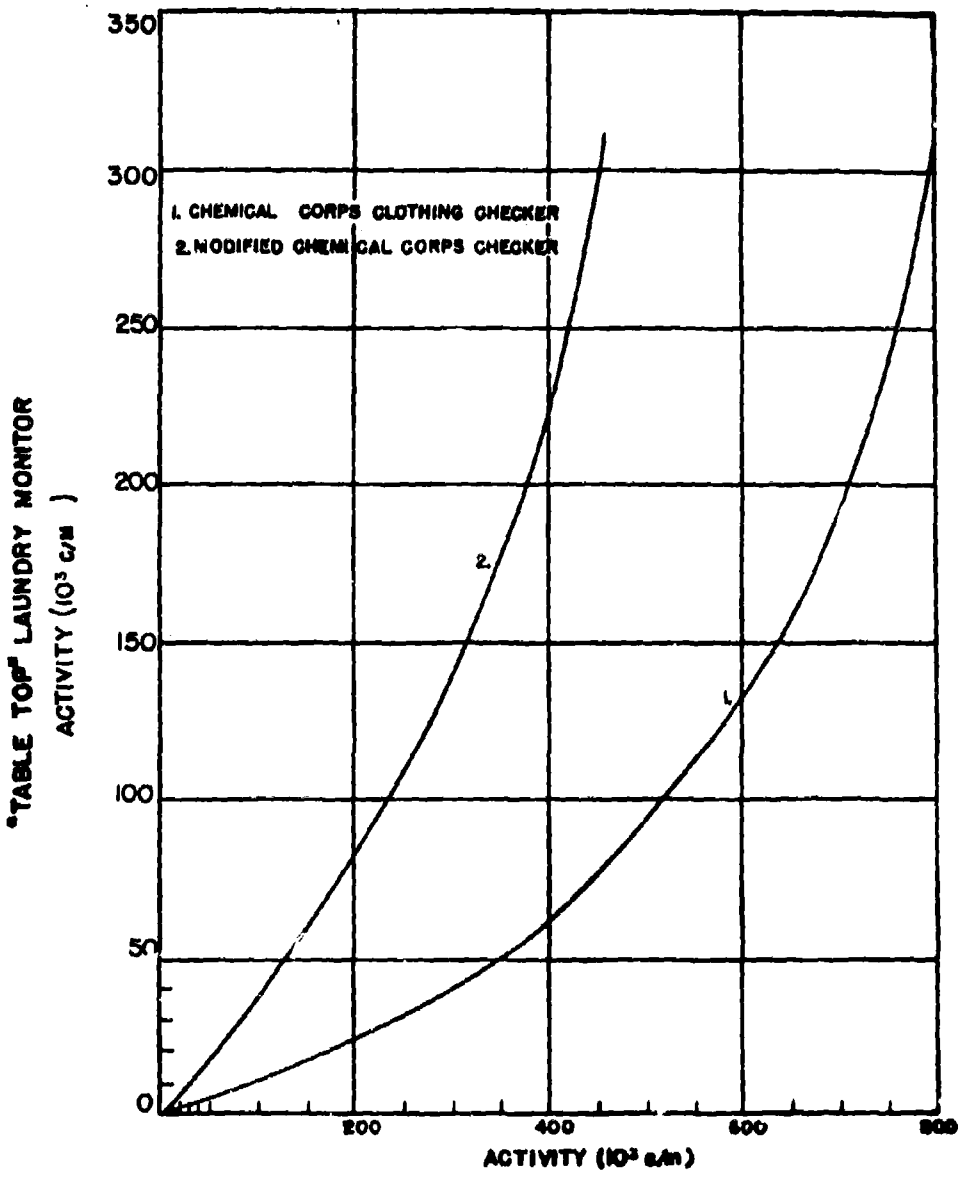


Fig. 5.3 Table Top vs Chemical Corps Types

c/m, it is evident that the maximum capacity of the Chemical Corps Clothing Checker is below the established tolerance for clothing.

As the curve in figure 5.4 is approximately a straight line, the counting efficiency of the Scanning Arm instrument is approximately the same as that of the Table Top instrument.

Measurements were made with the Signal Corps Table Top instrument by taking the scaler readings in counts per minute and dial readings from a count rate meter. Scaler readings were used in the laundry formula and fabric evaluation phases. The count rate meter readings were used in order to evaluate the desirability of using this instrument as a field instrument for screening clothing more rapidily. The count rate meter was equipped with both a high range and a low range scale. It appears, now, that one range scale would be adequate if the center of the range was equivalent to approximately 200,000 counts per minute as measured by the scaler.

During this experiment it was decided to investigate the amount of dosage one's pocket dosimeter would indicate if he had worn a garment which was contaminated at various levels of activity. Two Keleket pocket dosimeters were placed on a contaminated piece of cloth for a period of four hours at each of several levels of contamination. A graph of these dosimeter readings versus the Table Top instrument readings are shown in figure 5.5.

When the Table Top Clothing Monitor registered 200,000 counts per minute (approximately the established clothing tolerance level) the pocket dosimeter was found to discharge at the rate of approximately 16 mr/hr, or approximately 0.4 Roentgen in a 24 hour period. This is not considering the decay factor.

5.3 DISCUSSION

The Signal Corps Table Top Laundry Monitor was equipped with a count rate meter which permitted a more rapid monitoring of garments than could be accomplished by taking a scaler count. This count rate meter could be operated on either high or low range and charts were provided for converting meter readings to the equivalent scaler readings in counts per minute. On the low range the curve through points of equivalent meter and scaler readings was not a straight line, therefore it was necessary to convert all readings to scaler count before subtracting the background. Also, the scaler count gave a more precise count than was possible by reading the count-rate meter since each graduation on the meter dial represented from two to four thousand counts per minute depending upon the degree of activity. Considering these

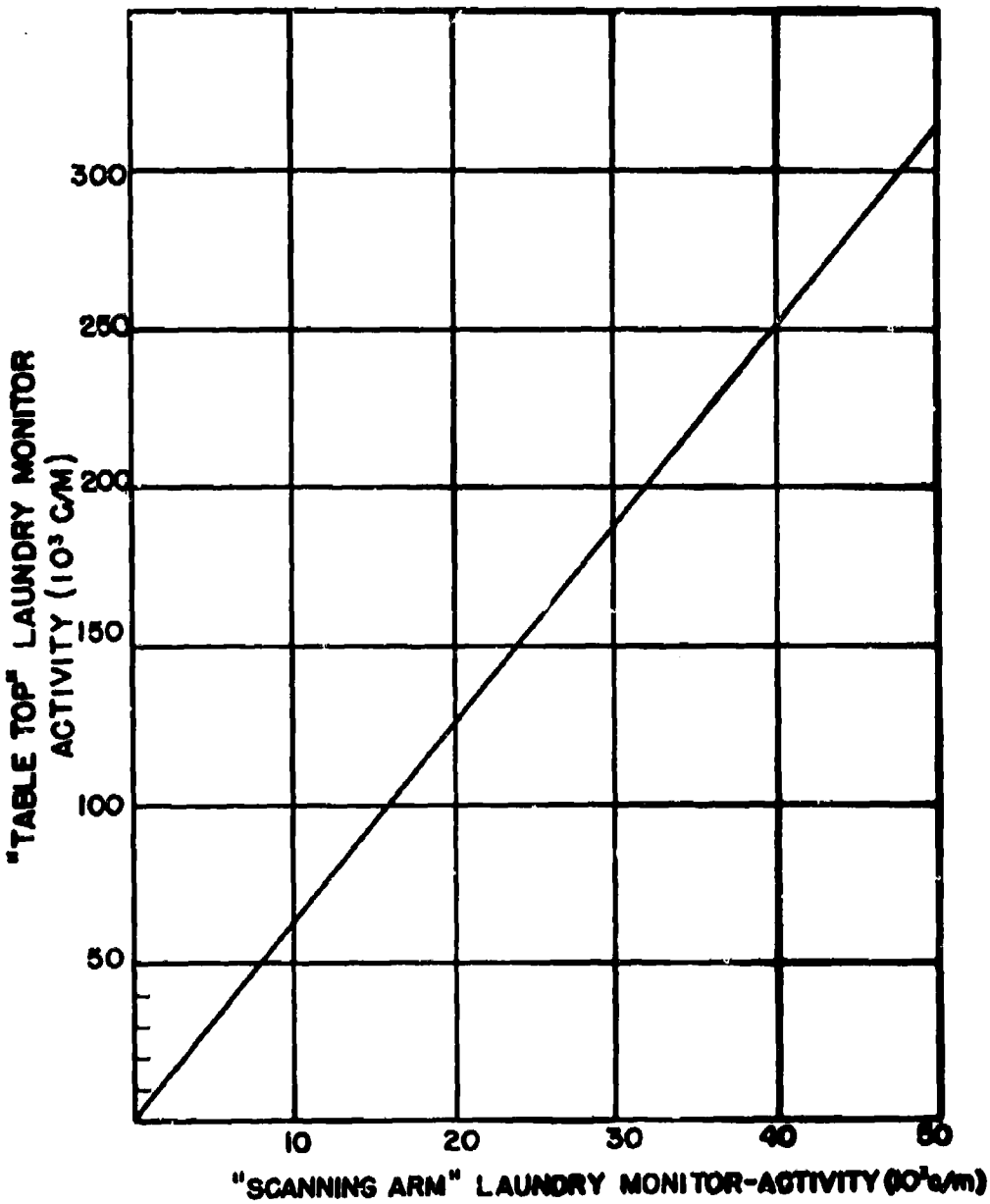


Fig. 5.4 Table Top vs Scanning Arm

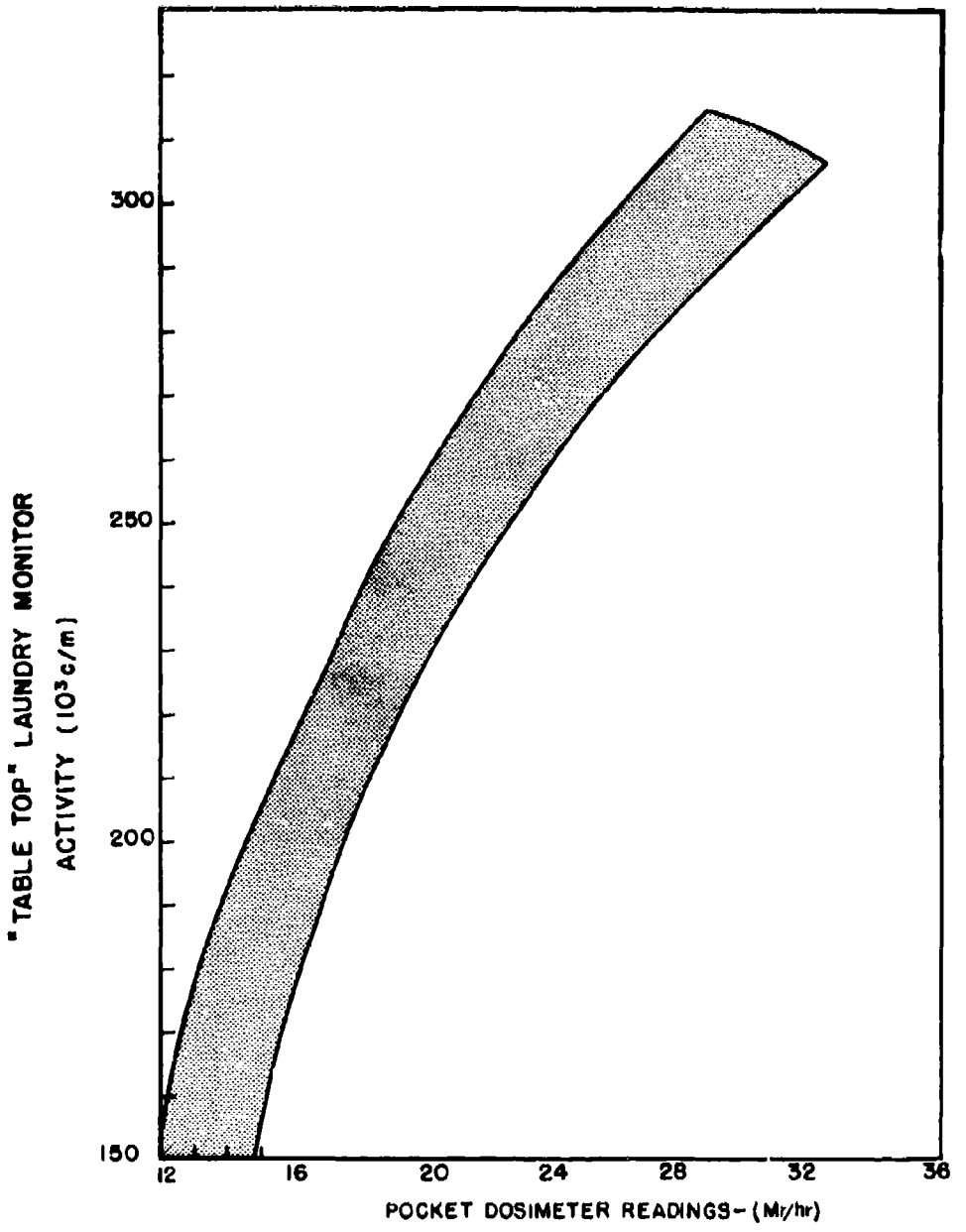


Fig. 5.5 Table Top vs Dosimeter (Converted to mr of Dosage in one Hour)

factors, it was decided to use only the scaler readings for evaluating laundry formulae and fabrics.

A field type clothing monitor should not require the use of a scaler, but should be equipped with a count rate meter or similar device to indicate whether garments are contaminated above or below a given tolerance. It would be desirable to have an adjustable visual signal to indicate when a prescribed tolerance was exceeded.

A problem exists in the monitoring of different size garments. For example, a pair of coveralls might be contaminated below tolerance and a bootee several times tolerance, yet the bootee would indicate a much lower reading on the clothing monitor than would the pair of coveralls, because of the difference in size and consequent total amount of activity. A solution to this problem might be to establish three separate tolerance levels when monitoring with this device, i.e., one level for bootees and gloves, one level for trousers and shirts, and another level for coveralls.

The Signal Corps provided a radioactive plastic sheet which proved quite valuable in evaluating the instruments. The radioactive material was of the strontium 90-yttrium 90 pair which has a 25 year half life and emits beta particles with a maximum energy of 2.3 Mev. This material was sandwiched between two vinylite sheets so that there was no danger of personnel contamination from handling. The activity of this sheet was 7 mr/hr at six inches as measured by a Nuclear Instrument Company Survey Meter, Model 2610-A using a thin-walled beta-gamma Geiger Tube.

This radioactive plastic sheet served as a check on the reproducibility of the instrument readings from time to time and also as a tolerance level calibration for the instrument. In checking the radioactive plastic sheet it did not appear that 7 mr/hr with the side window tube was comparable to 2 mr/hr with the end window tube when read with the AN/PDR-T-2A and AN/PDR 27A. The energies of the beta particles from the plastic sheet were 0.6 and 2.3 Mev, as contrasted with the range of energy levels from fission products encountered following a bomb burst. In attempting to answer this problem it was decided to conduct a subsequent experiment in which radioactivity resulting from a bomb burst was builtup in layers on a cloth swatch. Each time a layer was added, readings were taken on all of the clothing monitoring instruments, including the hand survey meters at a distance of six inches from the contamination, and pocket dosimeters in contact with the swatch. This information showed the relative readings of the instruments as well as the discharge rate of the pocket dosimeter and is an approximation of the dosage that

would be indicated if the dosimeter were worn in a pocket, however, the results obtained from the pocket dosimeter readings are only indicative.

[redacted]

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The results of the test of clothing decontamination procedures and evaluation of laundry methods after a surface and underground atomic bomb explosion lead to the conclusions that:

6.1.1 Evaluation of Laundry Equipment and Methods

The hazard of clothing contamination following an underground explosion is greater than that following either a surface or an air burst.

The Quartermaster Corps mobile field laundry formula (3 suds) resulted in satisfactory decontamination of clothing contaminated with the type of soil and activity present during the operation.

A more specific decontaminating laundry formula employing citric or tartaric acid followed by either an organic or inorganic chelating agent resulted in a higher degree of decontamination than other formulae tested.

The wooden laundry washer was found suitable for performing clothing decontamination and did not itself become excessively contaminated.

Highly contaminated garments should be separated from those having little or no radioactivity prior to laundering.

The handling of contaminated garments and cloth swatches presented no health hazard due to inhalation of contamination, which may be shaken from articles before they are washed.

6.1.2 Evaluation of Fabrics

The water repellent finishes tested caused fabric to pick up more contamination than had it not been so treated. Further, this test indicates that, Special Finish, Code C, is the least desirable water repellent for clothing which may become radioactively contaminated.

[redacted]

The two woolen fabrics tested, 18 oz. serge and 16 oz. felt shirting, are as acceptable, from the standpoint of contaminability and decontaminability, as cotton or synthetic fabrics.

Pockets of garments worn in contaminated areas are highly vulnerable to becoming contaminated.

6.1.3 Evaluation of Monitoring Instruments

Aside from a few minor features, the Signal Corps Table Top Laundry Monitor is satisfactory for use as a research type instrument and also appears to be adaptable for use as a field screening instrument.

6.2 RECOMMENDATIONS

Based on the results of the test program and the problems encountered during the test, it is recommended that the Quartermaster Corps, U. S. Army, be represented in future atomic and radiological warfare tests, and maintain close liaison with the Radiological Safety operation to the extent of observing the efficiency of clothing decontamination procedures and field testing of clothing monitoring equipment.

The Quartermaster Corps mobile field laundry formula with three suds steps be adopted for use in decontamination of clothing until it has been shown that a greater problem of clothing decontamination exists than appears at present.

The Quartermaster Corps radiological laboratory program includes the testing of fabrics coated with water repellent finishes and their effect on the contaminability and decontaminability of fabrics.

The development of a field type clothing monitoring instrument for use of mobile field laundries be continued.

[redacted]

APPENDIX

ROSTER OF PROJECT 6.7 PERSONNEL

Maj. Alfred H. Parthum, Jr.: Project Officer, AEC&R Liaison Officer, Research and Development Division, Office of The Quartermaster General. Major Parthum initiated the project proposal; supervised the over-all organization and planning of the project; received and edited the test plan and final report; assisted in the conduct of the test.

Lt. Col. Donald C. Hughes: Assistant Project Officer. Colonel Hughes was responsible for the direct supervision of decontamination operations and radiological monitoring of test clothing and fabrics to include preparation of reports. He also formulated basic plans for the project. He was the commanding officer of Detachment 7, 9135 TSU, Fort Lee, Virginia, the unit to which the Quartermaster officers and enlisted personnel were assigned for control and operational purposes.

Maj. Howard James: Assistant Project Officer. Major James was responsible for the immediate supervision of the chemical and radiological analysis of the laundry solutions during the decontamination process. He supervised the monitoring operation, recording of data, and computation of results. Following the work at the site, Major James directed the analysis of data and the preparation of the report.

Maj. Robert B. Bennett: Administrative and Supply Officer. Major Bennett supervised the administrative organization, maintenance of records and operating procedures pertaining to fiscal, supply, and management functions; initiated purchase requests for special equipment; maintained project records; assisted project officers in laundry operation and monitor instrumentation.

Capt. Joseph F. Nahan: Memorial Division, Office of The Quartermaster General. Captain Nahan worked closely with the Rad-Safe change house in the study of personnel and clothing contamination problems. This study provided information relative to the contamination hazard resulting from wearing garments in a contaminated area. Capt. Nahan also assisted in the clothing monitoring operations.

Capt. John C. McWhorter, Jr.: Assistant Project Officer. Captain McWhorter supervised the controlled contamination of the test material. He assisted in supervising the monitoring operation, recording of data, and computation of results. Following the work at the site, Captain McWhorter assisted in the analysis of the data and the preparation of the report.

[redacted]

Second Lt. William W. Goozee: Assistant Supply Officer. Lieutenant Goozee supervised the receipt, storage, maintenance, inventory, and issue of all supplies and equipment; supervised the packing, crating, and marking of supplies; arranged with the various transportation sections for shipments, and assisted in laundry and monitoring operations.

M/Sgt. Glenn E. Michael: Laundry Supervisor. Sergeant Michael operated as the unit First Sergeant. He assisted in supervising and operating the laundry decontamination operation. He also assisted in the clothing monitoring operation.

M/Sgt. Cecil McCaulley: Utilities Foreman. Sergeant McCaulley supervised and assisted in the installation and repair of plumbing apparatus, electrical circuits and outlets. He assisted project officers in the installation and operation of monitoring devices and other necessary utilities. He also assisted in the clothing monitoring operation.

SFC Donald C. Allgeier, Sr.: General Equipment Repairman. Sergeant Allgeier installed, adjusted, and maintained the unit machinery and vehicles. He converted a laundry tumbler into the valuable controlled contaminating device used during the operation and was responsible for the contaminating of test clothing during the test. He also assisted in the installation of monitoring and laundry equipment.

SFC William H. McConnell: Laundry Supervisor. Sergeant McConnell was directly responsible for the laundry operation and equipment. His duties required that the laundry formulae being tested were controlled precisely throughout the operation. He was also responsible for the preparation of the equipment for movement, preparation of the schedule of laundry trailer operations, and maintenance of the laundry equipment and power unit.

SFC Donald J. Petri: Laundry and Bath Supervisor and Instructor. Sergeant Petri was temporarily assigned to Detachment 7, 9135 TSU for duty during JANGLE Operation. His primary duty is an instructor in the Quartermaster Demonstration Unit. This operation permitted him to become familiar with the Quartermaster decontamination of personnel and clothing. Sergeant Petri assisted in the clothing monitoring operations.

Sgt. David M. Arnold: Administrative Non-commissioned officer. Sergeant Arnold prepared and typed unit and project correspondence and reports; posted and filed regulations, correspondence, project reports and all similar material. He also coded material by subject matter and maintained unit administrative records such as morning report, duty roster, sick book, etc. and assisted in the insallation and operation of monitoring devices and decontamination equipment.

[redacted]

PROJECT 6.7

PFC Bert S. Gorton: Chemical Staff Specialist. Private Gorton was temporarily assigned to Detachment 7, 9135 TSU for duty during JANGLE Operation. He is a graduate chemist and, during this operation, he performed the chemical and radioactivity measurements on the laundry waste water and solution samples. He also assisted in making the computations and plotting decay curves.

[redacted]

[redacted]

PROJECT 6.7

BIBLIOGRAPHY

Decontamination

Carlson, A. B. and William F. Neuman, The Removal of Uranium Compounds from Cloth, UR-108, University of Rochester, Technical Information Division, ORE, Oak Ridge, Tennessee.

Laundry Decontamination Test Conducted at Oak Ridge National Laboratory, Research and Development Division, Office of The Quartermaster General, Washington 25, D. C., 1951.

Protective Clothing and Clothing and Personnel Decontamination, Project 6.9, Operation GREENHOUSE.

Radiological Clothing Monitor, TCIR-606, Technical Command, Army Chemical Center, Maryland, 27 November 1951.

Laundry Operation

Operating Instruction and Parts List for Mobile Laundry Units, Department of the Army Technical Manual 10-351, Sept. 1942.

Quartermaster Fixed Laundry Organizations, Operation and Equipment, War Department Technical Manual 10-354, Sept. 1947.

Quartermaster Laundry (Semimobile) Laundering Process, War Department Technical Bulletin 10-352-2, 26 Feb. 1946.

Statistics

Croxton, Frederick E. and Cowden, Dudley J., Applied General Statistics, Prentice Hall, N. Y. 1942.

[redacted]

[redacted]

OPERATION JANGLE

PROJECT 6.8

EVALUATION OF U. S. ARMY FIELD WATER SUPPLY EQUIPMENT AND OPERATIONS

By

D. C. LINDSTEN
H. M. LOWE, JR.

15 MAY 1952

SANITARY ENGINEERING BRANCH
ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES
U. S. ARMY
FORT BELVOIR, VIRGINIA

[redacted]

[redacted]

[redacted]

PROJECT 6.8

PREFACE

This investigation was conducted to determine the resistance of GRS coated nylon fabric 3000 gallon water tanks to the blast and thermal effects of an atomic burst on the surface of the ground, and to evaluate U. S. Army Water Purification Equipment, Diatomite, Pack (Man), 15 GPM, Set No. 2, for removing radioactive contamination from water.

In addition, the potential problem of radioactive contamination of field water supplies following a highly contaminating atomic burst on the surface or under the ground was investigated and is reported on herein.

Test installations and operations were accomplished with the able assistance of M/Sgt R. H. Dean, Sgt F. L. Cobler, Cpl C. E. Graham, and Cpl H. M. Griffin. Active cooperation and help in accomplishing this investigation were given by the Special Projects Branch of the Engineer Research and Development Laboratories, the Weapons Effects Division of the Armed Forces Special Weapons Project and the Signal Corps Engineering Laboratory. Radioactivity counts were made by C. L. Blair, E. E. Anderson, PFC J. R. Coleman, and PFC J. J. Drexler of the Signal Corps.

[redacted]

[redacted]

PROJECT 6.8

CONTENTS

PRECEDING PAGE BLANK - NOT FILMED

[redacted]

[redacted]

PROJECT 6.8

ILLUSTRATIONS

TABLES

[redacted] [redacted]

[redacted]

PROJECT 6.8

ABSTRACT

An investigation was conducted under Project 6.8, Operation JANGLE to determine the resistance of coated fabric water tanks to the blast and thermal effect of an atomic burst on the surface of the ground, to evaluate a standard U. S. Army water purification unit for removing radioactive contamination from water and to determine if field water supplies may become contaminated following a surface or underground burst.

U. S. Army 3000 gallon GRS coated nylon fabric water tanks filled with water were undamaged at a distance of 500 yards from ground zero for a 1.2 KT atomic ground surface burst. Thus these tanks withstood overpressure as high as 5 psi and thermal flux of 20 cal/cm^2.

U. S. Army Water Purification Equipment, Diatomite Pack (Man), 15 GPM, Set No. 2, was found capable of removing 84.5 per cent of the activity of a field water supply deliberately contaminated to greater than seven times the safe drinking tolerance.

A field water supply may become contaminated to a significant degree as a result of fall-out of radioactive material following a surface or underground atomic burst if in a down-wind position from the burst.

[redacted]

[redacted]

CHAPTER 1

FIELD WATER STORAGE TANKS

1.1 OPERATIONS

Four standard U. S. Army GRS coated nylon fabric, 3000 gallon water tanks were placed on a line 50° East of North from ground zero at distances of 500, 925, 1500, and 2030 yards (see Figure 1.1). The tanks were filled with local drinking water (from 500 foot wells at Frenchman Flat) and left uncovered. In addition, one covered 3000 gallon tank was installed at the 500 yard site. All tanks were placed on ground level and were not fortified or "dug in".

1.2 RESULTS

The tanks were essentially undamaged following the 1.2 KT atomic burst on the surface of the ground. This detonation produced an overpressure of 5 psi and thermal flux of 20 cal/cm^2 at a distance of 500 yards from ground zero. The top cover sheet of the covered tank at 500 yards from ground zero was partially torn from the ring loops and had dropped into the tank. The wood staves facing ground zero were slighly charred. Figure 1.2 and Figure 1.3 show the undamaged condition of the tanks located 500 yards from ground zero.

1.3 CONCLUSION

Standard U. S. Army 3000 gallon GRS coated nylon fabric water tanks filled with water can withstand a 1.2 KT atomic surface burst at distances of 500 yards or more from ground zero without damage (overpressure 5 psi, thermal flux 20 cal/cm^2).

[redacted]

[redacted]

PROJECT 6.8

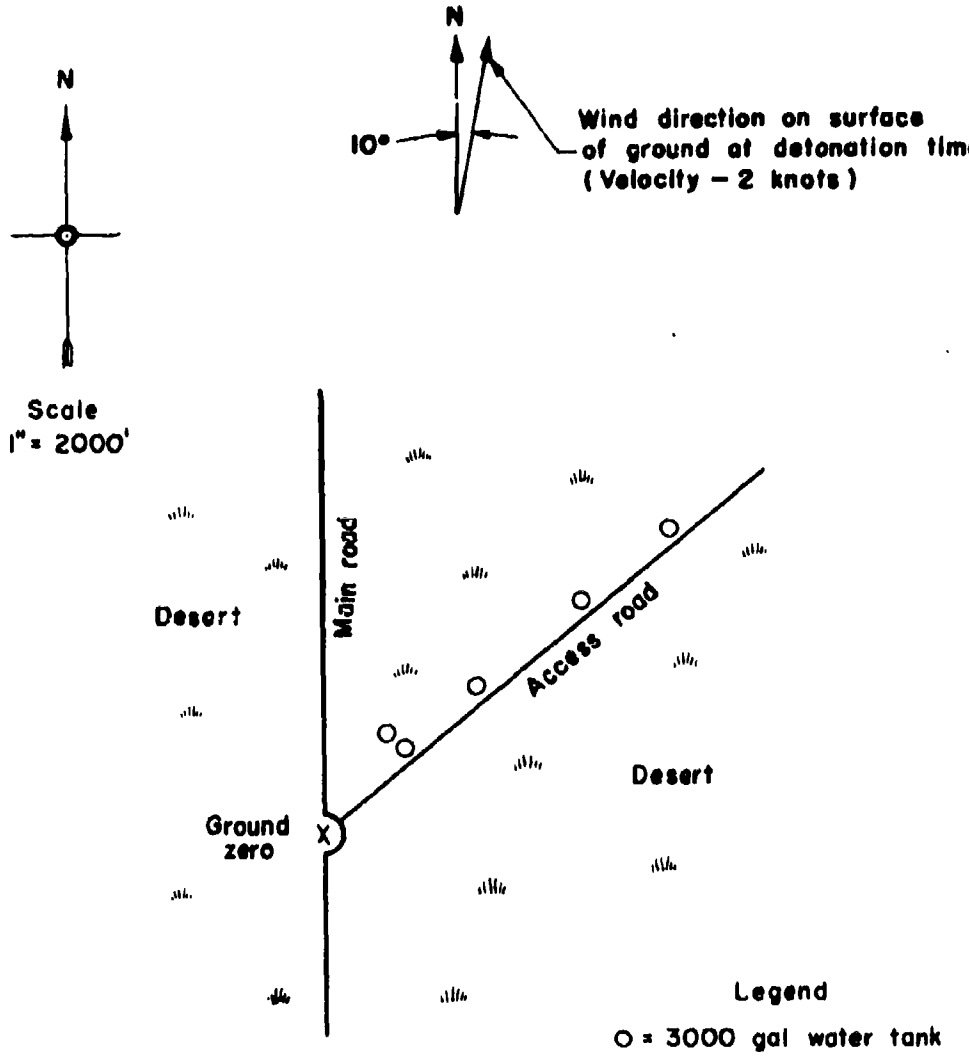


Fig. 1.1 Map-layout of Water Tanks for Jangle 6.8 (Nevada Test Site)

[redacted]

Fig. 1.2 Post Shot Photograph of Tanks at 500 Yards From Ground Zero. (Cover Sheet on Tank on the Right Partially Torn From Ring Loops.)

Fig. 1.3 Post Shot Photograph of Side of Tank Facing Zero at 500 Yards. (Note Sagebrush Blown Behind Stave While Tank was Distorted During Peak Overpressure Period)

[redacted]

CHAPTER 2

FIELD WATER PURIFICATION EQUIPMENT

2.1 OPERATIONS

In order to evaluate the Water Purification Equipment, Diatomite Pack (Man), 15 GPM, Set No. 2, it was necessary to deliberately contaminate a supply of water. This contaminated water supply was purified by a procedure consisting of slurrying with powdered iron, coagulating with ferric chloride and limestone, and filtering with diatomite. In addition, data on the decay of the radioactivity of the contaminated water was secured for comparison purposes.

2.1.1 Deliberate Contamination

Approximately 70 pounds of lip material taken from near ground zero 26 hours after the atomic surface burst was added to 3000 gallons of water in the test tank at 925 yards from ground zero, agitated, and settled. A radiac survey instrument read 20 r/hr directly above the 70 pounds of lip material. After deliberate contamination of the water, a radiac survey instrument read 100 mr/hr directly above the tank.

2.1.2 Slurrying With Powdered Iron

Ten pounds of powdered iron was placed in the bottom of a 500 gallon canvas tank, and the tank filled with contaminated water from the 3000 gallon tank. After filling, which was accomplished in twelve minutes, the 500 gallons of water was vigorously agitated for 18 minutes by recirculating the water with the same pump used for filling. The water was then allowed to settle for twenty minutes.

2.1.3 Coagulation

Approximately 450 gallons of the supernatant from the 500 gallon canvas tank was pumped into another 500 gallon tank and treated with one pound five ounces of pulverized limestone and ferric chloride ($FeCl_3 \cdot 6\ H_2O$) in the estimated amount of two pounds. This high dosage of chemicals is considered to be practical for decontaminating purposes. The floc formed was of excellent quantity and quality and settled well during the twenty minute settling period allowed. The chemicals used are not standard with the Water Purification Equipment, Diatomite, Pack

[redacted]

(Man), 15 GPM, Set No. 2 but are expected to become standard with new water purification equipment now being developed by the Corps of Engineers. The conditions of this test did not permit the use of the standard coagulants, ammonium alum and soda ash which would be expected to produce similar results but require more trials for optimum results.

2.1.4 Filtration

After settling, the supernatant was filtered through the diatomite filter in accordance with standard practice. The elements were precoated with six ounces of standard diatomite and a body feed dosage of four ounces was employed.

2.1.5 pH and Alkalinity

The pH and alkalinity of the water at various stages in the purification process is shown in Table 2.1.

TABLE 2.1

The pH and Alkalinity of Water Used in Evaluation of Water Purification Process

Sample	pH	Alkalinity (total)
Contaminated Water	8.5	216
After Slurrying with Powdered Iron	8.3	218
After Coagulation	6.5	112
After Diatomite Filtration	6.5	110

2.2 RESULTS

The radioactivity count of the water originally contaminated to 2.59×10^{-2} microcuries per ml by addition of lip material from the atomic surface burst was reduced by 84.5 per cent to 4.00×10^{-3} microcuries per ml in the purified water. Complete data on radioactivity measured at various stages in the purification process is shown in Table 2.2. Decay of samples from the water purification process is shown in Table 2.3.

[redacted]

PROJECT 6.8

TABLE 2.2

Radioactivity Count in Water Samples from Water Purification Process

Sample	Gross Beta-Gamma Activity	
	Microcuries per ml	D/M/Ml
Contaminated Water:		
Suspended Turbidity	1.74×10^{-2}	38500
Dissolved	0.85×10^{-2}	18820
Total	2.59×10^{-2}	57320
After Slurrying with Powdered Iron (Filtrate from laboratory filtration)	0.86×10^{-2}	19100
After Coagulation (Filtrate from laboratory filtration)	3.81×10^{-3}	8450
Purified Water after Diatomite Filtration	4.00×10^{-3}	8880

Note: Count corrected for background, coincidence, standard factor, and to 100% geometry.

[redacted]

[redacted]

PROJECT 6.8

TABLE 2.3

Decay of Samples from Water Purification Process

Hours after Contamination of Water in Tank	Sample	Gross Beta-Gamma Activity D/M/ml
5.92	Contaminated water (suspended turbidity from laboratory filtration)	38500
30.75	" "	32870
45.20	" "	27036
69.75	" "	19630
6.62	Contaminated water (filtrate from laboratory filtration)	18820
30.92	" "	9327
45.15	" "	7589
69.87	" "	5613
7.0	Purified Water	8880
30.87	" "	4472
45.20	" "	3315
69.76	" "	2204

Notes: 1. Reservoir tank contaminated 26 hours after detonation.
2. Count corrected for background, coincidence, standard factor and to 100% geometry.
3. No alpha count in any of the samples.

[redacted]

A measure of the efficiency in terms of time for this means of decontamination of water supplies as compared to gross decay is shown graphically in Figure 2.1. By processing with Water Purification Equipment Diatomite, Pack (Man), 15 GPM, Set No. 2, decontamination of water was accomplished in less than two hours, whereas natural decay of radioactivity of the contaminated water to the same level would have taken considerably in excess of three days.

2.3 CONCLUSIONS

Although it was not the purpose of this evaluation to determine whether or not this equipment eliminates all physiological hazard from radioactively contaminated drinking water, it has been shown that the equipment is entirely adequate for military field use when used by competent and trained personnel.

It is recommended that care be taken in operating purification equipment in the field to prevent recontamination of the final purified water. The purified water tank should be kept covered at all times, and water from the filter should be run to waste for a few minutes when first starting operations.

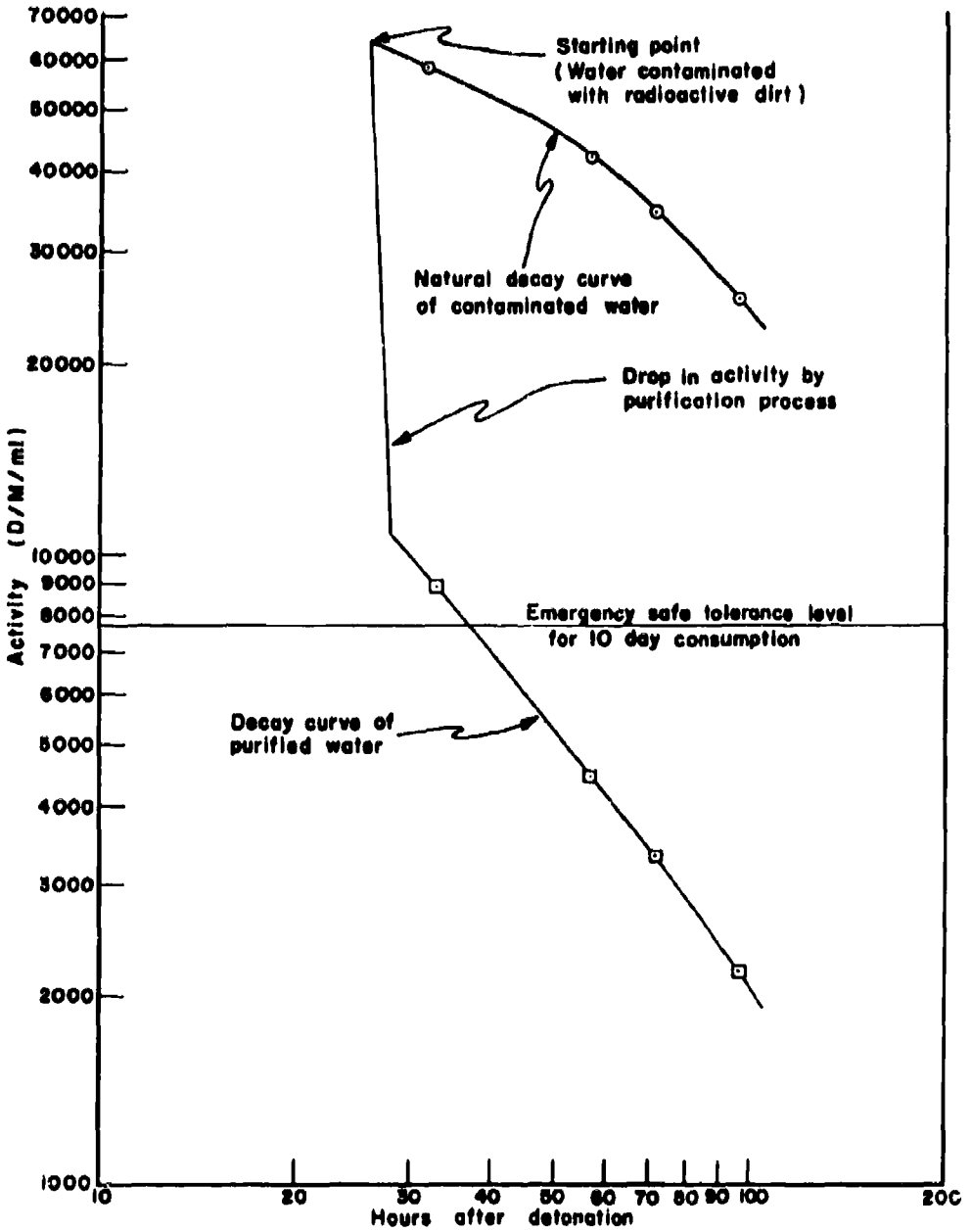


Fig. 2.1 Natural Decay of Contaminated Water vs Purification Process

[redacted]

CHAPTER 3

RADIOLOGICAL CONTAMINATION OF FIELD WATER SUPPLY

3.1 RADIOACTIVITY TOLERANCES

The conclusions of a careful study of the levels of radioactivity permissable in drinking water made by Mr. W. F. Bale, Division of Biology and Medicine, Atomic Energy Commission, are summarized in Table 3.1. These tolerances are considered to be very conservative and contain a substantial factor of safety. They are based on the ingestion of radioactive strontium isotopes which are among the most physiologically damaging of all the radio isotopes.

TABLE 3.1

Proposed Emergency Levels for Beta-Gamma Activity in Drinking Water In Period Immediately Following Bomb Blast (After Bale)

Time Water is to be consumed	Safe		Low Acceptable Risk	
	Microcuries/ml	D/M/ml	Microcuries/ml	D/M/ml
10 Days	3.5×10^{-3}	7.7×10^{3}	$9. \times 10^{-2}$	$2.\times 10^{5}$
One Month	1.1×10^{-3}	2.6×10^{3}	$3. \times 10^{-2}$	$7.\times 10^{4}$

Note: D/M/ml is disintegrations per minute per milliliter.

3.2 CONTAMINATION

No activity was found in the water contained in the five tanks exposed to the 1.2 KT surface burst. This was due to the fact that the tanks were not in the direct path of the fall-out of radioactive material. Contamination would undoubtedly have occurred had the tanks been placed downwind from ground zero.

No water tanks were set out for the underground burst. However, certain ground contamination data were collected by Project 2.8, Operation JANGLE, "Analysis of Test Site and Fall Out Material". These data indicated that the heaviest contamination took place 1/2 mile downwind from ground zero where the fall-out was 37.50 grams per square foot with a specific activity of 4.23×10^{5} disintegrations per second per gram at

[redacted]

[redacted] Security Information

detonation time plus 28 days. Extrapolation by means of the mixed fission product decay law ($A = A_1 t^{-1.2}$) places this specific activity at 1.05×10^9 disintegrations per second per gram at detonation time plus one hour. Sieve size data of the material indicated that 8 per cent consisted of silt or clay particles less than 0.05 mm in diameter.

From these data a calculation of the degree of contamination in a field water supply located one half mile downwind from ground zero would show 1.67×10^6 D/M/ml at detonation time plus one hour. This calculation is based on the assumption that 8 per cent of the fall out material would dissolve or become suspended in the water. It is also assumed that the water supply is 4 feet deep (the depth of water in a 3000 gallon tank). The figure 1.67×10^6 D/M/ml is above emergency tolerance figures. Using the standard decay law for mixed fission products it is calculated that the activity would decrease to the 10 day "acceptable risk" emergency tolerance of $2. \times 10^5$ D/M/ml in 5.9 hours. It would require 88.0 hours to decrease to the 10 day "safe" emergency tolerance of 7.7×10^3 D/M/ml. These data are summarized in Table 3.2 which also contains external dosage data obtained from the preliminary Jangle report.

TABLE 3.2

Summary of Computed Data-Contamination of Water by 1.2 KT Underground Burst

Hours after Detonation	Contamination of Water D/M/ml	r/hr (Due to Ground Contamination)
1.0	1.67×10^6	700
5.9	$2. \times 10^5$ (acceptable risk)	83
88.0	7.7×10^3 (safe)	32

Note: Above data for 1/2 mile downwind from ground zero.

3.3 CONCLUSIONS

Army field water supplies in GRS coated nylon fabric 3000 gallon water tanks may be contaminated to a significant level following a surface or underground atomic burst at distances at which the tanks are undamaged. Contamination will occur as a result of fall-out of radioactive material into tanks located in a downwind direction from ground zero.

Such a water supply located in an area contaminated to a level of 83 r/hr or greater following an atomic burst would be unsafe for drinking purposes until analysis for radioactivity proved otherwise.

3.4 RECOMMENDATIONS

A suitable instrument for field use for measuring radioactivity in drinking water supplies should be developed for use by field troops.

Standard operating procedures for installation of field water supply points should provide for dispersal of the points crosswind to the prevailing winds in the area at appropriate distances apart.

[redacted]

DISTRIBUTION

	Copy No.
ARMY ACTIVITIES	
Asst. Chief of Staff, G-1, Department of the Army, Washington 25, D. C.	1
Asst. Chief of Staff, G-2, Department of the Army, Washington 25, D. C.	2
Asst. Chief of Staff, G-3, Department of the Army, Washington 25, D. C.	3
Asst. Chief of Staff, G-4, Department of the Army, Washington 25, D. C.	4- 8
Chief of Ordnance, Department of the Army, Washington 25, D. C.	9- 11
Chief Chemical Officer, Temp. Bldg. T-7, Room G-522, Department of the Army, Washington 25, D. C.	12- 15
Chief of Engineers, Temp. Bldg. T-7, Room G-425, Department of the Army, Washington 25, D. C.	16- 18
The Quartermaster General, Second and T Sts. SW, Room 1139A, Washington 25, D. C.	19- 23
Chief of Transportation, Temp. Bldg, T-7, Room G-816, Department of the Army, Washington 25, D. C.	24- 25
Chief Signal Officer, Department of the Army, Washington 25, D. C.	26- 28
The Surgeon General, Main Navy Bldg., Room 1651, Washington 25, D. C.	29- 31
Provost Marshal General, Main Navy Bldg., Room 1065, Washington 25, D. C.	32- 34
Chief, Army Field Forces, Fort Monroe, Va.	35- 38
President, Army Field Forces Board No. 1, Fort Bragg, N. C.	39
President, Army Field Forces Board No. 2, Fort Knox, Ky.	40
President, Army Field Forces Board No. 3, Fort Benning, Ga.	41
President, Army Field Forces Board No. 4, Fort Bliss, Tex.	42
Commandant, The Infantry School, Fort Benning, Ga.	43- 44
Commandant, The Armored School, Fort Knox, Ky.	45- 46
President, The Artillery School Board, Fort Sill, Okla.	47- 48
Commandant, The AA&GM Branch, The Artillery School, Fort Bliss, Tex.	49- 50
Commandant, Army War College, Carlisle Barracks, Pa.	51- 52
Commandant, Command and General Staff College, Fort Leavenworth, Kans.	53- 54
Commandant, Army General School, Fort Riley, Kans.	55

[redacted]

[redacted] ATOMIC ENERGY [redacted]

[redacted]

DISTRIBUTION (Continued)

	Copy No.
Commanding General, First Army, Governor's Island, New York 4, N. Y.	56- 57
Commanding General, Second Army, Fort George G. Meade, Md.	58- 59
Commanding General, Third Army, Fort McPherson, Ga.	60- 61
Commanding General, Fourth Army, Fort Sam Houston, Tex.	62- 63
Commanding General, Fifth Army, 1660 E. Hyde Park Blvd., Chicago 15, Ill.	64- 65
Commanding General, Sixth Army, Presidio of San Francisco, Calif.	66- 67
Commander-in-Chief, European Command, APO 403, c/o Postmaster, New York, N. Y.	68- 69
Commander-in-Chief, Far East, APO 500, c/o Postmaster, San Francisco, Calif.	70- 71
Commanding General, U. S. Army, Pacific, APO 958, c/o Postmaster, San Francisco, Calif.	72- 73
Commanding General, U. S. Army, Caribbean, APO 834, c/o Postmaster, New Orleans, La.	74- 75
Commanding General, U. S. Army, Alaska, APO 942, c/o Postmaster, Seattle, Wash.	76- 77
Director, Operations Research Office, 6410 Connecticut Ave., Chevy Chase, Md.	78- 80
Commanding Officer, Ballistic Research Laboratories, Aberdeen Proving Ground, Aberdeen, Md.	81- 82
Commanding Officer, Engineer Research and Development Laboratory, Fort Belvoir, Va.	83
Commanding Officer, Signal Corps Engineering Laboratories, Fort Monmouth, N. J.	84- 85
Commanding Officer, Evans Signal Laboratory, Belmar, N. J.	86- 87
Commanding General, Army Chemical Center, Md. ATTN: Chemical and Radiological Laboratory	88- 89

NAVY ACTIVITIES

Chief of Naval Operations, Department of the Navy, Washington 25, D. C. ATTN: Op-36	90- 91
Chief, Bureau of Ships, Department of the Navy, Washington 25, D. C.	92- 95
Chief, Bureau of Ordnance, Department of the Navy, Washington 25, D. C.	96
Chief, Bureau of Medicine and Surgery, Department of the Navy, Washington 25, D. C.	97- 98
Chief, Bureau of Aeronautics, Department of the Navy, Washington 25, D. C.	99-100
Chief, Bureau of Supplies and Accounts, Department of the Navy, Washington 25, D. C.	101-102
Chief, Bureau of Yards and Docks, Department of the Navy, Washington 25, D. C.	103-105

[redacted] [redacted]

[redacted]

DISTRIBUTION (Continued)

	Copy No.
Chief of Naval Personnel, Department of the Navy, Washington 25, D. C.	106
Commandant of the Marine Corps, Washington 25, D. C.	107-109
Commander-in-Chief, U. S. Pacific Fleet, Fleet Post Office, San Francisco, Calif.	110
Commander-in-Chief, U. S. Atlantic Fleet, Fleet Post Office, New York, N. Y.	111
President, U. S. Naval War College, Newport, R. I.	112
Commandant, Marine Corps Schools, Quantico, Va.	113-114
Chief of Naval Research, Department of the Navy, Washington 25, D. C.	115-116
Commander, U. S. Naval Ordnance Laboratory, Silver Spring 19, Md.	117
Commander, U. S. Naval Ordnance Laboratory, Silver Spring 19, Md. ATTN: Aliex	118
Director, U. S. Naval Research Laboratory, Washington 25, D. C.	119
Commanding Officer and Director, U. S. Naval Electronics Laboratory, San Diego 52, Calif.	120
Commanding Officer, U. S. Naval Radiological Defense Laboratory, San Francisco 24, Calif.	121-124
Commanding Officer and Director, David Taylor Model Basin, Washington 7, D. C.	125
Commander, Naval Material Laboratory, New York Naval Shipyard, Naval Base, New York 1, N. Y.	126
Officer-in-Charge, U. S. Naval Civil Engineering Research and Evaluation Laboratory, U. S. Naval Construction Battalion Center, Port Hueneme, Calif.	127-128
Commanding Officer, U. S. Naval Medical Research Institute, National Naval Medical Center, Bethesda 14, Md.	129
Commander, U. S. Naval Ordnance Test Station, Inyokern, China Lake, Calif.	130

AIR FORCE ACTIVITIES

Assistant for Atomic Energy, Headquarters, United States Air Force, Washington 25, D. C.	131-132
Director of Operations, Headquarters, United States Air Force, Washington 25, D. C. ATTN: Operations Analysis Division	133-134
Director of Plans, Headquarters, United States Air Force, Washington 25, D. C. ATTN: AFOPD-P1	135
Director of Requirements, Headquarters, United States Air Force, Washington 25, D. C.	136
Director of Research and Development, Headquarters, United States Air Force, Washington 25, D. C.	137-138
Director of Intelligence, Headquarters, United States Air Force, Washington 25, D. C. ATTN: Phys. Vul. Branch, Air Targets Division	139-140

[redacted]

[redacted]

[redacted]

DISTRIBUTION (Continued)

	Copy No.
Director of Installations, Headquarters, United States Air Force, Washington 25, D. C.	141
Asst. for Development Planning, Headquarters, United States Air Force, Washington 25, D. C.	142
Asst. for Materiel Program Control, Headquarters, United States Air Force, Washington 25, D. C.	143
The Surgeon General, Headquarters, United States Air Force, Washington 25, D. C.	144
Commanding General, Strategic Air Command, Offutt Air Force Base, Nebr.	145-147
Commanding General, Air Research and Development Command, P.O. Box 1395, Baltimore 3, Md.	148-150
Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio	151-152
Commanding General, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio. ATTN: Air Installations Division	153-154
Commanding General, Tactical Air Command, Langley Air Force Base, Va.	155-157
Commanding General, Air Defense Command, Ent Air Force Base, Colo.	158-160
Commanding General, Air Proving Ground, Eglin Air Force Base, Fla.	161-162
Commanding General, Air Training Command, Scott Air Force Base, Belleville, Ill.	163-165
Commanding General, Air University, Maxwell Air Force Base, Montgomery, Ala.	166-168
Commanding General, Special Weapons Center, Kirtland Air Force Base, N. Mex.	169-171
Commanding General, 1009th Special Weapons Squadron, 1712 G St. NW, Washington 25, D. C.	172
Commanding General, Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio	173-176
Commanding General, Air Force Cambridge Research Center, 230 Albany St., Cambridge 39, Mass.	177-178
Commanding General, U. S. Air Forces in Europe, APO 633, c/o Postmaster, New York, N. Y.	179-180
Commanding General, Far East Air Forces, APO 925, c/o Postmaster, San Francisco, Calif.	181-182
Commanding General, Air Force Missile Center, Patrick Air Force Base, Cocoa, Fla.	183
Commandant, USAF School of Aviation Medicine, Randolph Air Force Base, Randolph Field, Tex.	184
The RAND Corporation, 1500 Fourth St., Santa Monica, Calif. ATTN: David T. Griggs	185
The RAND Corporation, 1500 Fourth St., Santa Monica, Calif.	186-187

[redacted] [redacted]

[redacted]

DISTRIBUTION (Continued)

	Copy No.
AFSWP ACTIVITIES	
Chief, Armed Forces Special Weapons Project, P.O. Box 2610, Washington 13, D. C.	188-196
Commanding General, Field Command, Armed Forces Special Weapons Project, P.O. Box 5100, Albuquerque, N. Mex.	197-202
OTHER ACTIVITIES	
Chairman, Research and Development Board, Department of Defense, Washington 25, D. C.	203
Director, Weapons System Evaluations Group, Office of the Secretary of Defense, Washington 25, D. C.	204
Executive Director, Committee on Atomic Energy, Research and Development Board, Department of Defense, Washington 25, D. C. ATTN: David Beckler	205
Executive Director, Committee on Medical Sciences, Research and Development Board, Department of Defense, Washington 25, D. C.	206
U. S. Atomic Energy Commission, Classified Document Room, 1901 Constitution Ave., Washington 25, D. C. ATTN: Mrs. J. M. O'Leary	207-209
Los Alamos Scientific Laboratory, Report Library, P.O. Box 1663, Los Alamos, N. Mex. ATTN: Helen Challenger	210-212
Sandia Corporation, Classified Document Division, Sandia Base, Albuquerque, N. Mex. ATTN: Wynne K. Cox	213-232

[redacted]

AEC, Oak Ridge, Tenn., A31954

[redacted]