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TITLE

CASUALTY PRODUCING POWER OF UNTHICKENED MUSTARD GAS SPRAYED FROM LOW ALTITUDES UNDER TEMPERATE WEATHER CONDITIONS

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SUFFIELD FIELD REPORT NO. 97
(21 Sept. 44)

Casualty Producing Power of Unthickened Mustard Gas Sprayed from Low Altitudes Under Temperate Weather Conditions

REFERENCE

Field Experiment No. 251, trials 1 & 2 carried out 4 & 8 August, 1944.
U.S. Project Co-ordinate Board Meeting held at Edgewood 27 April 1944.
D.C.W. & S. Project S 143.
Suffield Field Reports No. 76 and 88.

INTRODUCTION

1. Field Experiments No.'s 229, and 243, reported in Suffield Field Reports No.'s 76 and 88 were carried out to determine the casualty producing power of low spray with unthickened HS Levenstein. A total of 48 observers were exposed on these experiments. On Field Experiment 229 most of the observers were exposed at points where the ground contamination ranged from 1 to 6 g/sq.m. On Field Experiment 243 most of the observers were exposed to ground contamination densities of less than 1 g/sq.m.

2. Field Experiment 251 was designed to obtain more observer results in the range 1 - 2 g/sq.m. Two trials were carried out, the first of which was largely unsuccessful due to difficulty in aiming the spray under the conditions of the trial. The results of this trial have been reported as Appendix I to this report. The body of this report deals with trial 2.

MATERIAL

3.
(i) One M10 Tank charged 326 lbs. HS (Levenstein) dyed 1.0% Williams Red dye. The charging was filtered before use.

(ii) The tank was fitted with a No. 2 detonator at the air inlet and a No. 3 detonator at the discharge outlet.

(iii) The viscosity (Ostwald) of the charging at 25°C was 5.1 centipoises before and after dyeing.

(iv) The Specific gravity of the charging at 10°C was 1.34.

(v) Temperature of the charging at take off was 16°C.

PROCEDURE

Observers

4. Thirty-five observers were disposed in five lines of seven observers each, the lines being 60, 80 90, 100 and 120 yards downwind of the upwind edge of the layout as shown in Appendix II.

PROCEDURE (cont.)

5. During the spraying the observers stood facing downwind. They were dressed as follows:

Battle-dress non-impregnated.
Shirts, long sleeved cotton.
Anklets socks and boots.
Respirators at the gas position.
Impermeable clothing (coat and trousers) was worn over the battle-dress, impermeable hoods were worn over the head, and rubber gloves on the hands. No underwear was worn by the observers.

6. Windows 4" x 4" were cut in the impermeable clothing in the position listed below:-

(i) One window at the back of each shoulder.
(ii) One window at the centre of the back just above the belt on the loose fitting part of the battle-dress blouse.
(iii) One window in the area of each collar bone in front. (Trials at Dugway have shown that there is a certain amount of contamination deposited on the downwind surface of the observers.)

The edges of the windows were sewn down to the underlying battle-dress.

7. A filter paper assembly fitted with a cardboard stiffener was fastened to the back of each observer just below the waist line so that it hung in a vertical plane.

8. After the spray had fallen the observers moved off the contaminated area and the impermeable clothing was removed. The remainder of the clothing was worn for four hours after the spraying. During this time 15 of the men took part in outdoor station fatigues (shovelling gravel). The remaining 20 men sat or lay about in a room at 75°F.

Assessment of Ground Contamination

9. Twenty - one rows of filter paper assemblies, 50 yards between rows, were laid out parallel to the wind direction. Each row was 250 yards long and consisted of filter paper assemblies at 5 yard intervals for the first 150 yards downwind, and at 10 yard intervals for the remaining 100 yards. At each observer position, 3 additional papers were placed as shown in Appendix II.

10. At each observer position and at all filter paper assembly points on Row E a piece of photographic paper 2" x 1" was placed in the ground to obtain a sample of the contamination for drop size analysis by the method outlined in Suffield Technical Minute No. 9.

11. Samples of the sprayed mustard gas were collected in chloroform in pie plates one of which was placed at each of positions 9, 13, 17, 21 and 29 of rows G, J, and L. The amount of dye in each plate was determined colorimetrically. The amount of mustard gas on each plate was estimated by the bromine titration method. A sample of charging from the spray tank was similarly analysed for dye and mustard content.

12. The M10 tank was functioned from the starboard wing stowage of a Boston IV (A 20 J) aircraft. The aircraft flew at a height of 50 feet, (measured by theodolites) at a true air speed of 225 mi/hr. The track was 30 yds. upwind of the edge of the layout.

RESULTS

Meteorological Conditions

13. Time: 0832 hrs. M.D.T.
Wind velocity at 2 metres at time of spraying 8.4 mi/hr.
Air temperature 17°C (62°F)
Ground temperature 20°C (68°F)
Relative humidity 61 %
Temperature gradient 39 ft. to 4 ft. -1.2°C to -2.0°C.

Contamination Densities

14. The contamination densities found by extraction and colorimetric estimation of the dye caught on filter paper assemblies on the layout at observer positions and on the backs of observers are given in Appendix III. A plot of the total area contaminated is given in Appendix IV. The contamination of the layout is summarized in table I below:

Table I

Summary of Contamination found on layout.

Density Range (g/sq.m)	Area Contaminated (sq. yds.)	Mean Density (g/sq.m.)	Recovery, percent of weapon contents
10 to 50	1000	22	12.6
5.0 to 10	3000	7.0	11.9
1.0 to 5.0	35800	2.2	45
0.50 to 1.0	22500	0.72	9.2
0.10 to 0.50	68000	0.24	8.9
< 0.10	97400	0.025	1.4
Totals	227000	0.69	89
Totals > 1.0	39800	0.31	69.5

15. The results of the colorimetric and chemical analyses of the spray as caught on the choloroform-filled plates are given in table II below. The mean ratio of H content of the plates by analysis to charging content by colorimetric estimation of dye, was 0.65. This figure was obtained by giving the ratio found for each plate a weight proportional to the ground contamination density found from the total amount of dye in the plate. Since the H content of the original charging was 71 % H, it follows that the mean loss of H due to evaporation was approximately 8 % over the range of positions investigated (70 yards downwind of A/C track to 170 yards downwind).

Table II

Position on Layout		Amount of charging caught in plate (mg.)	Ratio H content of plate (by Br.) / Charging (by dye)
J	9	23	0.65
	13	23	0.64
	17	62	0.68
	21	62	0.70
	25	12	0.63
	29	3.0	0.63
G	9	35	0.66
	13	70	0.59
	17	41	0.67
	21	13	0.69
	25	8	0.63
	29	8	0.63
L	9	51	0.62
	13	84	0.68
	17	49	0.68
	21	39	0.69
	25	45	0.68
	29	19	0.65
	(Original Charging		0.71)

Drop Spectrum Produced

16. By counting and sizing the stains found on the filter papers where contamination was not too heavy, and on the photographic papers where contamination was heavy the drop spectrum at each point on Row E was obtained. From a knowledge of the contamination density at each point the spectrum was obtained for all spray reaching the ground from the upwind edge of the contamination to a point 235 yards downwind of this. (Contamination began at line 4 on Row E, and extended to line 41). The percentage by weight of drops in various size groups is given below.

Size Group: drop wt. mg.	Size Group: drop diam. mm.	% by weight of total contamination found on Row E.
< 0.01	< 0.24	32
0.01 - 0.025	0.24 - 0.33	31
0.025 - 0.05	0.33 - 0.41	16
0.05 - 0.10	0.41 - 0.52	12
0.10 - 0.25	0.52 - 0.70	6
> 0.25	> 0.70	3

Effects on Observers

17. At 8 hours

(i) The men were examined 8 hours after zero. At this time one man showed extensive erythema and oedema of his back from shoulders to waist and a small vesicle was apparent in the region of the right shoulder blade.

(ii) Thirteen men showed areas of extensive erythema, varying from areas in the shoulder regions to extensive erythema involving the entire back.

17 (cont.)

(iii) Six men had faint areas of erythema, involving the areas of one or both shoulders.

(iv) Fifteen men showed no effects.

18. At 24 hours

(i) Five men showed areas of extensive vesication with erythema, and oedema extending from the shoulders to the belt line.

(ii) Seven men had areas of pin point vesication with erythema and oedema varying from localized areas in the region of the windows on the shoulders to extensive areas involving the entire back.

(iii) Three men showed definite areas of erythema, and oedema of the back, extending across the areas between the two windows on the shoulders.

(iv) Six men showed definite areas of erythema, demarcated by the windows on both shoulders.

(v) Eleven men showed faint erythema on one or both shoulders in the region of the windows.

(vi) Only 3 men showed nil effects.

19. At 48 hours

(i) Ten men showed large vesicles with areas of erythema and oedoma. The erythema varied from areas on the shoulders to extensive areas involving the shoulders and back, and in one case extending down the natal cleft.

(ii) Five men showed areas of pin point vesication with erythema, andoedema of the shoulders extending down the back to the belt line in some cases.

(iii) Two men had areas of erythema and oedema of the shoulders.

(iv) Four men had areas of erythema involving the skin in the region of the windows on the shoulders.

(v) Ten men had faint erythema of one or both shoulders in the region of the windows.

(vi) Four men showed no effects.

20. At 72 hours

The only change at this time was one case of erythema and oedema which had subsided and was now classed as erythema.

21. By seven days, most of the areas were healing, even on the more severely burned cases and pigmentation was quite well developed in the majority of cases. For a detailed description of lesions see Appendix V.

22. In no case did an observer become sufficiently contaminated in the region of the collar bone for any lesions to develop which could be attributed to the windows in this area.

23. The correlation between ground contamination in the vicinity of an observer and the physiological effect of the spray on the observer is given in Appendix III (Part A). The data are also arranged in this Appendix (Part B) to demonstrate the correlation between contamination density on the observers back and the physiological effects on the observer.

24. Of the 16 observers who were classified as being casualties, 8 had been performing outdoor fatigues for 4 hours after the spray while 8 had been sitting or lying about in a room at 75°F for this time. Casualties were assessed by extrapolation of the results obtained from exposure of limited areas of the observers' bodies. See Appendix V.

Discussion of Results

25. The results given in Appendix III show that the correlation between ground contamination and physiological effect on an observer is not as good as the correlation between contamination on the observers back and the physiological effect on the observer. The poorer correlation in the former case is partly due to the difficulty of determining what ground contamination density corresponds precisely to the point at which the observer stands, and partly due to the variation in the angle between the observers backs and the wind direction. (It is impossible to control this angle accurately.)

26. It appears from Appendix III (a) that under the conditions of this trial men exposed at points where the ground contamination is between 1.5 & 2.5 g/sq.m. stand approximately a 50% chance of becoming casualties, those exposed at points where the ground contamination is in excess of 3 g/sq.m. are almost certain to become casualties, and those exposed at points where the ground contamination density is less than 1 g/sq.m. are unlikely to become casualties.

27. Appendix III (b) indicates that of men whose backs have been contaminated by low spray to a density of between 2 and 4 g/sq.m. approximately 50% will become casualties. Men whose backs have been contaminated in excess of 4 g/sq.m. will almost certainly become casualties; men whose backs have become contaminated to less than 2 g/sq.m. will rarely become casualties.

28. There is no evidence to indicate that the casualty producing power of unthickened mustard is dependent upon dominant drop size with which an observer is contaminated, at least for the range of sizes encountered on this trial. (0.010 mg. to 0.050 mg. - 0.24 mm. to 0.41 mm. diam.).

29. The absence of lesions due to the exposure of two 4 x 4 inch areas in the region of the collar bone suggests that for wind speeds of 8 mi/hr. and above only the upwind areas on a man will be contaminated by unthickened mustard spray.

30. The recovery on the layout of 89% of the charging of the M 10 tank under the conditions of this trial indicates that only a small proportion of the charging is carried more than approximately 250 yards downwind of the track of the A/C for a spraying height of 50 ft. with a wind speed of 8 mi/hr. The recovery of 69% of the charging in the areas contaminated in excess of 1 g/sq.m., and the negligible area contaminated in excess of 10 g/sq.m. shows that under the conditions of this trial the performance of this M 10 tank charged unthickened HS Levinstein approaches the optimum for the production of anti personnel effects. (i.e. skin burns due to droplets.)

31. At an air temperature of 62°F the loss of mustard by evaporation from the spray droplets is not serious for a spraying height of 50 feet.

CONCLUSIONS

32 (i) The percentage of Casualties among troops sprayed with unthickened HS Levinstein in an 8 mi/hr. wind and wearing respirators, unimpregnated battle-dress, and long sleeved cotton shirts will be very high if the ground contamination is greater than 3 g/sq.m. and very low if the ground contamination is less than 1 g/sq.m.

(ii) The contamination found on observers' backs have been compared with the contamination to be expected from a knowledge of wind speed, drop size, and ground contamination. The geometric mean of the ratio of calculated to observed vertiaal contamination density for 34 observers is 1.6, the same result as was obtained in a 15 mi/hr wind on the trial reported in SFR 88 para. 22. (The arithmetic mean only was reported; the geometric mean, of more significance was 1.6)

CONCLUSIONS (cont.)

(ii) The percentage of casualties among troops sprayed with unthickened HS Levinstein and dressed as in (i) above will be very high if the contamination density on their backs exceeds 4 g/sq.m., and very low if this density is less than 2 g/sq.m.

33. Unthickened HS Levinstein, when sprayed from an M 10 carried on a Boston (A20J) A/C flying at 50 ft. at a speed of 225 mi/hr. has contaminated an area of 36,000 sq. yards (500 x 75 yds. approx.) in excess of 1 g/sq.in. About 60% of the charging reached the ground in drops smaller than 0.025 mg. drop weight (0.33 mm. diam.); and approximately 90% in drops smaller than 0.10 mg. drop weight (0.52 mm. diam.).

AWB:pkn

A W Birnie

(A. W. Birnie) Capt.
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Experimental Station

Appendix I

Trial I of Field Experiment 251

MATERIAL

1. The charging used on this trial was prepared in the same manner as that used in Trial 2, and had the same viscosity and specific gravity. Temperature of charging at take - off was 17°C. The spray tank installation was the same on both trials.

PROCEDURE

Layout

2. The layout used on trial 1 was the same as that used on trial 2. (See paras 9,10, and 11 body of the report, and Appendix II.)

Observers

3. Twenty - five observers were disposed in lines of five observers each, 60, 80, 90 . 100 and 120 yards downwind of the upwind edge of the layout. They were positioned on alternate lines from E to N. On this trial the observers stood midway between the two upwind papers of the four forming a square on the ground near the observer.

4. The observers were stationed facing downwind. They were dressed as for trial 2 (see paras 5, 6, and 7 body of report).

5. The M 10 tank was functioned from the starboard wing stowage of a Boston IV (A 20J). The A/C flew at a height of 360 feet at a true air speed of 225 mi/hr. The track was 30 yards upwind of the upwind edge of the layout.

6. After the spray the observers were removed from the layout and stripped of their impermeable clothing. They wore the remainder of their clothes for 4 hours. During this time 12 men took part in out door fatigues (shovelling gravel) and the remaining men spent the time indoors, sitting or lying down at a temperature of 75°F.

RESULTS

Meteorological Conditions

7. Time 0845 hrs. M.D.T.
Wind speed at 2 metres at time of spraying 5.5 Mi/hr.
Air Temperature 73°F (23°C).
Surface temperature 77°F (25°C).
Relative Humidity 38%
Temperature Gradient -1.0 to - 0.5°C.

8. The layout had been put down for a predicted West wind and the observers were stationed facing East. The wind at the time of the trial was S.W. and variable. Although the spray contaminated a fair portion of the layout. and gave a pattern indicating that the direction of the mean wind to height was approximately S.W., an examination of the observers before they removed their impermeable clothing showed that the wind direction at 2 meters was very nearly due South at the time the spray reached the ground. The observers showed relatively dense contamination on the impermeable clothing down their right side, but very little on their backs. Consequently observers standing in regions of relatively heavy ground contamination showed no effects from their exposure.

9. Only two observers J 13 and N 17 were sufficiently contaminated to show lesions. No effects were observed corresponding to the sites of the windows cut in the area of the collar bone.

10. The contamination density on the back of Observer J 13 was 0.85 g/sq.m. of drops approximately 0.2 mm. diam. (0.008 mg.). Ground contamination at this position was 1.3 g/sq.m. At 24 hours this man showed erythema and oedema of the right shoulder, with pin point vesication 4.5 x 3.0 cms. His left shoulder showed erythema and oedema corresponding to the site of the window in the impermeable clothing. At 48 hours the pin point vesication had increased to 8.0 x 5.5 cms. No change was observed on the left shoulder. At 7 days both shoulders were pigmented and desquamation had started in the centre of the patches. It is considered that this man would have become a casualty had he not been protected by impermeable clothing. (except for windows.)

11. The contamination density on the back of observer N 17 was 0.54 g/sq.m. of drops approximately 0.33 mm. in diameter (0.025 mg.). The ground contamination density at this point was 2.6 g/sq.m. At 24 hours this observer showed two areas of erythema approaching erythema and oedema corresponding to the 2 holes cut in the shoulders of his impermeable clothing. At 48 hours there was no change. At 6 days both areas were pigmented and showed some desquamation. It is considered that this man would not have become a casualty had he not worn the impermeable clothing.

12. A limited number of filter paper assemblies and photographic papers was examined to determine drop spectrum at various points throughout the contaminated area. The greater part of the charging appeared to have reached the ground in droplets less than 0.24 mm. in diameter (0.0010 mg.).

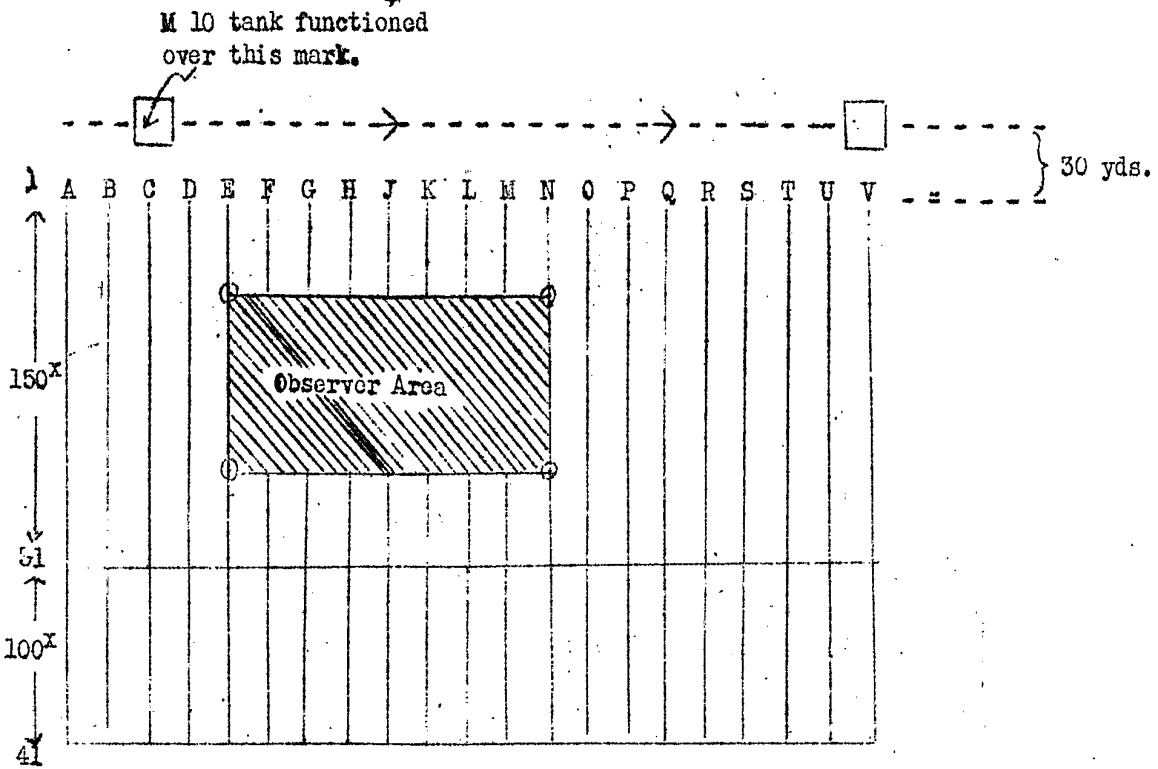
13. Of the chloroform - filled plates exposed to the spray, 7 were sufficiently contaminated for an estimation of dye and mustard content to be made. These results are given below.

Position	Contamination found in plate (g/sq.m.)	Ratio: H content of plate (by Hr.) / Charging content (by dye)
J 9	2.1	0.62
J 13	0.7	0.55
L 9	1.1	0.68
L 13	0.25	0.49
L 17	0.15	0.45
L 25	0.05	0.32
G 9	0.04	0.42

14. The weighted mean ratio of H content of the plates to amount of charging in plate is 0.58. Since the original H content of the charging was 71%, the average loss by evaporation corresponds to 18% of the original H content. This figure is only approximate since the contaminated area was not uniformly sampled.

Discussion

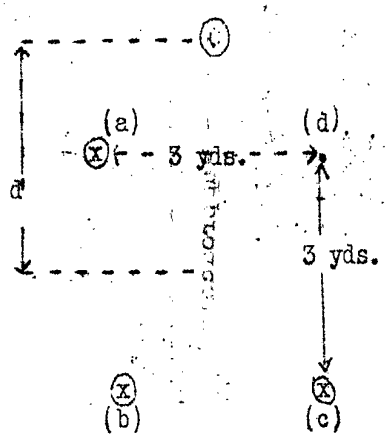
15. The physiological results obtained on this trial are too meagre for any conclusions to be drawn. However the trial has served to show that the technique of exposing observers protected by impermeable clothing except for windows has practical limitations. If it is desired to correlate physiological effect on observers with the ground contamination in the vicinity of the observer, it is essential in using the window technique that the observer be similarly orientated with respect to wind direction at 2 meters on all trials. Orientation of the observer would not be as critical if unprotected observers were used, since some part of the observer would always be exposed perpendicular to the wind direction.



tracking marks (white jump cards in form of inverted V 4 ft. high) opposite rows C and V.

additional tracking marks -- white jump cards opposite rows J and Q.

Rows A to V were 50 yards apart.
Each row consisted of 31 filter paper assemblies 5^X apart (positions 1 to 31) and 10 papers 10^X apart (positions 32 to 41).
Observers were positioned on rows E, G, H, J, K, L and N, 60, 80, 90, 100 and 120 yds. downwind of the upwind edge of the layout (25 observers). Near each observer additional filter paper assemblied were placed as indicated below.



Ⓞ observer
• layout filter paper assembly
Ⓧ additional papor assembly

$$d\ (\text{yds.}) = \frac{\text{windspeed at 6 ft. in mi/hr.}}{4}$$

(Drops 0.35 mm. in diameter will travel this distance downwind in falling from a height of 3 ft. - the height of the filter paper attached to observers.)

Appendix III

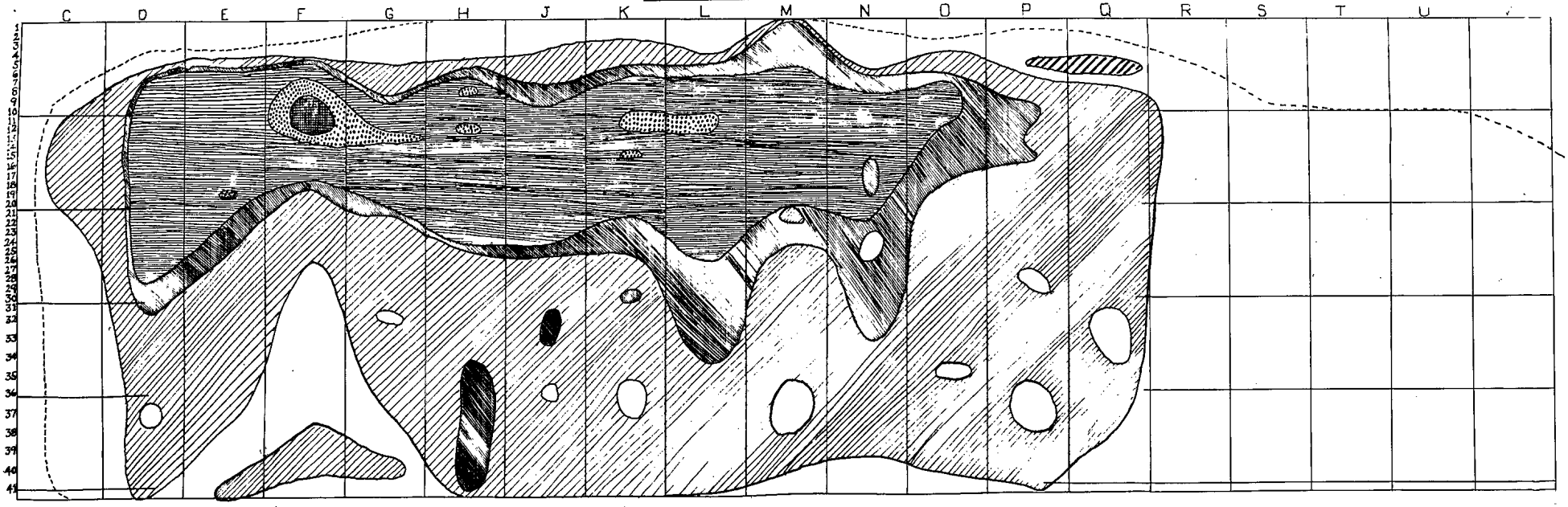
Part "A"						Part "B"			
Observer	Ground Contamination Density near Observer (g/sq.m.).	Dominant Drop Size mg. wt.	Dominant Drop Size mm. diam.	Physiological Effect	* Casualty	Observer	Contamination Density on Observer's Back (g/sq.m.)	Physiological Effect	* Casualty
E 13	5.2	0.020	0.30	V E +	Yes	E 17	10.5	V E +	Yes
G 13	4.4	0.025	0.33	V E +	Yes	K 13	10.5	V E +	Yes
J 17	3.8	0.025	0.33	E	No	L 13	10.5	V E +	Yes
E 19	3.7	0.010	0.24	PPV E +	Yes	E 19	9.0	PPV E +	Yes
E 13	3.4	0.035	0.37	V E +	Yes	E 13	7.6	V E +	yes
L 13	3.0	0.025	0.33	V E +	Yes	H 17	7.0	V E +	Yes
N 13	2.7	0.035	0.37	V E +	Yes	L 19	6.0	V E +	Yes
J 19	2.7	0.035	0.37	E -	No	E 21	5.4	V E +	Yes
H 13	2.6	0.050	0.41	PPV E +	Yes	H 13	4.9	PPV E +	Yes
E 21	2.5	0.010	0.24	V E +	Yes	G 13	4.8	V E +	Yes
E 17	2.2	0.040	0.39	PPV E +	Yes	N 13	3.9	V E +	Yes
J 21	2.2	0.025	0.33	E	No	G 21	3.8	PPV E +	Yes
L 17	2.1	0.020	0.30	PPV E +	Yes	L 17	3.7	PPV E +	Yes
G 17	2.0	0.025	0.33	E -	No	J 21	3.6	E	No
G 19	1.8	0.050	0.41	E -	No	G 17	3.1	E -	No
H 17	1.7	0.050	0.41	V E +	Yes	N 17	2.5	E -	No
H 19	1.6	0.025	0.33	E +	No	N 19	2.1	PPV E +	Yes
H 21	1.4	0.025	0.33	E -	No	L 25	2.0	E	No
N 17	1.4	0.020	0.30	E -	No	J 13	2.0	V E +	Yes
N 19	1.2	0.025	0.33	PPV E +	Yes	H 19	1.6	E +	No
N 21	1.1	0.020	0.30	E	No	G 19	1.6	E -	No
L 19	1.1	0.025	0.33	V E +	Yes	K 19	1.6	PPV E +	Yes
L 21	1.1	0.010	0.24	Nil	No	G 25	1.5	E -	No
L 25	1.1	0.010	0.24	E	No	J 19	1.4	E -	No
E 25	1.0	0.010	0.24	E -	No	K 17	1.4	E	No
J 13	1.0	0.050	0.41	V E +	Yes	J 25	1.3	E	No
K 17	1.0	0.050	0.41	E	No	N 21	1.2	E	No
K 19	1.0	0.010	0.24	PPV E +	Yes	N 25	0.94	E -	No
K 21	1.0	0.010	0.24	Nil	No	H 21	0.65	E -	No
N 25	1.0	0.010	0.24	E -	No	K 21	0.62	Nil	No
J 25	0.6	0.025	0.33	E	No	J 17	0.61	E	No
H 25	0.5	0.010	0.24	Nil	No	K 25	0.44	E	No
K 25	0.47	0.010	0.24	E	No	E 25	0.29	E -	No
G 21	0.43	0.025	0.33	PPV E +	Yes	L 21	0.17	Nil	No
G 25	0.18	0.010	0.24	E -	No	H 25	trace	Nil	No.

* The decision as to whether or not an observer was classified as a casualty was based on the severity of the lesions which it was considered would have occurred had the observer been exposed without any part of his body protected by impermeable clothing.

TRACK OF A/C →

WIND DIRECTION ↓

APPENDIX IV S.F.R. No. 97



BOUNDARY OF CONTAMINATION -----

CONTAMINATION <.1 g/sq.m. □

" 0.1 - 0.5 g/sq.m. ▨

" 0.5 - 1.0 g/sq.m. ■

" 1.0 - 5.0 g/sq.m. ■

" 5.0 - 10.0 g/sq.m. ▩

" 10 - 50 g/sq.m. ■

N

50"

APPENDIX V

DETAILED DESCRIPTION OF LESIONS

The decision as to whether or not an observer was classified as a casualty was based on the severity of the lesions which it was considered would have occurred had the observer been exposed without impermeable clothing, extrapolating from the lesions resulting from exposure of three areas 4 x 4 inches on the back, and two 4 x 4 inch areas in front.

It was difficult to make this extrapolation with accuracy. Consequently in this appendix the observers have been divided into four groups: (1) casualty, (2) probable casualty, (3) possible casualty (4) non-casualty. For the tables in the body of the report all first three groups are classed as casualties.

Casualties are definite, showing extensive areas of vesication, erythema and œdema.

Probable casualties show small vesicles or areas of pin-point vesication which do not become confluent, but which, if they occurred on sensitive areas of the body, would likely result in the man becoming a casualty.

Possible casualties may show areas of pin-point vesication which are delayed in appearing or which cover a small area of the body. These lesions, if they occurred in more sensitive areas of the body, might result in the man becoming a casualty.

Non-casualties show areas of erythema and œdema or less, with no tendency to vesicate.

Detailed descriptions of the physiological effects found on the various observers are given below.

LINE E, Position 13.

Ground contamination - 5.2 g/sq.m.
Contamination on Observer's back - 7.6 g/sq.m.
Dominant drop size - 0.020 mg. (0.30 mm.) diam.

At 8 hours this man showed erythema across the entire upper back and down the mid-line to the waist. At 24 hours: left shoulder - pin-point vesication 6.0 x 2.0 cm. on shoulder blade; right shoulder - pin-point vesication 4.0 x 2.8 cm. on shoulder blade. Both these areas were surrounded by erythema and oedema 30 x 30 cm. At 48 hours: left - vesication 3 x 1.8 cm. surrounded by pin-point vesication 8 x 4 cm. Erythema in left armpit; right - pin-point vesication 4 x 3 cm.; mid-line - pin-point vesication 13 x 3 cm. This whole area surrounded by an area of erythema and oedema 38 x 37 cm. At 72 hours: Left shoulder - area of ruptured vesicles and pin-point vesicles 20 x 20 cm. The skin was pigmenting. (Casualty).

LINE E, Position 17.

Ground contamination - 2.2 g/sq.m.
Contamination on Observer's back - 10.5 g/sq.m.
Dominant drop size - 0.040 mg. (0.39 mm.) diam.

At the 8-hour examination this man showed erythema of the upper back. At 24 hours: the back showed erythema going on to erythema and oedema over an area 24 x 26 cm. At 48 hours: Erythema and oedema of entire back 26 x 40 cm. There were a few small PPV's in mid-line. At 72 hours: Pin-point vesicles and devitalized skin had increased to cover an area 10 x 20 cm. on the mid-line and extending up to the left shoulder. Erythema and oedema surrounded this area 23 x 38 cm. At 96 hours: There was erythema of the left armpit. The oedema of the back had disappeared and the erythema was fading.

(Possible casualty.)

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LINE E, Position 19.

Ground contamination - 3.7 g/sq.m.
Contamination on Observer's back - 9.0 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At the 8-hour examination this man showed extensive erythema of the upper back. At 24 hours: There was erythema and oedema of the upper back 30 x 30 cm. There were scattered pin-point vesicles on the left shoulder 4.0 x 2.5 cm. At 48 hours: The erythema and oedema of the back had increased to 40 x 32 cm. The pin-point vesication on the left shoulder had increased to an area of 12 x 8 cm. There was erythema at the posterior border of both armpits. At 96 hours: There was erythema and oedema of both armpits. Pin-point vesication of the left shoulder was 11 x 10.5 cm. and there was an area of pin-point vesication on the right shoulder 4 x 9 cm. Erythema and oedema surrounding this area was 30 x 38 cm. (Probable casualty.)

LINE E, Position 21.

Ground contamination - 2.5 g/sq.m.
Contamination on Observer's back - 5.4 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 8 hours: this man showed extensive erythema of the back. At 24 hours: Several huge vesicles had appeared: - left shoulder - vesicle 4.5 x 3 cm.; coalescent vesicles - 11.5 x 10.0 cm.; right shoulder - coalescent vesicles 13.0 x 10 cm.; small of back - vesicles 2.5 x 1.5 cm. This area was surrounded by an area of erythema and oedema 31 x 34 cm. At 48 hours: It was difficult to see much change at 48 hours except the coalescent vesicles had become confluent. At 96 hours: Two small vesicles had appeared, one on each side at the level of the lower border of the scapula, (1) 1.5 x 1.0 cm. and (2) 2.0 x 1.5 cm. (Casualty.)

LINE E, Position 25.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 0.29 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 8 hours there was a faint suggestion of erythema over the left shoulder. At 24 hours there was faint erythema of the left shoulder 9.5 x 8.0 cm. At 48 hours the erythema was fading (9 x 7 cm.). At 96 hours the erythema had faded. (Non-casualty.)

LINE G, Position 13.

Ground contamination - 4.4 g/sq.m.
Contamination on Observer's back - 4.8 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At the 8-hour examination there was extensive erythema of the entire back. At 24 hours there were several large vesicles over the back (1) 8 x 6 cm., (2) 3 x 3 cm., (3) 1 x 1 cm., (4) 1.8 x 1.0 cm., (5) 5.5 x 2.7 cm. The entire area was joined by coalescent small vesicles 28 x 27 cm. This whole area was surrounded by erythema and oedema 30.0 x 36.0 cm. At 48 hours the entire back was covered by coalescent vesication 30 x 30 cm. At 96 hours the large vesicle roofs had separated, the small coalescent vesicles had collapsed and the entire area was pigmenting. Faint erythema of the left armpit was present (Casualty.)

LINE G, Position 17.

Ground contamination - 2.0 g/sq.m.
Contamination on Observer's back - 3.1 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours there was questionable erythema of the left shoulder. At 24 hours there was faint erythema of the left shoulder 7.0 x 5.0 cm. At 48 hours both shoulders showed faint erythema. At 96 hours both shoulders were pigmenting. (Non-casualty.)

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LINE G, Position 19.

Ground contamination - 1.8 g/sq.m.
Contamination on Observer's back - 1.6 g/sq.m.
Dominant drop size - 0.050 mg. (0.41 mm.) diam.

At 8 hours there was no evidence of erythema. At 24 hours there was faint erythema of the left shoulder 4.0 x 3.0 cm. At 48 hours this was fading. At 96 hours there was slight pigmentation in this area.

(Non-casualty.)

LINE G, Position 21.

Ground contamination - 0.43 g/sq.m.
Contamination on Observer's back - 3.8 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours there was erythema of the upper back. At 24 hours there was erythema going on to erythema and oedema across the shoulders and extending down the mid-line of the back 27 x 23 cm. At 48 hours the erythema and oedema had increased to cover an area 32 x 30 cm. There was pin-point vesication on the left shoulder 4 x 3 cm. and an area 6 x 5 cm. on the right shoulder. At 96 hours the pin-point vesicles had collapsed and the erythema was fading.

(Possible casualty.)

LINE G, Position 25.

Ground Contamination - 0.18 g/sq.m.
Contamination on Observer's back - 1.5 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At the 8-hour observation there were two faint areas of erythema, one over each shoulder. At 24 hours there was faint erythema of both shoulders, left shoulder - 7.0 x 7.0 cm.; right shoulder - 9.0 x 8.0 cm. At 48 hours these areas were unchanged. At 96 hours both these areas were pigmenting.

(Non-casualty.)

LINE H, Position 13

Ground contamination - 2.6 g/sq.m.
Contamination on Observer's back - 4.9 g/sq.m.
Dominant drop size - 0.050 mg. (0.41 mm.) diam.

At 8 hours this man showed erythema over both shoulders. At 24 hours there was erythema going on to erythema and oedema extending over both shoulders and down the back 30 x 23 cm. There was pin-point vesication of the left shoulder 4 x 3 cm. At 48 hours there was erythema of both armpits and the erythema and oedema had extended to 35 x 36 cm. There were two vesicles on the left shoulder 1 x 1 cm. and 1.5 x 1.3 cm. This area was surrounded by pin-point vesication 8.5 x 5.8 cm. At 72 hours the areas of the windows on the shoulders were becoming desquamated. There was one vesicle on the left shoulder 3 x 2.2 cm. surrounded by pin-point vesication 10.5 x 8.0 cm. (Probable casualty.)

LINE H, Position 17.

Ground contamination - 1.7 g/sq.m.
Contamination on Observer's back - 7.0 g/sq.m.
Dominant Drop Size - 0.050 mg. (0.41 mm.) diam.

At 8 hours this man showed extensive erythema of the upper back and shoulders. At 24 hours he showed a vesicle 4.5 x 3.5 cm. surrounded by numerous small vesicles on the left shoulder. This area was surrounded by erythema and oedema 11.5 x 10.0 cm. The right shoulder showed a vesicle 5.5 x 4.5 cm. surrounded by pin-point vesication 9.0 x 9.0 cm. The whole of the right shoulder was involved in erythema and oedema 24.0 x 13.5 cm. There were three small vesicles in the mid-line. At 48 hours there was very little change except that the erythema and oedema had become confluent to cover an area 38 x 39 cm. and erythema had developed in both armpits. At 72 hours the blister roofs had sloughed and pigmentation was developing between the sloughed area. (Casualty).

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LINE H, Position 19.

Ground contamination - 1.6 g/sq.m.
Contamination on Observer's back - 1.6 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed erythema of both shoulders in the region of the windows. At 24 hours there was erythema and oedema of both shoulders in the region of the windows; left shoulder - 12 x 12 cm.; right shoulder 13 x 11.5 cm. At 48 hours these areas were unchanged. At 72 hours the oedema had subsided and the areas were beginning to pigment. (Non-casualty.)

LINE H, Position 21.

Ground contamination - 1.4 g/sq.m.
Contamination on Observer's back - 0.65 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours nothing could be seen. At 24 hours there was faint erythema of the left shoulder. At 48 hours this had faded. (Non-casualty.)

LINE H, Position 25.

Ground contamination - 0.5 g/sq.m.
Contamination on Observer's back - Trace.
Dominant drop size -0.010 mg. (0.24 mm.)diam.

At no time was there any lesion. (Non-casualty.)

LINE J, Position 13.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 2.0 g/sq.m.
Dominant drop size - 0.050 mg. (0.41 mm.) diam.

At 8 hours this man showed erythema of his shoulders. At 24 hours he showed erythema going on to erythema and oedema of his back 31 x 31 cm. There were pin-point vesicles on his left shoulder 6 x 3.0 cm. The areas were joined by a confluent morbilliform type of rash. On questioning it was found that he had received an H burn on his forearm $1\frac{1}{2}$ months previously. At 48 hours the erythema and oedema had increased to 39 x 36 cm. The left shoulder showed pin-point vesication 9.5 x 6.0 cm. and the right shoulder showed an identical area 9.5 x 6.0 cm. There was a small area of pin-point vesication on the mid-line. At 72 hours the periphery of the area was pigmenting and the oedema was subsiding. There was an area of devitalized skin on the mid-line of the back 15 x 22 cm. At 96 hours there were two vesicles on the left shoulder 2.2 x 4 cm. and 1.5 x 2.2 cm. There was one vesicle on the right shoulder 3.8 x 2.1 cm. surrounded by pin-point vesication 10 x 12 cm. (Casualty.)

LINE J, Position 17.

Ground contamination - 3.8 g/sq.m.
Contamination on Observer's back - 0.61 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed faint erythema of the right shoulder. At 24 hours there was erythema of the right shoulder 17.5 x 9.0 cm. At 48 hours the erythema had decreased to 9 x 9.5 cm. At 72 hours there was a small area of desquamation on the right shoulder. (Non-casualty.)

LINE J, Position 19.

Ground contamination - 2.7 g/sq.m.
Contamination on Observer's back - 1.4 g/sq.m.
Dominant drop size - 0.035 mg. (0.37 mm.) diam.

At 8 hours no erythema was visible. At 24 hours there was faint erythema of the right shoulder 5 x 5 cm. At 48 hours the erythema, though faint, had increased to 4 x 7 cm. At 72 hours the erythema had faded. (Non-casualty.)

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LINE J, Position 21.

Ground contamination - 2.2 g/sq.m.
Contamination on Observer's back - 3.6 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed faint erythema of his shoulders. At 24 hours there was erythema of his left shoulder 11.0 x 8.0 cm. The right shoulder showed faint erythema 5.0 x 4.0 cm. At 48 hours these areas were unchanged. At 72 hours all erythema was fading. (Non-casualty.)

LINE J, Position 25.

Ground contamination - 0.6 g/sq.m.
Contamination on Observer's back - 1.3 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours there was faint erythema of both shoulders. At 24 hours there was erythema of both shoulders, left - 8.0 x 5.0 cm., right - 8.0 x 8.0 cm. At 48 hours these areas were unchanged. At 72 hours both shoulders were pigmenting. (Non-casualty.)

LINE K, Position 13.

Ground contamination - 3.4 g/sq.m.
Contamination on Observer's back - 10.5 g/sq.m.
Dominant drop size - 0.035 mg. (0.37 mm.) diam.

At 8 hours this man showed erythema of the back. At 24 hours there was pin-point vesication on both the left and right shoulders. Left shoulder - 10 x 7 cm., right shoulder - 10 x 7.5 cm. These areas were surrounded by erythema and oedema 40 x 43 cm. which extended onto both left and right armpits. There was a morbilliform rash superimposed on the redness. On questioning the man, it was found that he had received an H burn on the right forearm nine months previously. At 48 hours there was a vesicle 5.5 x 2.4 cm. on the left shoulder surrounded by pin-point vesication 10 x 8 cm. There was a vesicle 5.5 x 5.3 cm. on the right shoulder surrounded by pin-point vesication 12 x 11 cm. The entire back to the beltline was involved in erythema and oedema which also extended onto the armpits. At 96 hours these lesions were improving. (Casualty.)

LINE K, Position 17.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 1.4 g/sq.m.
Dominant drop size - 0.050 mg. (0.41 mm.) diam.

At 8 hours this man showed faint erythema of both shoulders. At 24 hours there was erythema of the right shoulder 9.5 x 11.0 cm. and faint erythema of the left shoulder 9 x 7 cm. At 48 hours these areas were unchanged. At 72 hours the erythema was fading on both shoulders. (Non-casualty.)

LINE K, Position 19.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 1.6 g/sq.m.
Dominant Drop Size - 0.010 mg. (0.24 mm.) diam.

At 8 hours this man showed erythema of his shoulders. At 24 hours he showed erythema going on to erythema and oedema 30 x 17 cm. with scattered pin-point vesicles through this area. At 48 hours the area had increased to erythema and oedema 30 x 35 cm. with scattered pin-point vesicles throughout the area. There was a faint erythema of the right armpit. At 72 hours there was erythema of both armpits and the skin on the back was pigmenting. There were several small pustules formed on the right shoulder blade 2 x 5 cm. (Possible casualty.)

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LINE K, Position 21.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 0.62 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At no time did this man show any sign of erythema. (Non-casualty.)

LINE K, Position 25.

Ground contamination - 0.47 g/sq.m.
Contamination on Observer's back - 0.44 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 24 hours this man showed erythema of both shoulders in the region of the windows. Left shoulder - 12 x 10.5 cm.; right shoulder - 14 x 13 cm. At 48 hours these areas were unchanged. At 72 hours these was desquamation of the right shoulder over an area 7 x 9 cm. (Non-casualty.)

LINE L, Position 13.

Ground contamination - 3.0 g/sq.m.
Contamination on Observer's back - 10.5 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed extensive erythema of the entire back. At 24 hours there were several large vesicles ppresent: right shoulder - 6.5 x 4.0 cm., 5.0 x 4.5 cm. These two were joined by a confluent area of pin-point vesication 12.5 x 10 cm. Right shoulder - vesicle 3 x 2.5 cm. surrounded by confluent small vesicles 12.5 x 9.5 cm. There were several vesicles in the mid-line starting from the level of the lower border of the scapula and extending down past the small of the back: (1) 3.5 x 3.5 cm. (2) 7.0 x 5.5 cm., (3) 6.0 x 4.0 cm., (4) 4.5 x 3.7 cm. (5) 5.5 x 6.0 cm. (6) 7.1 x 2.5 cm. This whole area was joined by confluent small vesicles 42 x 16 cm. The whole of the back was involved in erythema and oedema 45.0 x 60.0 cm. which extended down to and involved the natal cleft. At 48 hours the areas of small vesicles were coalescing. At 96 hours erythema and oedema of the left armpit. The large vesicle roofs had sloughed, the small coalescent vesicles had collapsed and there was a dusky pigmentation to the entire area. (Casualty.)

LINE L, Position 17.

Ground contamination - 2.1 g/sq.m.
Contamination on Observer's back - 3.7 g/sq.m.
Dominant drop size - 0.020 mg. (0.30 mm.) diam.

At 8 hours this man showed erythema of his shoulders and mid-line of his back. At 24 hours there was erythema going on to to erythema and oedema of the right shoulder 12 x 10.5 cm., with a few scattered pin-point vesicles. There was erythema of the left shoulder 6 x 9 cm. There was faint erythema progressing to sharp erythema in the mid-line of the back 11 x 5 cm. At 48 hours the erythema had become confluent and covered an area 31 x 30 cm. Pin-point vesication was unchanged. At 72 hours pin-point vesication was present on the left and right shoulders and on the mid-line of the back: left shoulder - 8 x 5 cm., right shoulder - 7 x 5 cm., Mid-line of back - 18 x 4 cm. (Probable Casualty.)

LINE L, Position 19.

Ground contamination - 1.1 g/sq.m.
Contamination on Observer's back - 6.0 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed erythema of the shoulders and mid-line of the back. At 24 hours he showed erythema going on to erythema and oedema of the back 30 x 32 cm. There were two small vesicles below the right shoulder blade 1 x 1 and 0.7 x 0.4 cm. At 48 hours one more vesicle had formed on the right shoulder 1 x 0.5 cm. There was erythema of both armpits. At 72 hours one more vesicle had appeared on the mid-line. Pin-point vesicles extended

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down the mid-line 19 x 12 cm. Pin-point vesicles on the left shoulder covered an area 8 x 6 cm. At 96 hours a rash appeared in the mid-axillary line of the right side and extended around to the front of the abdomen on that side. This rash faded in another 24 hours. (Probable Casualty.)

LINE L, Position 21.

Ground contamination - 1.1 g/sq.m.
Contamination on Observer's back - 0.17 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At no time did any lesions appear. (Non-casualty.)

LINE L, Position 25.

Ground contamination - 1.1 g/sq.m.
Contamination on Observer's back - 2.0 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 8 hours this man showed faint erythema of both shoulders. At 24 hours there was faint erythema of the left shoulder 9 x 8.5 cm. and well defined erythema of the right shoulder 8.5 x 8.5 cm. At 48 hours these areas were the same. At 72 hours the erythema on both shoulders was fading. (Non-casualty.)

LINE N, Position 13.

Ground contamination - 2.7 g/sq.m.
Contamination on Observer's back - 3.9 g/sq.m.
Dominant drop size - 0.035 mg. (0.37 mm.) diam.

At 8 hours this man showed erythema of the entire back. At 24 hours there were numerous areas of coalescent small vesicles: left shoulder - (1) 6 x 4 cm., (2) 3 x 2 cm.; right shoulder (1) 6.8 x 5.2 cm.; mid-line-(1) 24 x 5 cm. There were 2 vesicles on this area in the mid-line 2.1 x 2.5 and 2.2 x 2.5 cm. The entire area was surrounded by erythema and oedema 31 x 36 cm. At 48 hours the vesicles on the shoulder and the mid-line had become confluent. At 96 hours the left shoulder had a vesicle 5.2 x 3.5 cm. surrounded by collapsed small vesicles 10 x 10 cm., and the right shoulder, extending down the mid-line, pin-point vesicles 15 x 5 cm. In the mid-line was (1) vesicle 3.5 x 3.2 cm., and (2) vesicle 5.5 x 2.8 cm. (Casualty.)

LINE N, Position 17.

Ground contamination - 1.4 g/sq.m.
Contamination on Observer's back - 2.5 g/sq.m.
Dominant drop size - 0.020 mg. (0.30 mm.) diam.

At 8 hours there was faint erythema of both of his shoulders. At 24 hours there was faint erythema of both shoulders: left - 5 x 8 cm., right - 4 x 2 cm. At 48 hours these areas were unchanged. At 72 hours both these areas were fading in color. (Non-casualty.)

LINE N, Position 19.

Ground contamination - 1.2 g/sq.m.
Contamination on Observer's back - 2.1 g/sq.m.
Dominant drop size - 0.025 mg. (0.33 mm.) diam.

At 8 hours this man showed erythema of both shoulders in the region of the windows. At 24 hours there were a few scattered pin-point vesicles on the left shoulder surrounded by an area of erythema and oedema 8.5 x 9 cm. There was erythema and oedema of the right shoulder 8 x 8 cm. At 48 hours there was pin-point vesication on the left shoulder 5 x 3 cm. surrounded by erythema and oedema 12 x 11 cm. There was pin-point vesication of the right shoulder 4 x 2 cm. surrounded by erythema and oedema 12 x 9 cm. At 72 hours these areas of pin-point vesication were unchanged and the oedema was subsiding. (Possible casualty.)

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LINE N, Position 21.

Ground contamination - 1.1 g/sq.m.
Contamination on Observer's back - 1.2 g/sq.m.
Dominant drop size - 0.020 mg. (0.30 mm.) diam.

At 8 hours this man showed faint erythema of the right shoulder. At 24 hours there was faint erythema of the right shoulder in the region of the window. At 48 hours there was faint erythema of the left shoulder 5 x 4 [redacted] and the faint erythema of the right shoulder had progressed to erythema 8 x 7 cm. At 72 hours both areas of erythema were fading. (Non-casualty.)

LINE N, Position 25.

Ground contamination - 1.0 g/sq.m.
Contamination on Observer's back - 0.94 g/sq.m.
Dominant drop size - 0.010 mg. (0.24 mm.) diam.

At 8 hours this man showed no erythema of either shoulder. At 24 hours he showed faint erythema of the right shoulder 7 x 6 cm. At 48 hours this area was unchanged. At 72 hours the erythema was fading. (Non-casualty.)

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