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TITLE

THE SUPPRESSION OF SECONDARY AEROSOLS FROM CONTAMINATED CLOTHING

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SUFFIELD MEMORANDUM NO. 1045

THE SUPPRESSION OF SECONDARY AEROSOLS FROM CONTAMINATED CLOTHING [redacted]

by

D.C. O'Connell, D.E. Davids, E.E. Howlett,
F.W. Stevenson and L.A. White

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September 1981

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Abstract

(U) Secondary aerosolization of microbiological particles deposited on clothing poses a respiratory hazard during undressing procedures in small enclosed spaces. The hazard based on inhalation doses of more than 100 simulant spores (BG) being an infectious dose, was the same whether the cubicle was ventilated or not. Shedding of particles from clothing was greatly reduced by wetting down with either water or a hypochlorite solution. (U)

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Introduction

Preliminary experiments revealed that secondary aerosols were created when troops, who had previously been exposed to aerosols of BG spores, removed their clothing. This finding caused us to question whether or not such secondary aerosols were sufficiently concentrated to pose an infection hazard to unmasked personnel, especially if clothing were removed in a confined area such as a tent, bunker or ventilated protective shelter. Accordingly, tests were conducted to a) determine the extent of the hazard and to b) study the effectiveness of "wetting down" as a method of suppressing the shedding of biological particles from clothing. The purpose of this paper is to report the findings of these experiments.

Respiratory Hazard

The respiratory hazard was determined by experiments in which clothing was contaminated by sprayer emission in the field and subsequently removed in confined spaces. Enumeration of the microorganisms which would represent an inhalation dose was made; and on the basis of 100 cells constituting an infectious dose in 50 percent of individuals (ID_{50}), the hazard was ascertained. Troops or test volunteers were undressed individually in small cubicles, both ventilated and unventilated.

PROCEDURES

Test subjects were dressed in either cotton coveralls or the Canadian Chemical Protective Coverall (CCPC), placed downwind from an aerosol emission line and subjected to clothing contamination by air-borne particle deposition. As soon as possible after the exposure and without touching each other, the test individuals were directed to enter the undressing area one at a time (still masked) and requested to remove their outer clothing. The cotton coveralls were removed as simply as possible whereas the CCPCs were removed carefully without unnecessarily touching the exterior of the garment with the bare hands.

METHODS AND MATERIALS

Clothing Contamination

Aqueous suspensions of BG spores (*B. subtilis* var *niger*) were sprayed from the Jet Pack Sprayer (Sprayon Products, Cleveland, Ohio) (Figure 1) to contaminate the clothing of personnel positioned one arms length apart, 50 feet (15.2 m) downwind of an emission line (Figure 2). Analyses of the aerosols produced by this device in preparatory tests

indicated that at this distance downwind (WS 7-10 mph), 79 percent of the airborne particles containing BG spores were less than 8 μm in diameter.

Clothing contamination densitites were determined by assessment of the numbers of BG spores recovered from filter paper swatches (15.2 cm^2) which were pinned to the clothing at the chest level (Figure 3). In some cases, other positions were utilized. The swatches were cut from the same filter material that was used in determining the respiratory dose of secondary aerosols as described below. Although Rodac contact agar plates (25 cm^2) have been used in some tests for determination of contamination densitites on clothing, these provide particle counts only, whereas total spore counts are preferred and such were obtained by use of the filter paper swatches.

Respiratory Challenge

Respiratory exposures due to secondary aerosols created by the removal of contaminated clothing were determined by the use of a filter paper sampler (1) affixed to the C1 canister of the Canadian C-2 respirator (Figure 4). The respirator was worn during the undressing procedure. This filter material allows an individual to breathe through it without undue stress while filtering out a very high percentage (99.9%) of biological particles in the respirable size range (1 - 5 μm). In addition, the inclusion in the fiber formulation of a warm-water-soluble binder allows disintegration of the filter and release of the collected spores into liquid suspension on shaking.

Numerical Assessment of BG Spores

Liquid suspensions prepared from contaminated clothing swatches and external canister sampler filters were assessed for spore content by plating on Tryptose agar. Plates were incubated at 37°C for approximately

18 hours. When Rodac plates were used they contained Tryptose agar as well and were incubated directly.

SITES AND FACILITIES

Troops and test volunteers wearing cotton coveralls were contaminated by aerosol emission, as described, adjacent to a small telephone booth-like structure which later served as the undressing room (Figure 5). The construction of the small building was such that its two side doors could be opened allowing the prevailing wind to flush out any residual aerosol. The volume of the structure was approximately 82 cu. ft. Two minutes was usually allowed for undressing and bagging of the clothing and an interval of 3 to 5 minutes elapsed between individual clothing removals, depending on the speed of the existing wind,to allow for adequate flushing.

Similarly, a clothing contamination test was carried out in the field adjacent to the U.S. KMU 450/F Collective Protector (2) (Figure 6). The area (ingress airlock) in which test subjects removed their protective clothing according to the accepted procedure of "safe removal of the Canadian Chemical Protective Coverall", was ventilated. At the proper operating pressure, approximately 125 cu. ft. of air per minute was vented (approximately 2 changes per minute) through the airlock.

Test subjects passed through the undressing area in succession. Each removed his clothing by himself, placed it in the bins provided and moved on into the other collective protector areas. The next subject entered the undressing area immediately. Approximately 5 minutes was required by each man to remove his own clothing, particularly if difficulty was experienced in removing the protective overboots.

EXPERIMENTAL

A. Contaminated Clothing Removal Without Treatment

Test subjects were exposed to downwind aerosols of BG spores on nine separate occasions. Collections were made by the canister sampler in the unventilated undressing facility during a 2 minute period while contaminated cotton coveralls were removed. Six troops were similarly exposed on another occasion and the air sampled while using the undressing facility. The effect of ventilation of the undressing area on the density of the secondary areosol created in undressing was determined using the ingress airlock of the KMU 450/F collective protector as an undressing area. Ten troops wearing the Canadian Chemical Protective Coverall (CCPC) were undressed individually. Secondary aerosols were collected using the special filters attached to the protective respiratory as previously described. Approximately five minutes was required for removal of the CCPCs because of more difficult removal procedure.

B. Contaminated Clothing Removal After Treatment

Twelve subjects were exposed to a downwind aerosol of BG spores and wetted down with water (Figure 7) before entering the undressing cubicle facility. Collections were made by the canister samplers in the unventilated area during a two minute period while contaminated cotton coveralls were removed. In a companion experiment, ten subjects were similarly exposed and then wetted down with SLASH (a self-limiting activated solution of calcium hypochlorite) (3). Clothing was then removed and the secondary aerosol created was measured.

RESULTS

The results clearly indicate that unprotected men are subjected to potentially infectious levels of biological aerosols while removing contaminated clothing. For agents with an ID_{50} dose of 100 cells, chances of infection would be virtually 100% (Tables I, II and III). If the contaminated clothing is wetted down prior to removal, secondary aerosols are greatly suppressed (Tables IV and V), and if a hypochlorous acid-based decontaminant is used, the hazard of infection is almost totally eliminated (Table V). The results are summarized and compared in Table VI.

DISCUSSION

It is evident that the removal of contaminated clothing in a small unventilated enclosed area presents a respiratory hazard. Ventilation does not eliminate this hazard and indeed in the KMU 450/F test, seemed to have had little effect on the number of spores collected. The suppression of secondary aerosols of BG spores from contaminated clothing during removal in an enclosed space was easily effected by a thorough wetting down with either water or a solution of hypochlorous acid. Three exposures of greater than 100 spores (our theoretical ID_{50} level) were observed in the wetdown tests, but two of these were only marginally greater and may have been due to direct contact between the contaminated clothing and the external canister sampler filters. Such contact due to certain body movements had been observed in other tests.

CONCLUSION

When clothing is contaminated with aerosolized microorganisms, these microorganisms can be reaerosolized by body movement during removal. If this removal takes place in a small enclosed space, ventilated or not,

the undresser is exposed to the aerosols and when unmasked may sustain a potentially hazardous dose of pathogenic microorganisms. Employing realistic clothing contamination densities, it has been shown that troops could be exposed to respiratory doses in excess of 100 spores. This number of certain potential BW agents could be considered an infectious dose.

References

1. Davids, D.E. and D.C. O'Connell. 1973. "A man-operated particulate aerosol sampler". In Proceedings of the Fourth International Symposium on Aerobiology. Enschede, the Netherlands. J.F. Ph. Hers and V.C. Winkler (Eds.). Oosthoek Publishing Co., Utrecht, The Netherlands, pp. 42-47.

2. "Installation, Operation and Maintenance Instructions with Illustrated Parts Breakdown C-B Modification Kit for Field Structures". Part No. 14500-100. Technical Manual, Edgewood Arsenal. September 1974. UNCLASSIFIED.

3. Fielding, G.H., R.A. Neihof, W.H. Echols and R.L. Dimmick. 1970. Disinfection with hypochlorite: Application to clothed men, construction materials, and electronic and electrical items. NRL Report 7067, Naval Research Laboratory, Washington, D.C.

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TABLE I

RESPIRATORY DOSES OF BG SPORES COLLECTED BY SUBJECTS DURING A CONTAMINATED CLOTHING REMOVAL PERIOD OF 2 MINUTES IN AN UNVENTILATED CUBICLE (TEST I)

Clothing Not Treated

Test No.	Clothing* Contamination Density/cm^2**	Respiratory Dose Collected by ECS***
1	256	6640
5	396	3600
6	400	3680
7	1730	8480
2	2160	5560
8	2160	2560
4	2550	5200
9	2600	6773
3	5400	6960
MEAN	1961	5495

* White cotton coveralls.

** Density/cm^2 determined by recovery of BG spores deposited on filter paper swatches.

*** Respiratory doses determined by recovery of BG spores collected on filters of the external canister sampler (ECS) fixed to the respirator.

[redacted]

TABLE II

RESPIRATORY DOSES OF BG SPORES COLLECTED BY SUBJECTS DURING A CONTAMINATED CLOTHING REMOVAL PERIOD OF 2 MINUTES IN AN UNVENTILATED CUBICLE (TEST II)

Clothing Not Treated

Subject No.	Clothing* Contamination Density/cm^2**	Respiratory Dose Collected by ECS***
3	311	980
2	326	2340
4	635	1720
5	960	640
6	1530	620
1	3140	2820
Mean	1150	1520

* White cotton coveralls.

** Density/cm^2 determined by recovery of BG spores deposited on filter paper swatches.

*** Respiratory doses determined by recovery of BG spores collected on filters of the external canister sampler (ECS) fixed to the respirator.

[redacted]

TABLE III

RESPIRATORY DOSES OF BG SPORES COLLECTED BY SUBJECTS DURING A CONTAMINATED CLOTHING REMOVAL PERIOD OF 2 MINUTES IN A VENTILATED CUBICLE

	Clothing Not Treated	
Subject No.	Clothing* Contamination Density/cm^2**	Respiratory Dose Collected by ECS***
2	492	620
10	524	840
7	663	1500
1	664	200
8	721	1000
6	730	380
9	974	400
5	997	300
3	1000	580
4	1138	240
MEAN	790	606

* Canadian Chemical Protective Coveralls.

** Density/cm^2 determined by recovery of BG spores deposited on filter paper swatches.

*** Respiratory doses determined by recovery of BG spores collected on filters of the external canister sampler (ECS) fixed to the respirator.

[redacted]

TABLE IV

RESPIRATORY DOSES OF BG SPORES COLLECTED BY SUBJECTS DURING A CONTAMINATED CLOTHING REMOVAL PERIOD OF 2 MINUTES IN AN UNVENTILATED CUBICLE

Clothing Wetted Down With Water

Subject No.	Clothing* Contamination Density/cm^2**	Respiratory Dose Collected by ECS***
8	318	20
7	530	40
5	777	300
6	850	20
4	1080	0
1	1200	0
9	1640	40
2	2190	0
11	2700	60
12	2875	20
3	2900	0
10	4200	100
MEAN	1772	50

$\frac{ID_{50}s}{N} = \frac{2}{12}$

* White cotton coveralls.

** Density/cm^2 determined by recovery of BG spores deposited on filter paper swatches.

*** Respiratory doses determined by recovery of BG spores collected on filters of the external canister sampler (ECS) fixed to the respirator.

[redacted]

TABLE V

RESPIRATORY DOSES OF BG SPORES COLLECTED BY SUBJECTS DURING A CONTAMINATED CLOTHING REMOVAL PERIOD OF 2 MINUTES IN AN UNVENTILATED CUBICLE

Clothing Wetted Down With SLASH****

Subject No.	Clothing* Contamination Density/cm^2**	Respiratory Dose Collected by ECS***
1	960	0
2	1815	0
3	1990	9
5	2050	40
4	2340	0
10	3050	0
9	3225	0
7	3830	0
6	3840	1660
8	7000	0
MEAN	3010	170

$\frac{ID_{50}s}{N} = \frac{1}{10}$

* White cotton coveralls.

** Density/cm^2 determined by recovery of BG spores deposited on filter paper swatches.

*** Respiratory doses determined by recovery of BG spores collected on filters of the external canister sampler (ECS) fixed to the respirator.

**** Acidified solution of hypochlorous acid (3).

[redacted]

TABLE VI

SIMULATED INFECTIOUS DOSES* (ID_{50}) SUSTAINED BY TEST SUBJECTS
DURING REMOVAL OF CONTAMINATED CLOTHING IN
BOTH VENTILATED AND UNVENTILATED
CONFINED SPACES

Test Subjects	Cubicle	Wet Down Treatment	Clothing Contamination Density BG Spores/cm^2	Ratio ID_{50}:N
1	Not Ventilated	none	1961 (256-5400)	9/9
6	Not Ventilated	none	1150 (311-3140)	6/6
10	Ventilated	none	790 (492-1138)	10/10
12	Not Ventilated	H_2O	1772 (318-4200)	2/12
10	Not Ventilated	SLASH	3010 (960-7000)	1/10

* 100 cells is assumed to represent an infectious dose.

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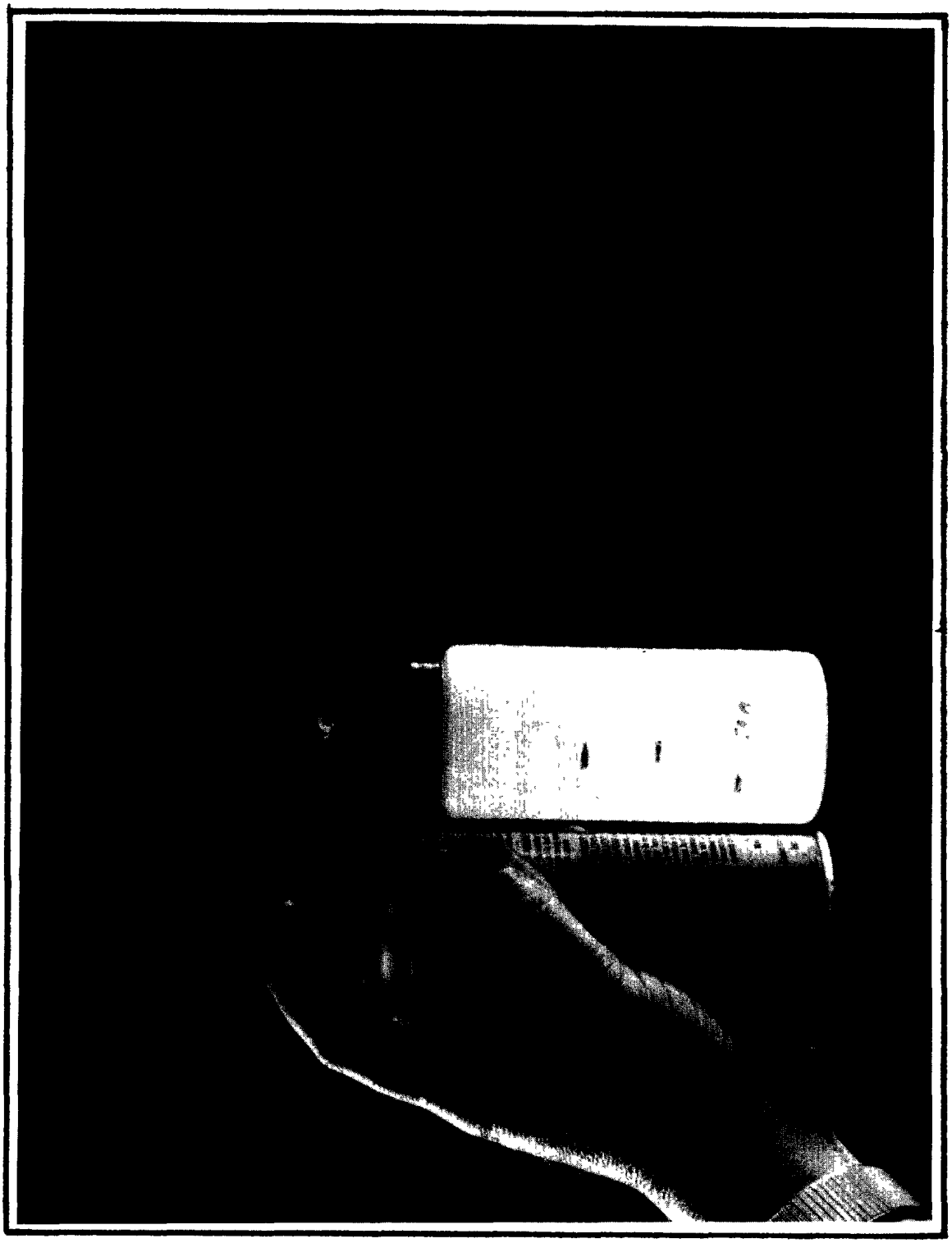

Figure 1

Jet Pack Sprayer

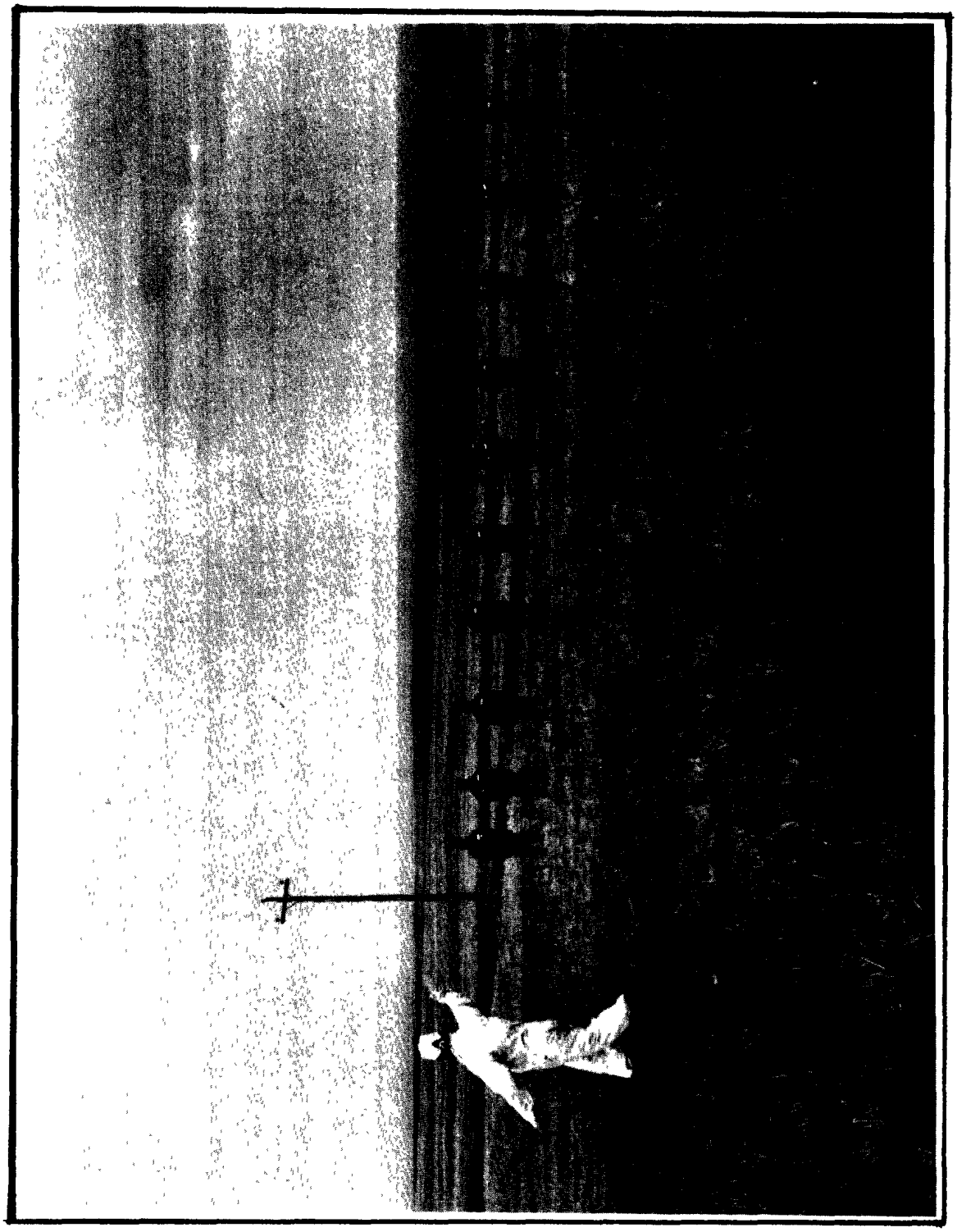

Figure 2

Exposure of Test Subjects to Primary Aerosol of BG

Figure 3

Placement of Filter Paper Samplers Used to Determine Degree of Contamination of Clothing by Primary Aerosols

Figure 4

Canadian C-2 Respirator Fitted with Filter Paper Sampler

Figure 5

Undressing Cubicle Used to Enclose Secondary Aerosols Generated by the Removal of Contaminated Clothing

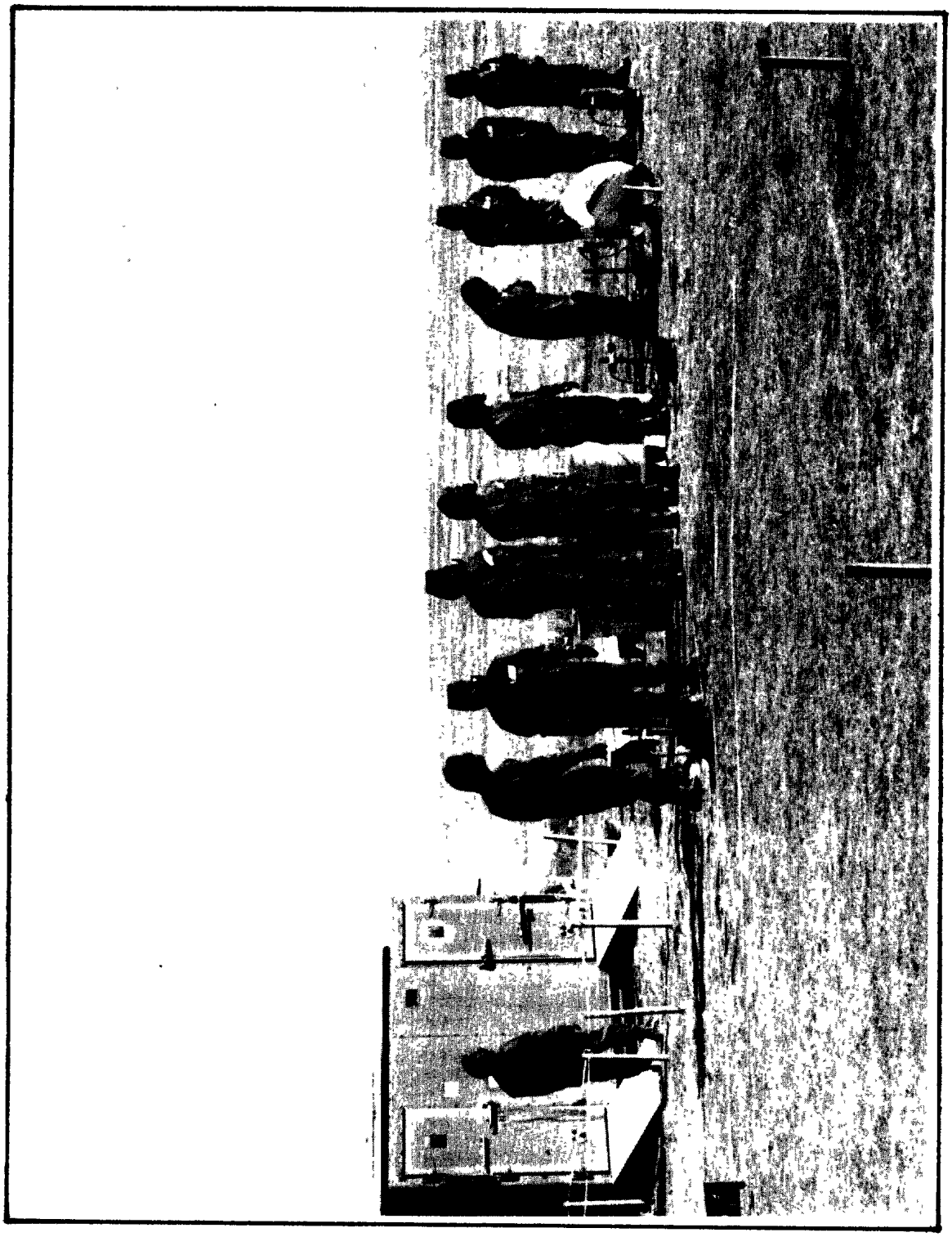

Figure 6
KMU 450/F Collective Protector

Figure 7

Wetting of Contaminated Clothing to Reduce the Secondary Aerosol Generated During Undressing Procedures

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