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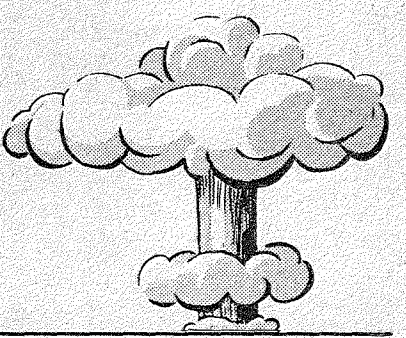
JANGLE

NEVADA PROVING GROUNDS
OCTOBER-NOVEMBER 1951

Project 6.7

CLOTHING DECONTAMINATION AND
EVALUATION OF LAUNDRY
METHODS



ARMED FORCES SPECIAL WEAPONS PROJECT
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OPERATION JANGLE

PROJECT 6.7

CLOTHING DECONTAMINATION AND EVALUATION OF LAUNDRY METHODS

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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.

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 artifically 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 RW-type contaminants.

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[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.

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.

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

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.

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

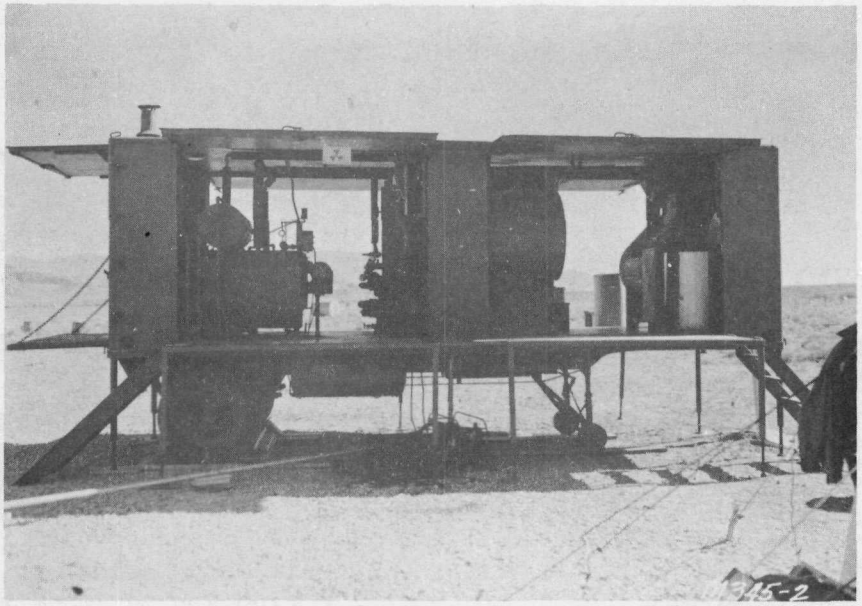

Fig. 2.1 Quartermaster Corps Mobile Field Laundry, 10-Ton Van Type

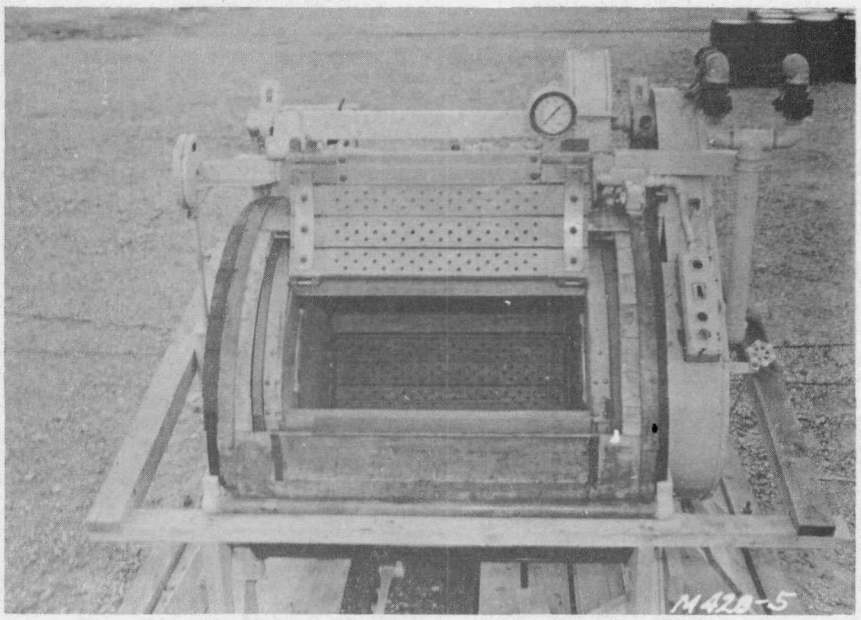

Fig. 2.2 A 36 x 36 inch Wooden Washer

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.

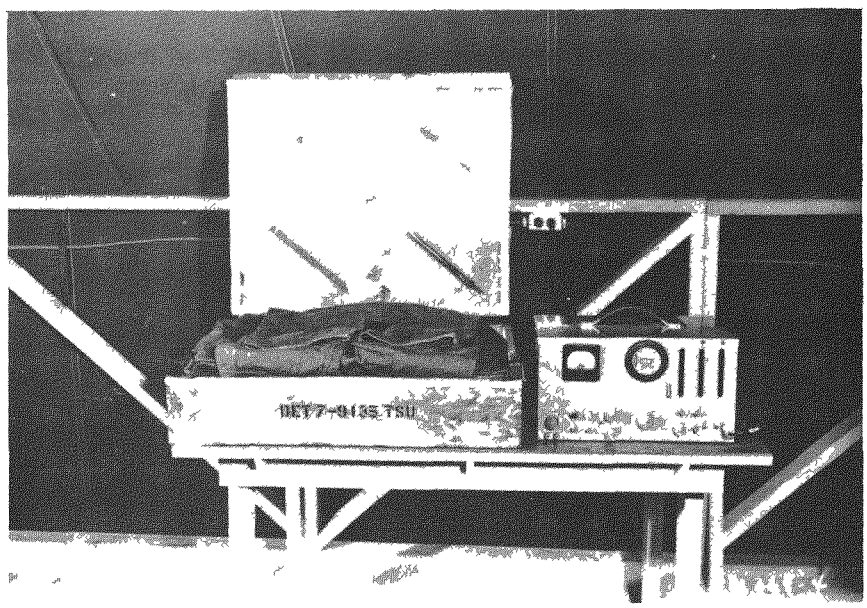

Fig. 2.3 Chemical Corps Clothing Checker

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[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.

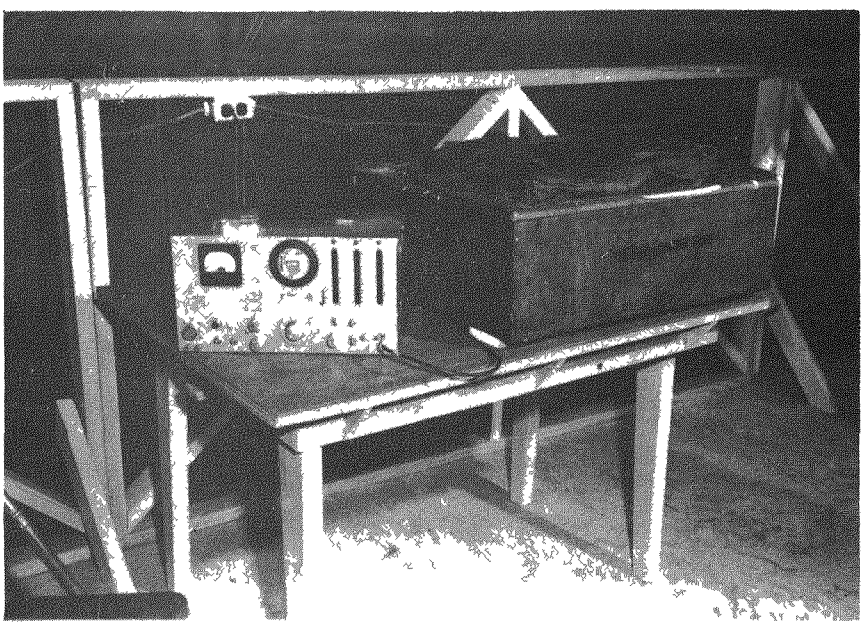

Fig. 2.4 Modified Chemical Corps Checker

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.

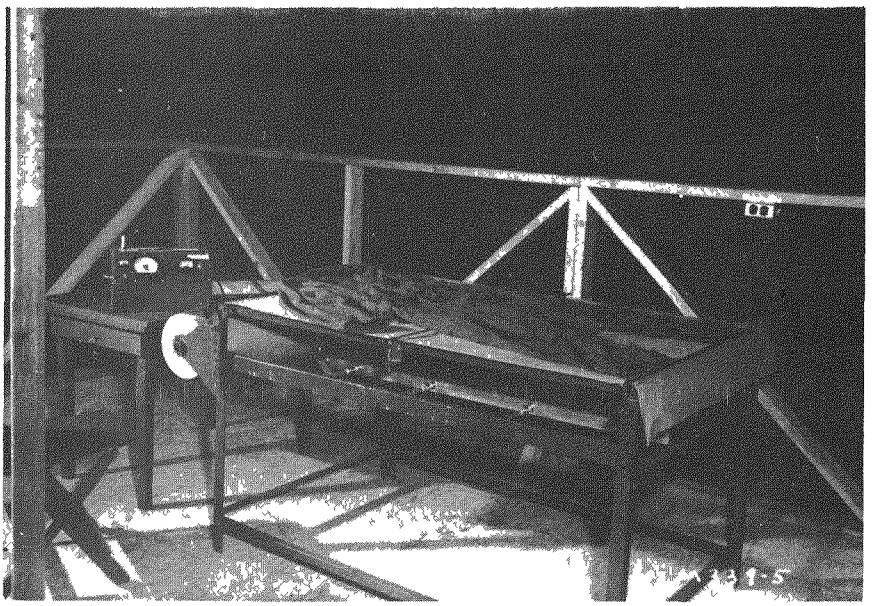

Fig. 2.5 Signal Corps Table Top Laundry Monitor

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.

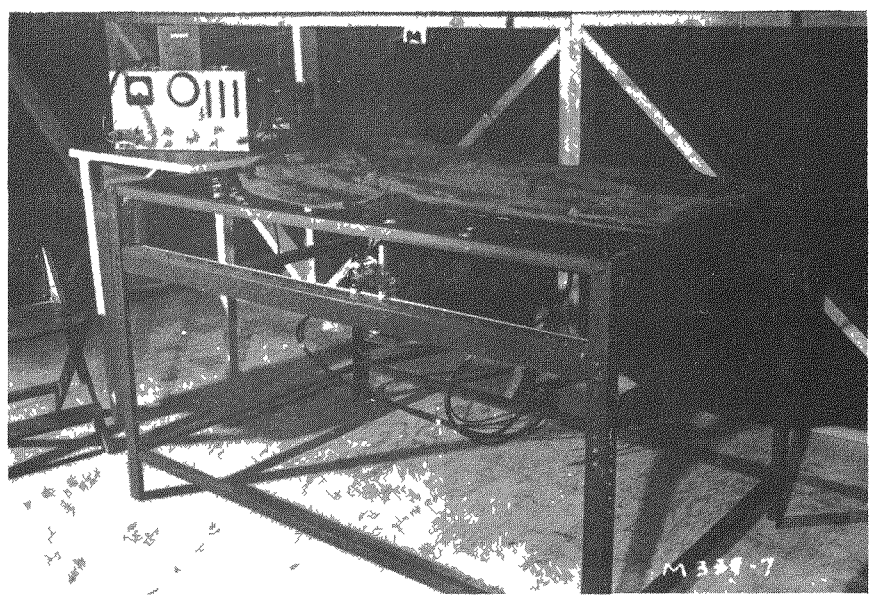

Fig. 2.6 Signal Corps Scanning Arm Laundry Monitor

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.

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.

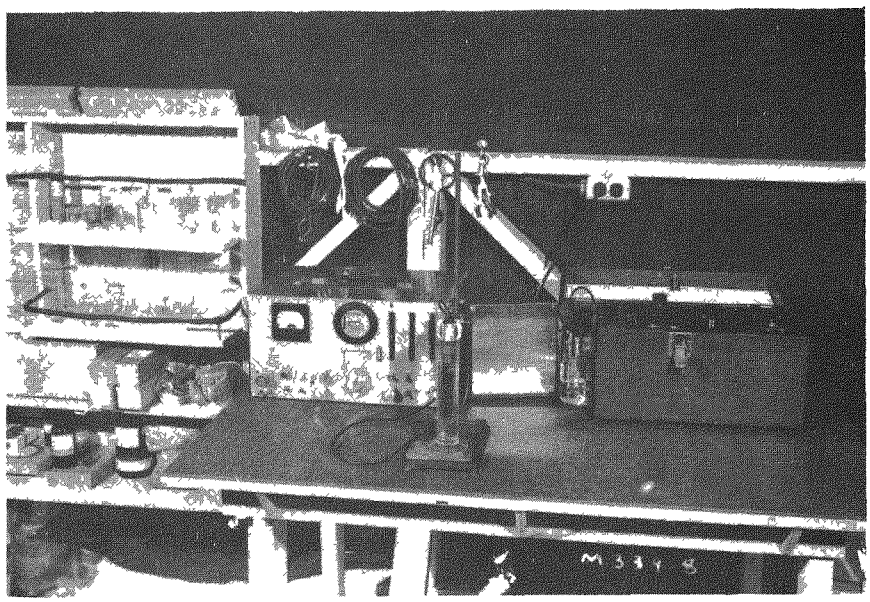

Fig. 2.7 Liquid Contamination Counting Device

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

sheet metal duct was connected from the blower exhaust to the top of the tumbler and connected to another fan placed on top of the machine. Test items were loaded into the rotating tumbler cylinder with a weighed amount of contaminated soil. The circulating fans then provided continuous recirculation of air and dust throughout the entire system. An exhaust bag was provided to collect the excess contaminant upon completion of each contaminating process.

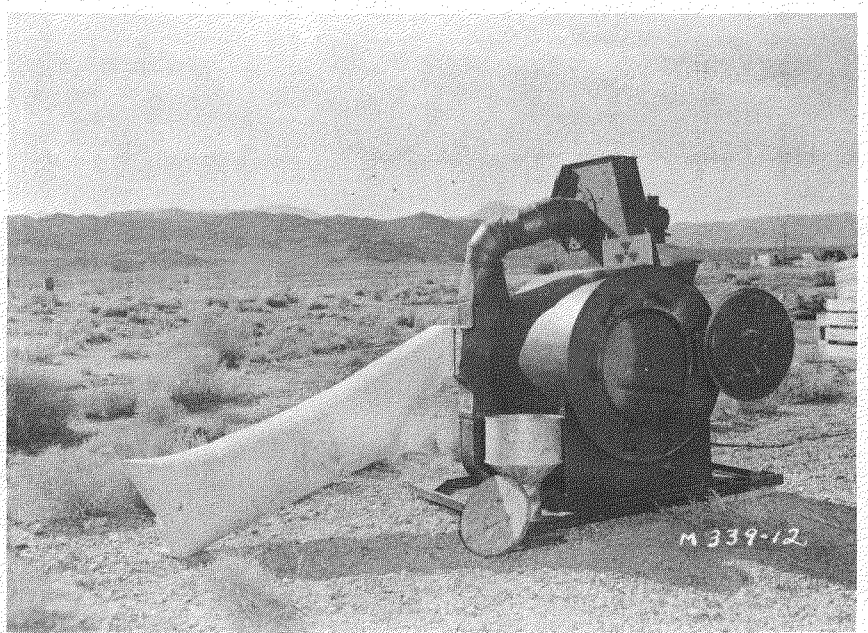

Fig. 2.8 Controlled Contamination Tumbler

2.6 CONTAMINATED MATERIALS PROCESSED

Standard and special clothing items as listed in Table 2.1 were available for conduct of the controlled test on contamination and decontamination.

Special swatches were made for the fabric evaluation operation of the test. Each of the swatches was similar to a pillowcase. The finished dimensions of the pillowcase were 22 x 26 inches. The case was seamed on three sides with a non-raveling seam and the open end was the selvedge edge of the fabric. In all cases except the rayon fabric, the face of the fabric was on the outside. The back of the rayon fabric was on the outside. The swatches which were tested are listed with their code letters in Table 2.2.

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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

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

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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

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)

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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.

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

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[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.

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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

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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

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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

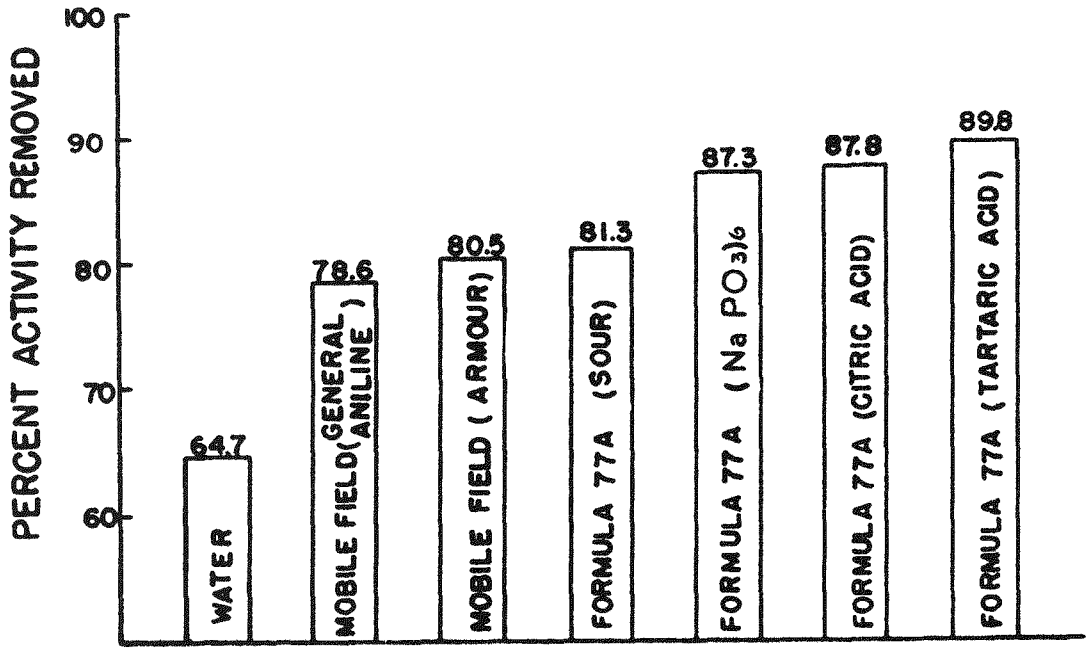

Fig. 3.1 Efficiency of Laundry Formula

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 formulae and processing the same type garments, contaminated under the same conditions. The average percent decontamination achieved by four

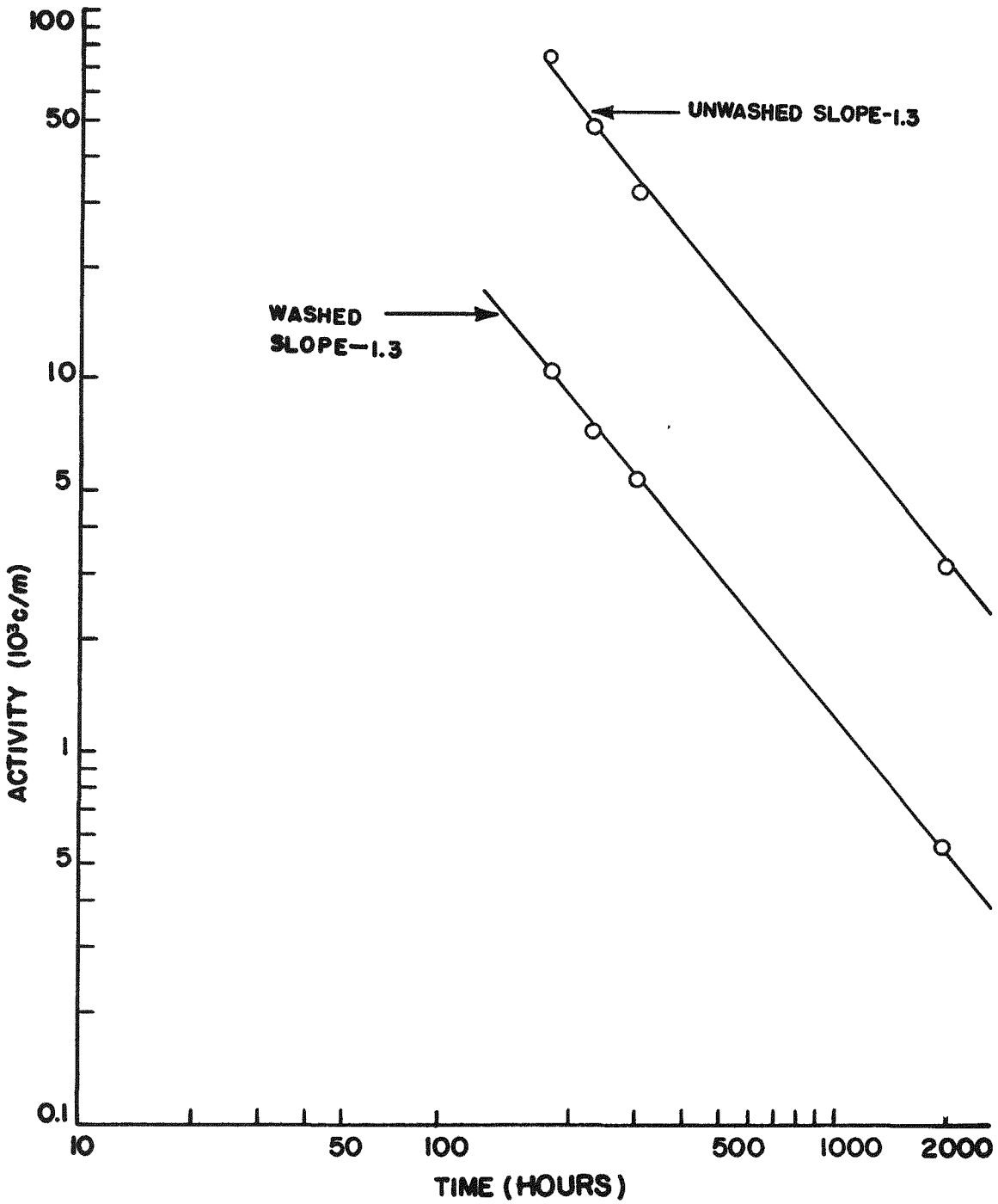

Fig. 3.2 Logarithmic Plot of the Beta, Gamma Activity Decay of Nylon Swatches Surface Shot

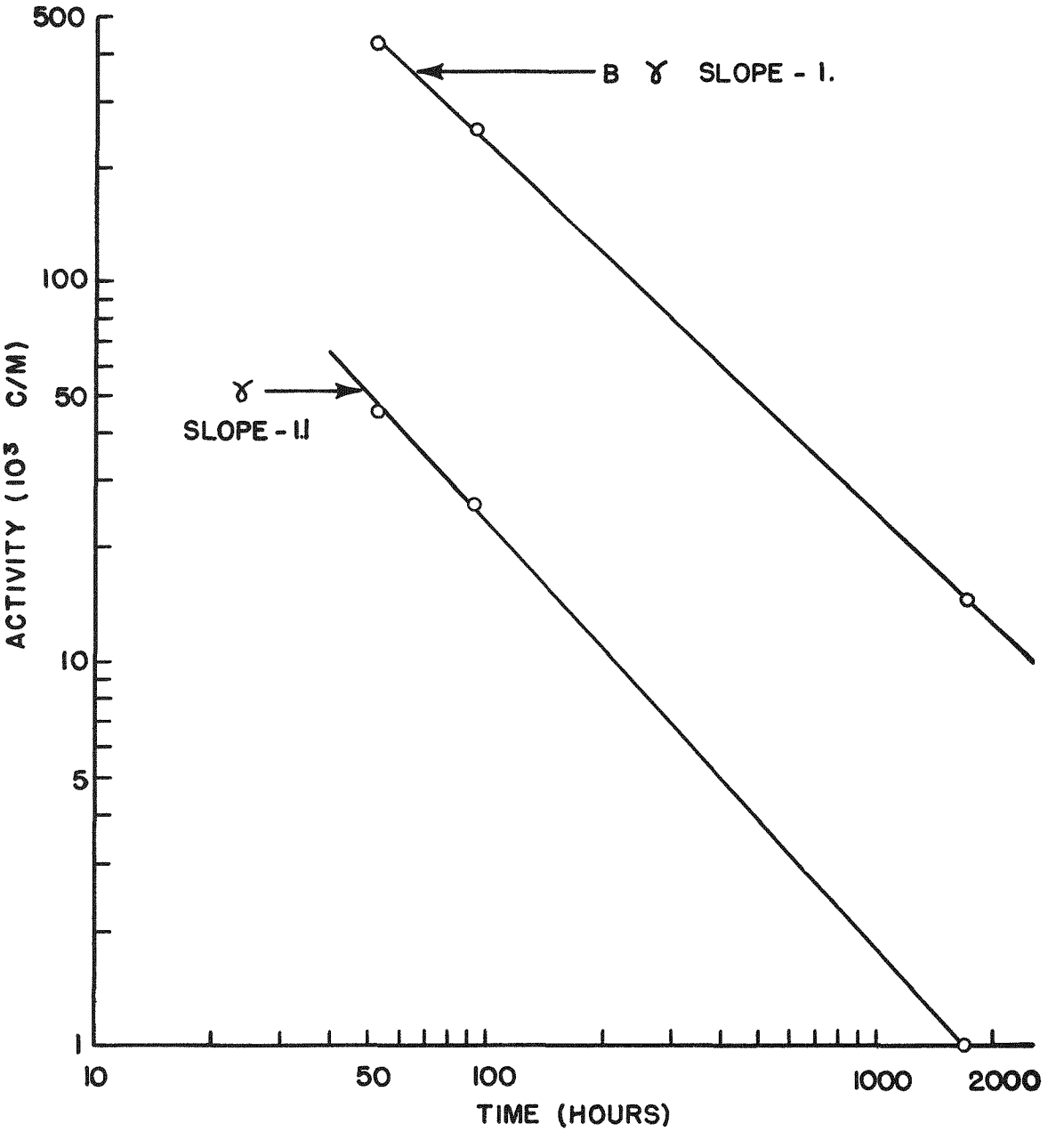

Fig. 3.3 Logarithmic Plot of the Activity Decay of Coveralls Contaminated in Underground Shot Area

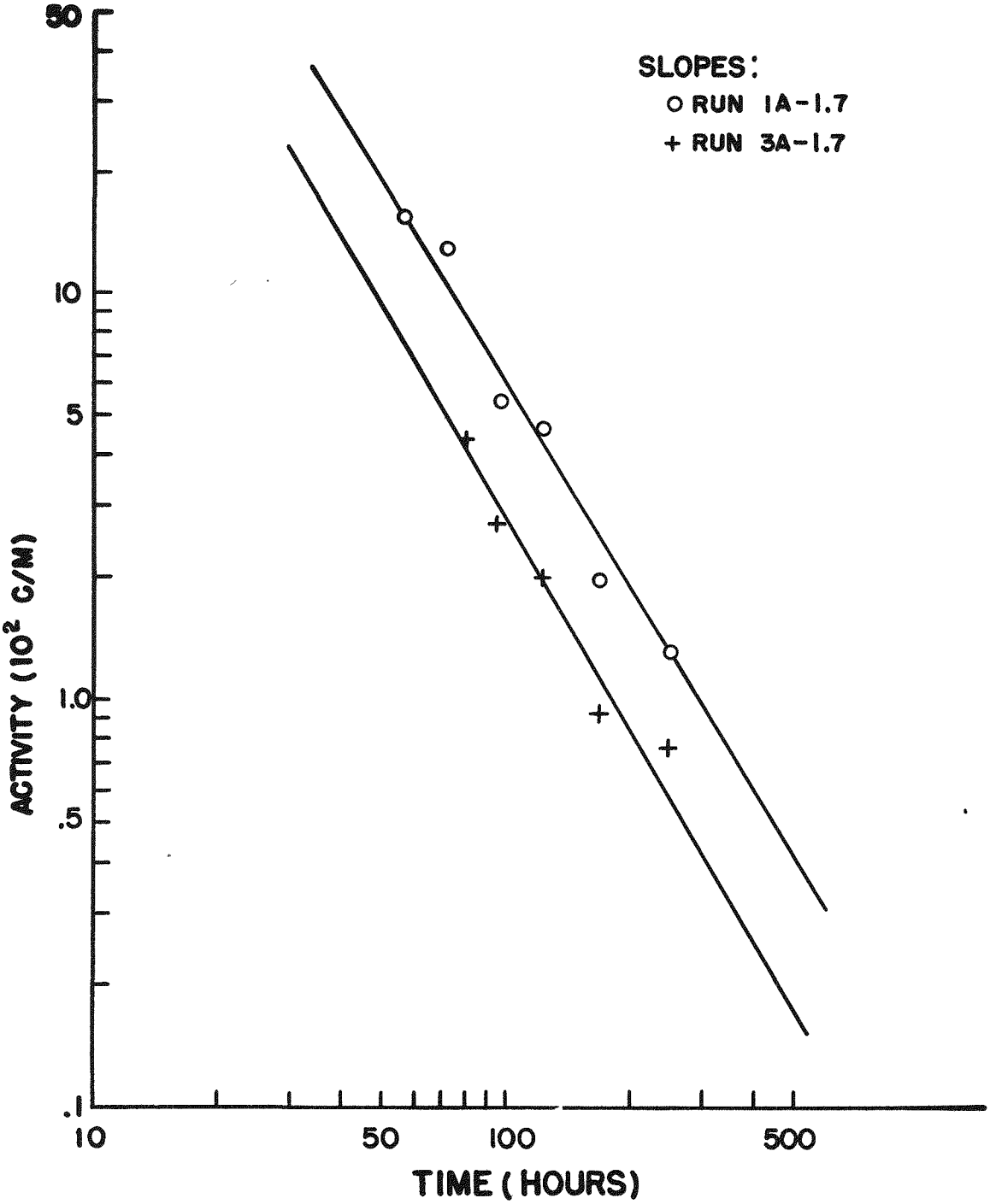

Fig. 3.4 Logarithmic Plot of the Beta, Gamma Decay Rate for Laundry Evaluation Runs

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]

$$\frac{X}{\sigma} = \frac{\bar{x}_1 - \bar{x}_2}{\sigma_{\bar{x}_1 - \bar{x}_2}} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\left(\frac{SD_1}{\sqrt{N_1}}\right)^2 + \left(\frac{SD_2}{\sqrt{N_2}}\right)^2}} \qquad (3.2)$$

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.

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[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.

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

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.

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.

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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.

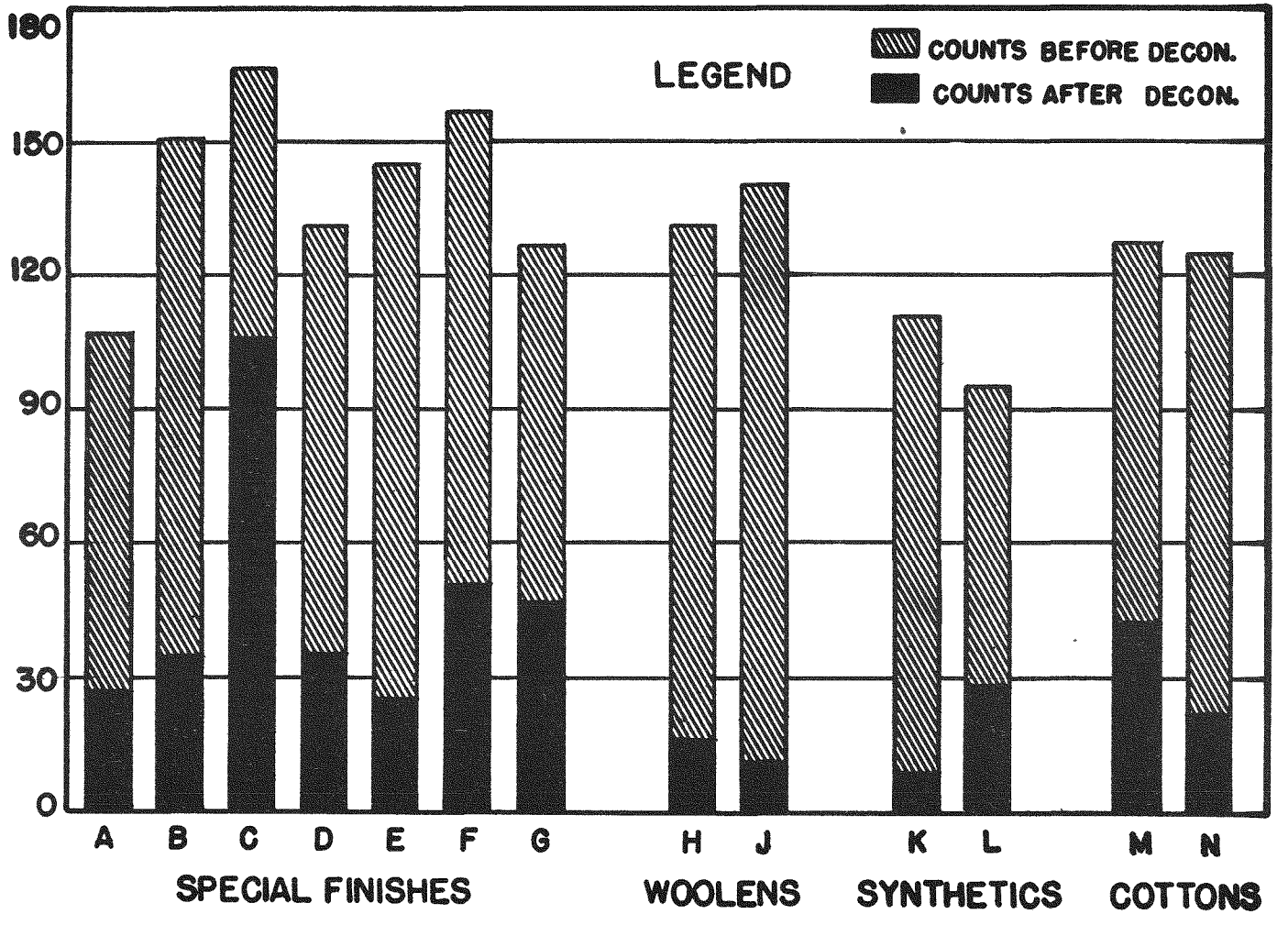


Fig. 4.1 Graph of Relative Contaminability and Decontaminability of Fabric Swatches

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

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

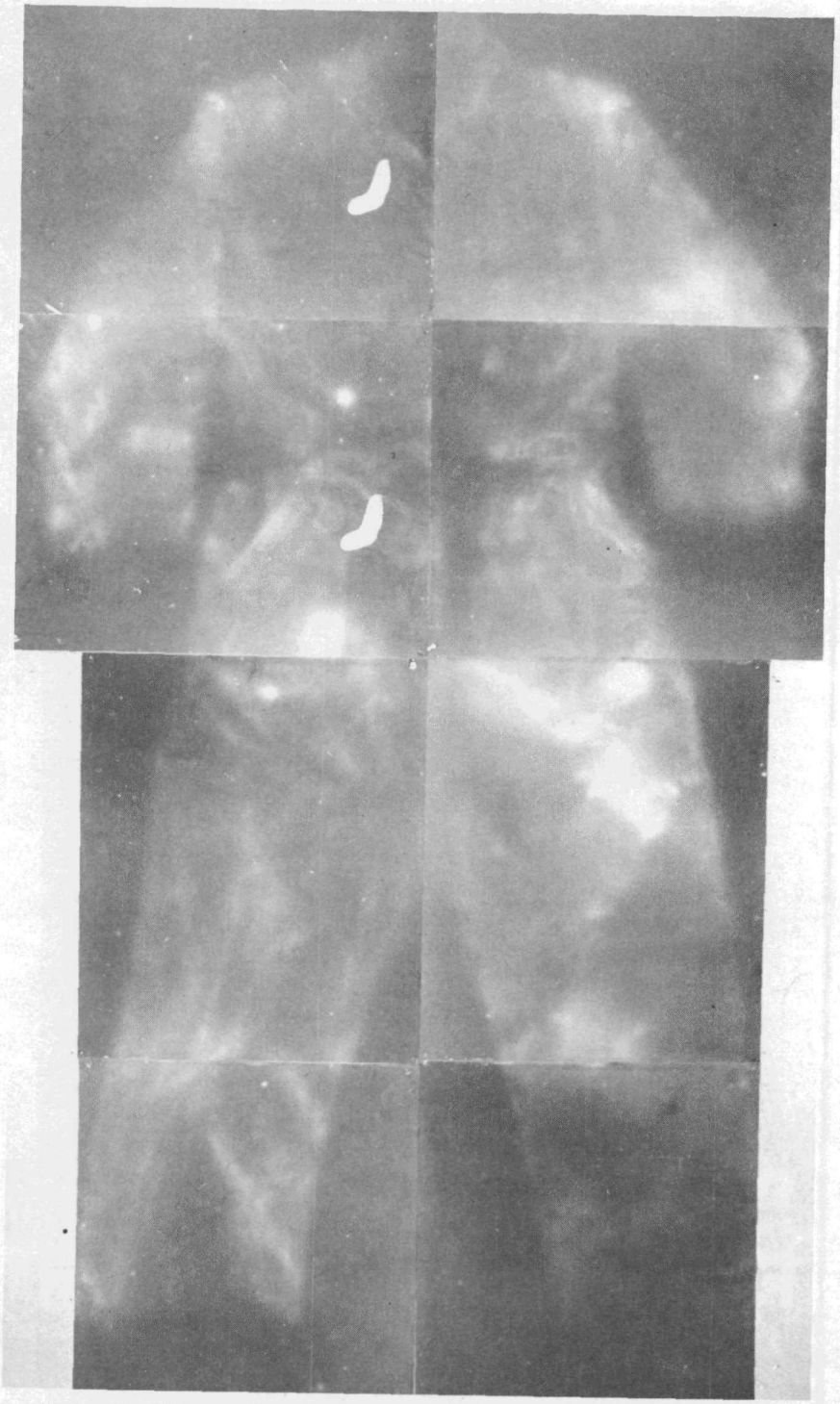


Fig. 4.2 Radiograph of Coveralls Worn in the Underground Shot Area on Underground plus One Day

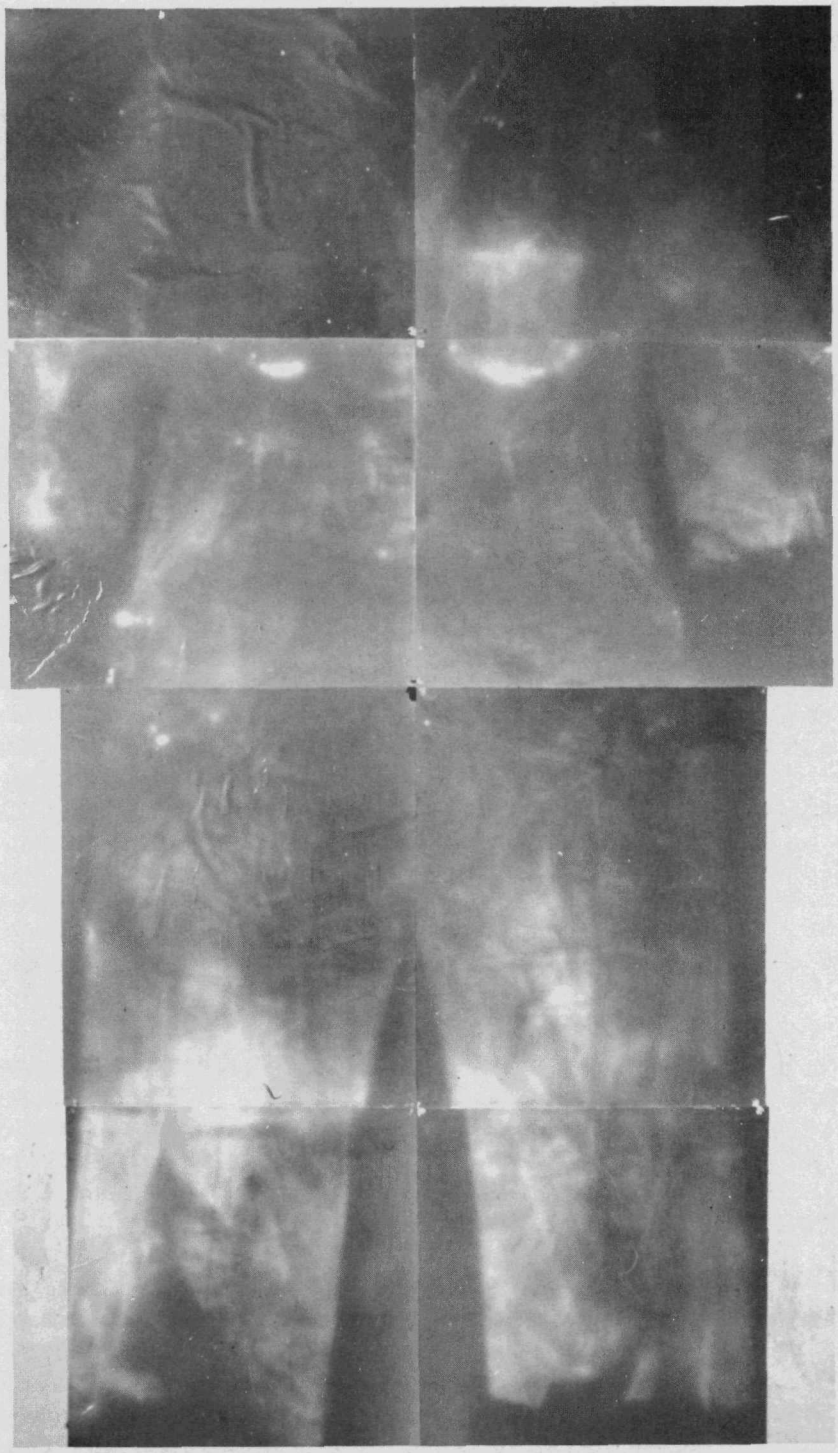


Fig. 4.3 Radiograph of Coveralls Worn in the Underground Shot Area on Underground plus two Days

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.

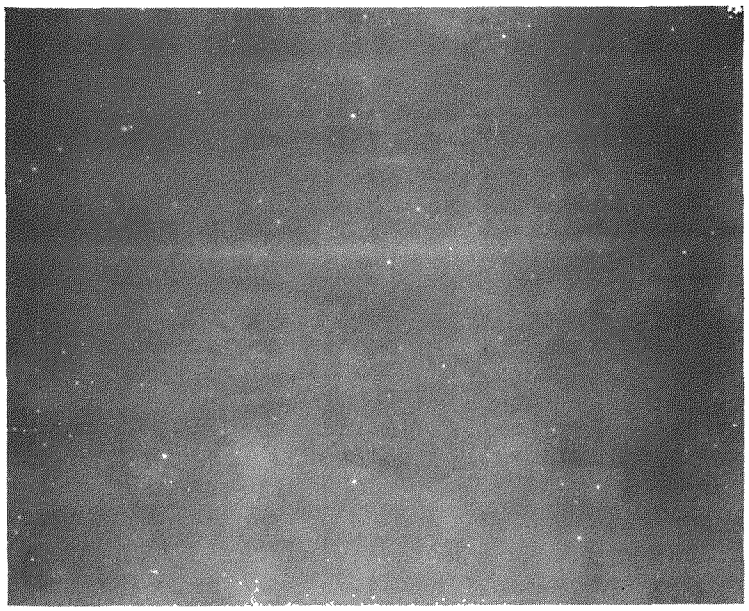
4.3.1 Clothing Contaminated Through Wear in the Shot Area (Surface Shot)

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.

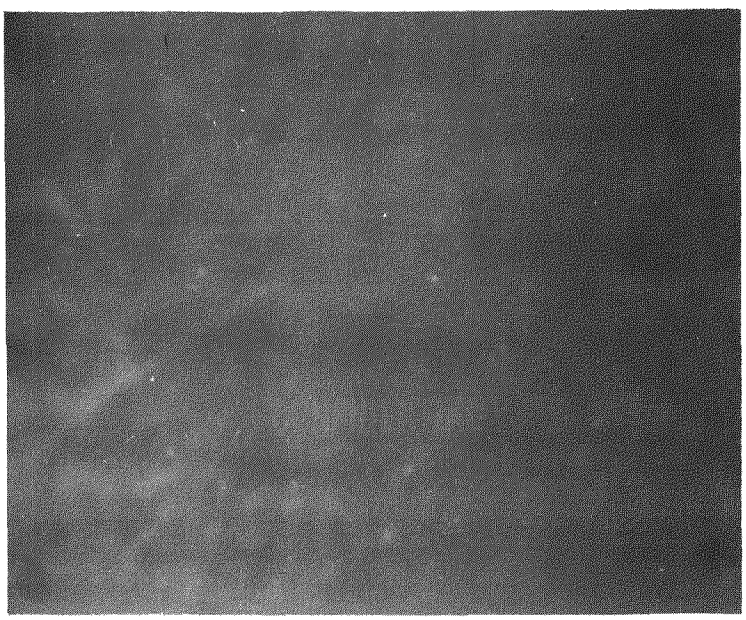
4.3.2 Swatches Contaminated by Controlled Methods (Special Finishes)

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,

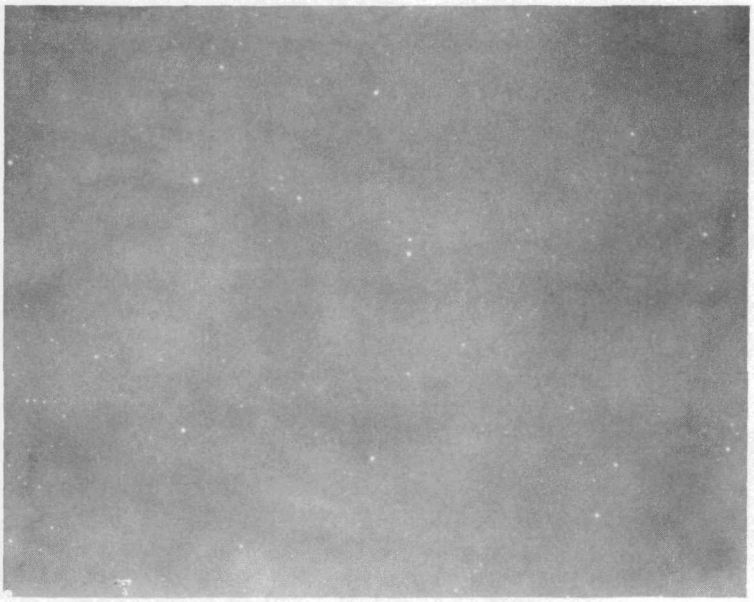


Contaminated Rayon: AN/PDR-T-2A - 6 mr/hr - Exposed 6 hrs.

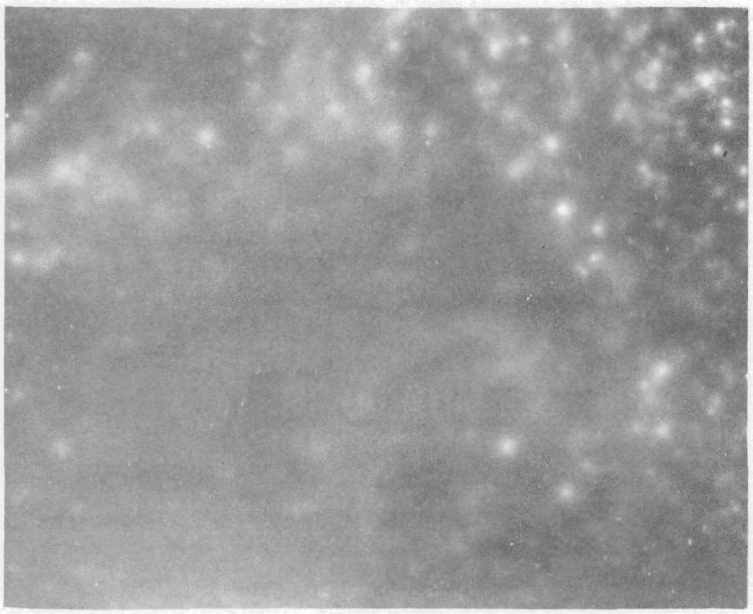


Decontaminated Rayon: AN/PDR-T-2A - 4.5 mr/hr - Exposed 11 hrs.

Fig. 4.4 Radiographs of Rayon Before and After Laundering.

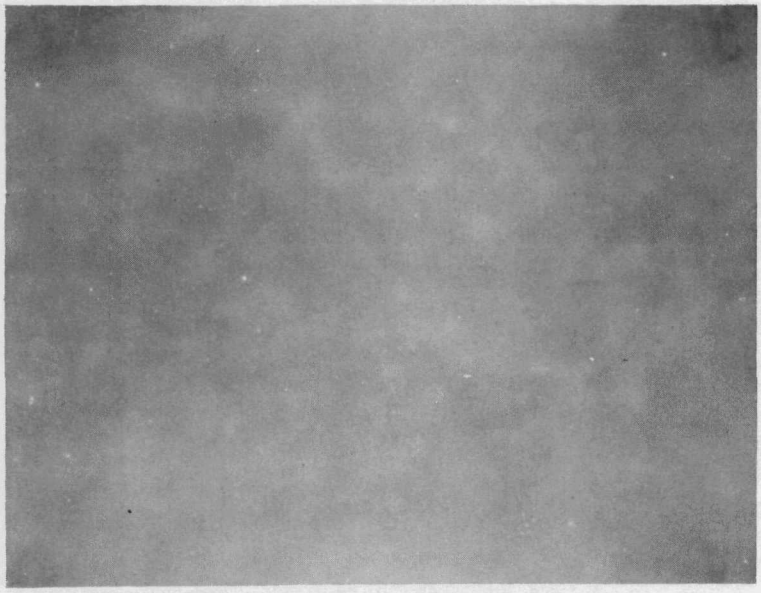


Contaminated Nylon: AN/PDR-T-2A - 6 mr/hr - Exposed 6 hrs.

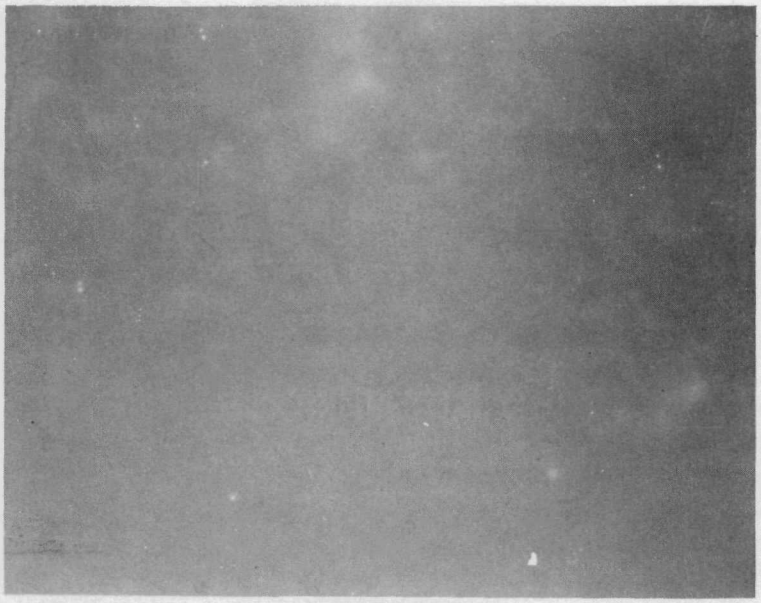


Decontaminated Nylon: AN/PDR-T-2A - 2.5 mr/hr - Exposed 9 hrs.

Fig. 4.5 Radiographs of Nylon Before and After Laundering.

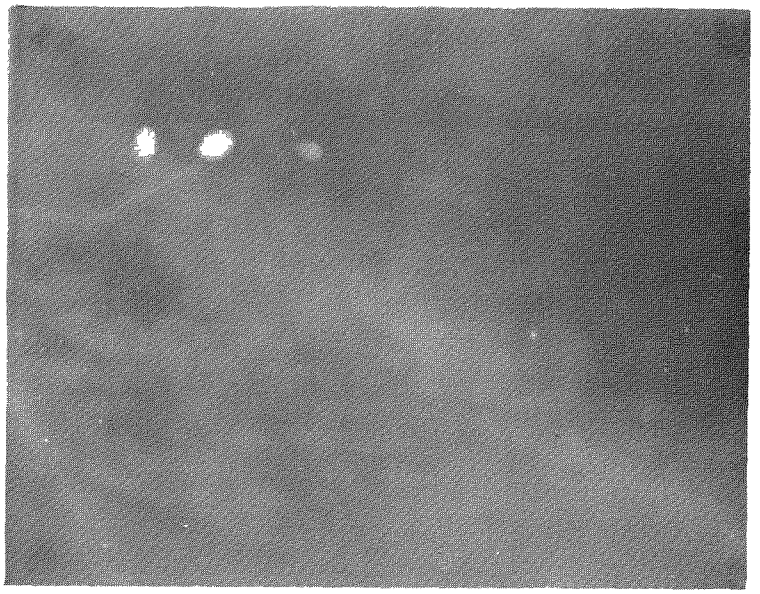


Contaminated Sateen: AN/PDR-T-2A - 12 mr/hr - Exposed 3 hrs.

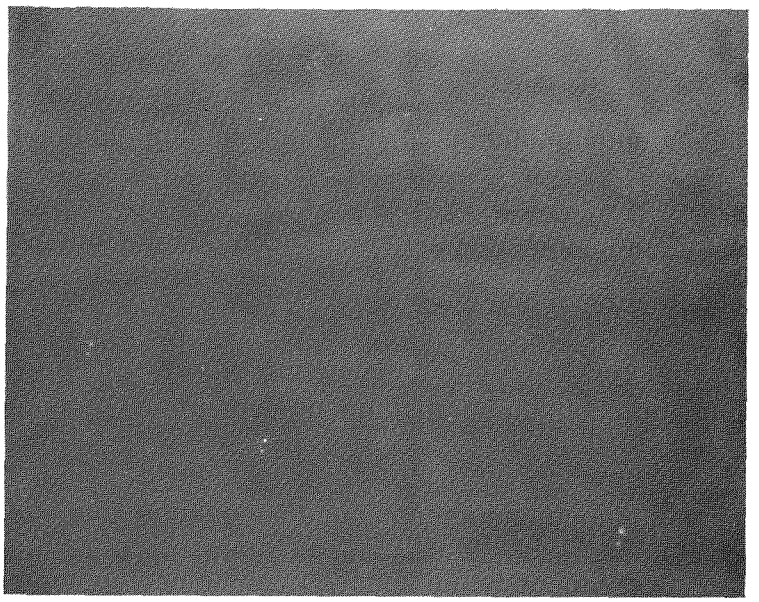


Decontaminated Sateen: AN/PDR-T-2A - 2 mr/hr - Exposed 12 hrs.

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.

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.

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

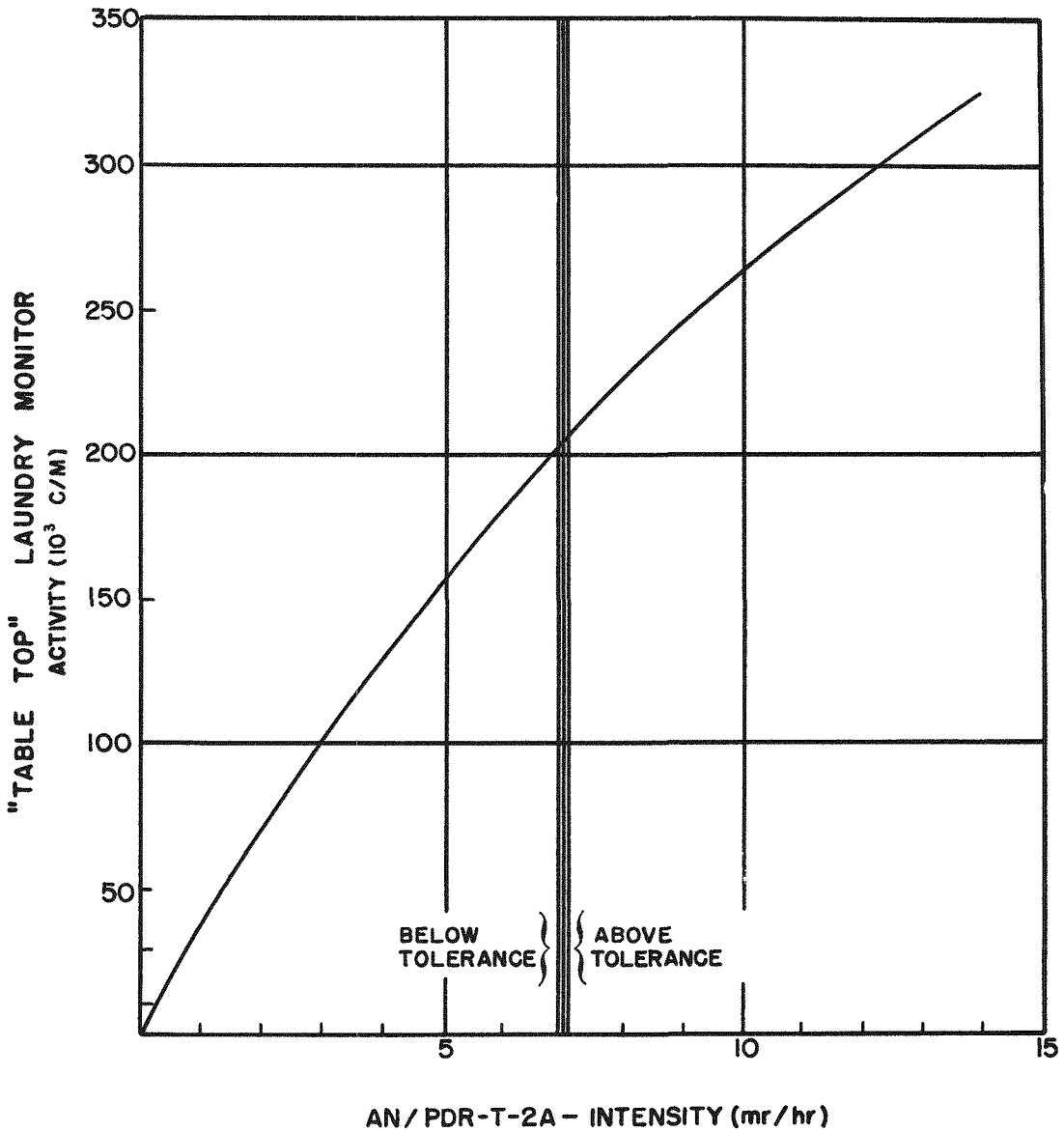


Fig. 5.1 Table Top vs AN/PDR T-2A

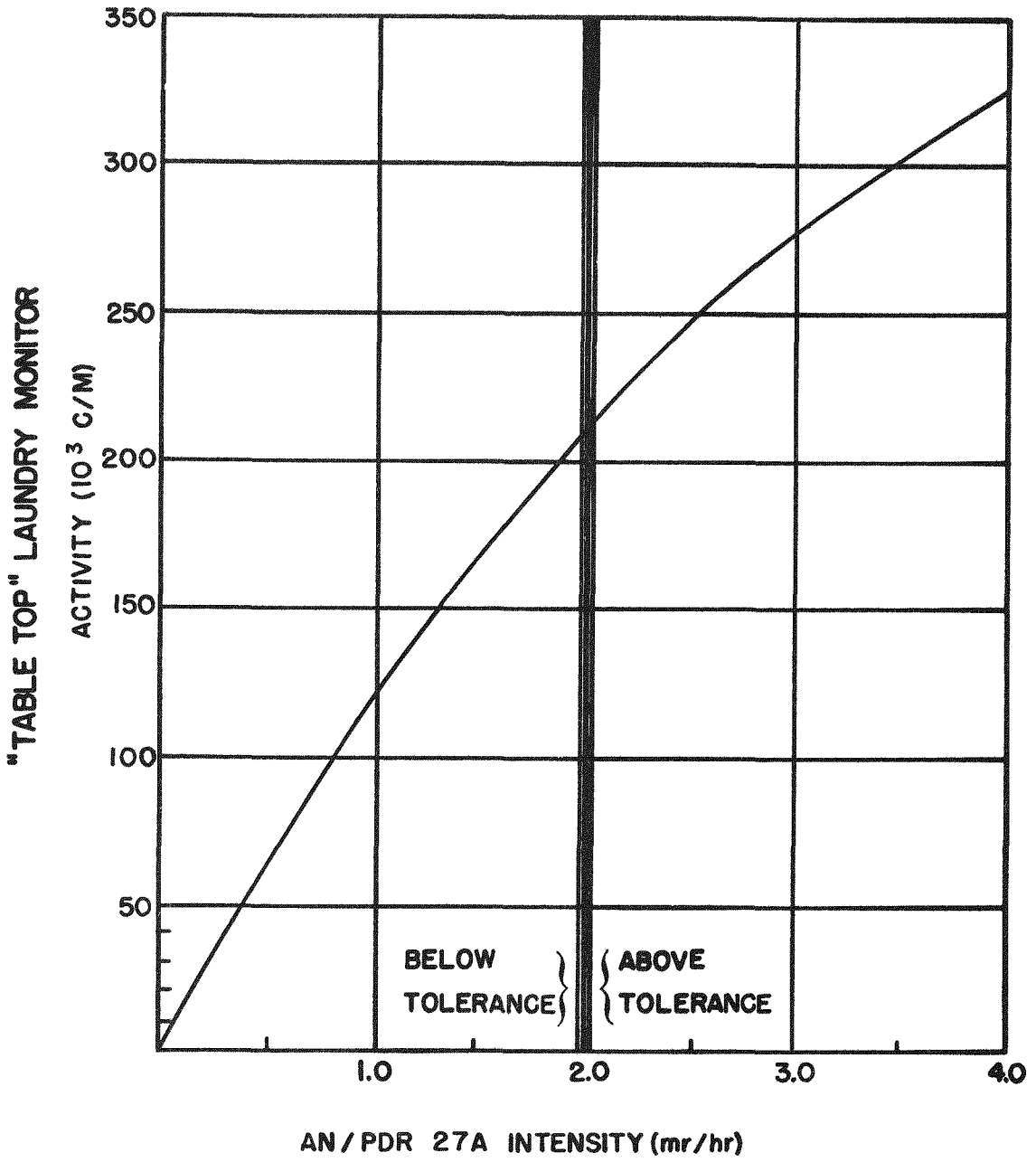


Fig. 5.2 Table Top vs AN/PDR 27A

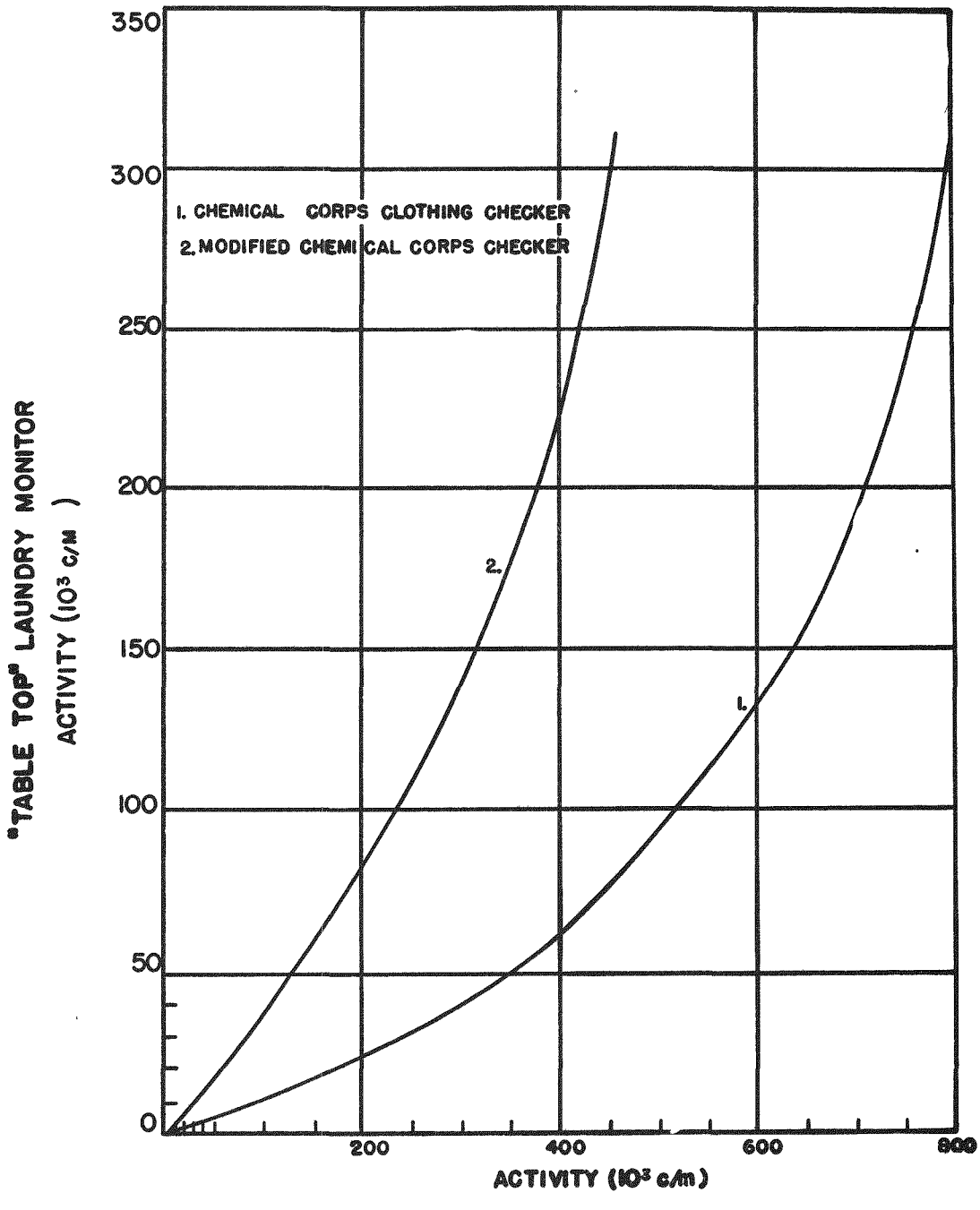


Fig. 5.3 Table Top vs Chemical Corps Types

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

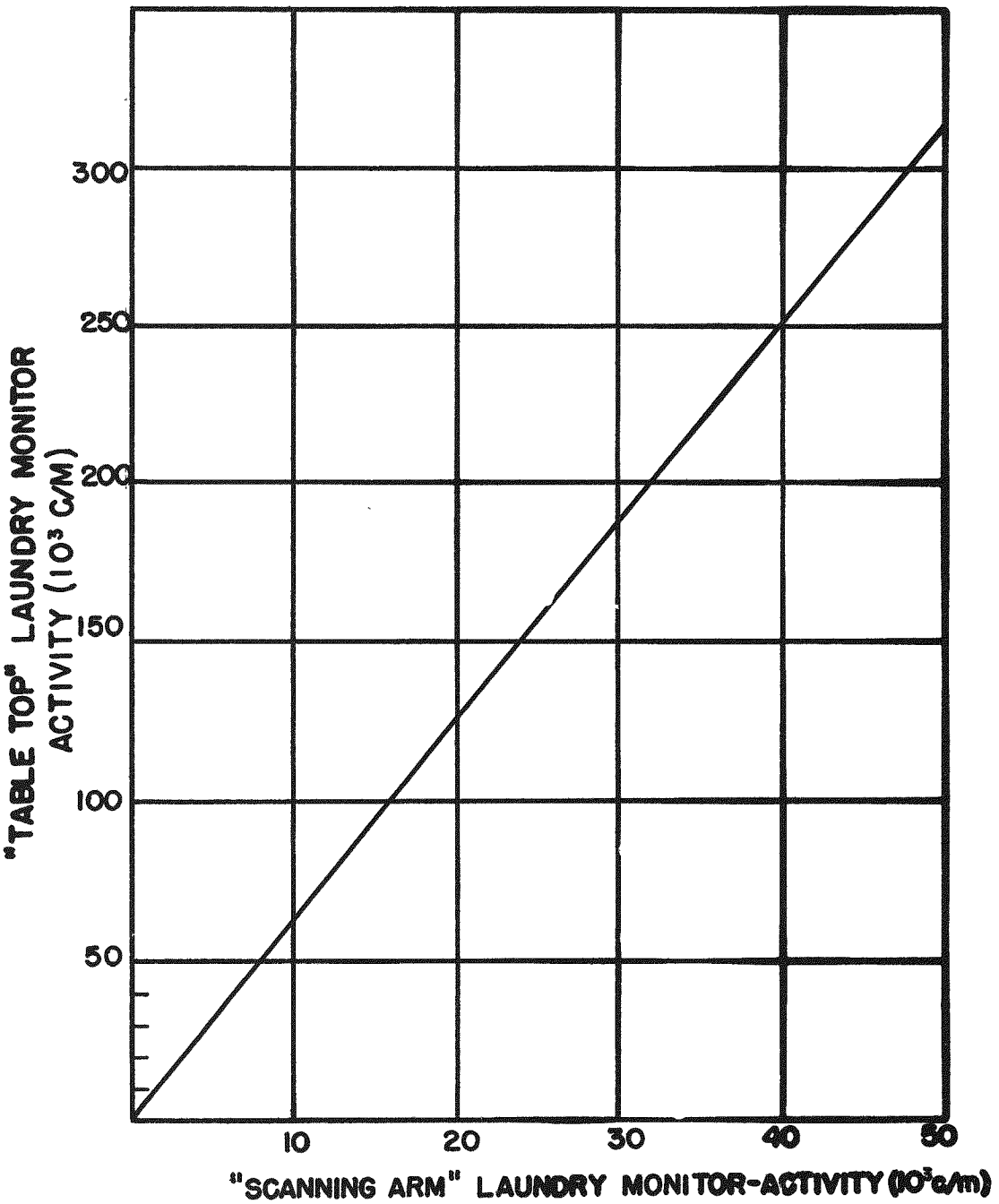


Fig. 5.4 Table Top vs Scanning Arm

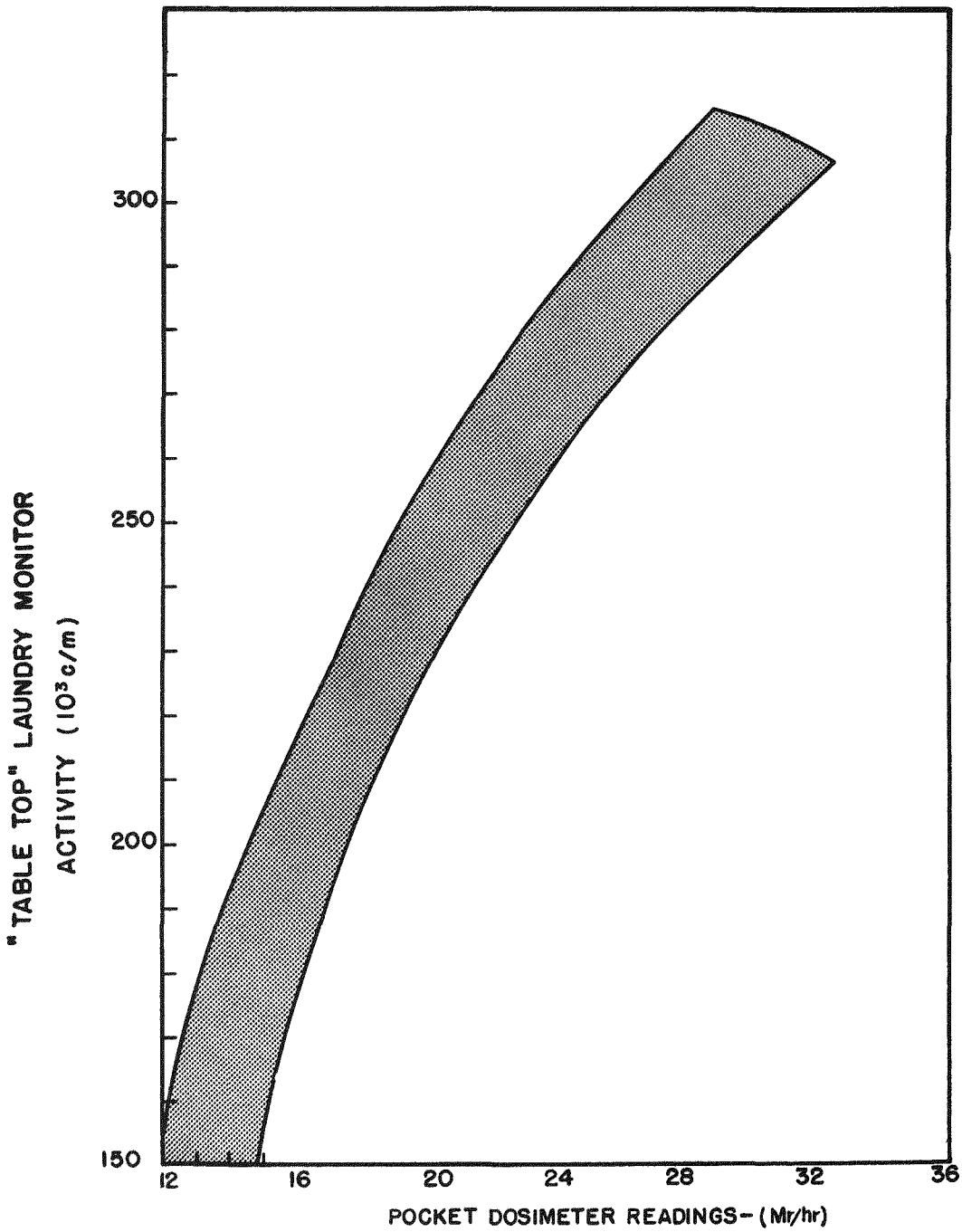


Fig. 5.5 Table Top vs Dosimeter (Converted to mr of Dosage in one Hour)

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.

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.

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.

APPENDIX

ROSTER OF PROJECT 6.7 PERSONNEL

Maj. Alfred H. Parthum, Jr.: Project Officer, ABC&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.

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.

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.

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PROJECT 6.7

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