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CHEMISTRY DIVISION - PROTECTIVE CHEMISTRY SECTION

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CHAMBER TESTS WITH HUMAN SUBJECTS XII. SUIT AND MAN "BREAKS" WITH CC-2 IMPREGNATED CLOTHING

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ABSTRACT

This report describes the results of two types of tests with H vapor on solvent, solvent + ZnO, and aqueous CC-2 impregnated clothing. The first type, called "suit-break" tests, consisting of repeated exposures of the same suit, showed that the total protective capacity of suits impregnated by the three systems is largely a function of the initial active chlorine content. An average loss of 0.009 - 0.010 mg. Cl+/cm.^{2} occurred for each standard exposure and wear period, i.e., CT-1200 (60 Min.); 90°F, 65% R.H., followed by 4 hrs. wear. The final active chlorine content of the solvent type suits was 0.07 - 0.14 mg/cm.^{2} and that of the aqueous type was 0.25 mg./cm.^{2}. This confirmed the desirability of a higher reimpregnation level for the aqueous type suits.

The second type, called "man-break" tests, was carried out by successive daily exposures of the same subject in a given suit at CT 1200 (60 min.) at 90°F, 65% R.H. In these tests the solvent and solvent + ZnO types gave greater protection than the aqueous type, the number of exposures tolerated being 7.3, 6.7 and 4.1 respectively for concurrent 1 layer tests.

For the aqueous impregnated suits, the number of exposures tolerated was 3.8, 4.3 and 6.6 for 1, 1-1/2 and 1-3/4 layers respectively. However 19 of 55 men in the one layer tests eventually suffered ulcerated or crusted lesions of the genitalia, whereas, of 81 men in the 1-1/2 layer tests, no men had genital burns of this severity. The value of protective shorts is evident from these results.

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INTRODUCTION

A. Authorization

1. This work was authorized under Project 547/41, "Maintenance, Bureau of Ships", dated 16 December 1940. The problems which were proposed for study were given in Bureau of Ships letter S-S77-2(Dz), Serial 811, of 17 December 1940.

B. Statement of Problem.

2. This investigation was undertaken to evaluate Navy Issue Protective Clothing impregnated by the three accepted methods of impregnation with regard to (a) the total protective capacity, (b) the protection afforded one individual and (c) the relative merits of 1, 1-1/2 and 1-3/4 layer protection.

C. Known Facts Bearing on Problem and Theoretical Considerations.

3. T.D.M.R. No. 845 dated 21 August 1944, gives a comprehensive summary of all data available to 1 March 1944 on the vesicant protection afforded by permeable protective clothing. It was recommended that wherever possible 2 layer protection be worn, and that the aqueous system of impregnation be considered as giving greater H vapor protection than the solvent system. More recent reports such as the CWS series on "Gas Chamber Tests" and reports from India and Australia confirm the desirability of protecting the genitalia by more than one layer of impregnated clothing. CDRE Rept. 277 (India) recommends the issue of "bathing slip" design shorts to be impregnated in the field should the necessity arise.

4. Whereas the CWS has adopted the use of 2 layers of impregnated clothing, the Navy at present is issuing a single layer 2 piece protective suit. Suits impregnated by three methods have been issued,

solvent, stabilized solvent and aqueous suspension. At present only the last method is being employed for impregnation, largely because of the greater ease of production.

D. Previous Work Done at This Laboratory.

5. This report is the twelfth of a series on "Chamber Tests with Human Subjects" in which the results obtained in the evaluation of various protective equipment against the vesicant effects of persistent chemical warfare agents are reported. NRL Report No. P-2208, "Chamber Tests with Human Subjects, I and II", dated 22 December 1943, gives some of the preliminary data obtained in the "suit-break" tests reported herein.

EXPERIMENTAL

Part I - "SUIT-BREAK" TESTS

A. Introductory

6. The operation of the chamber, the method of testing and preliminary data on the "suit-break" tests were given in NRL Report No. P-2208. However the data on the entire "suit-break" series of tests is reported here for completeness.

7. Arnzen cloth Navy style protective suits impregnated by three different systems were used in these tests.

(a) Aqueous Suspension Clothing - Impregnated in a Navy Portable Plant with a water suspension at room temperature using the following formula: 100 CC-2/75 CP/25 ZnO/3.75 PVA/0.75 Daxad 11/0.15 Duponol ME/9 Pigment, with enough water added to give a bath containing approximately 10% CC-2.

(b) Solvent Clothing - Impregnated in a Navy M-1 Plant with a solution of CC-2 in tetrachloroethane at 55°C.

(c) Solvent + ZnO Clothing - Impregnated at

35°C in a Navy M-1 Plant with a solution of CC-2 in tetrachloroethane containing 15% ZnO based on the weight of CC-2.

B. Procedure

8. Each man exposed in the chamber was provided with the following protective equipment:

(a) Navy diaphragm mask, Mark III. (Except for a few of the earlier exposures, sleeves made from CC-2 impregnated cloth were placed on the connecting hoses to prevent absorption of H by the rubber, thereby increasing the effective life of the mask).
(b) Impregnated Arnzen protective suits.
(c) Standard Navy underwear (unimpregnated).
(d) Impregnated socks (1 pair) and gloves (elbow-length wool).
(e) Overshoes (Arctics).
(f) Protective Ointment S-461 or S-330 (Applied to the neck and face extending just inside the edge of the mask facepiece).
(g) Impregnated shorts (Heavy cotton rib-knit underwear cut off at knee and rolled up. Worn over plain shorts.)

9. Five suits of each impregnation type were used throughout the series. Men dressed in these suits (and accessories) were exposed to H vapor at CT 1200 (20 γ H/l for 60 min.) and at 90°F and 65% R.H., and 2 - 2.5 m.p.h. wind velocity with four hours wear after each exposure. Repeated exposures were given until the man were withdrawn from the test by the Medical Officer. At this point, the suits were reissued to a new group of men and the exposures continued. In the first nine exposures of the solvent and aqueous suits, a given man did not always wear the same suit. For all subsequent exposures one man always wore the same suit until he was withdrawn from the test.

10. Each suit was exposed 2 to 4 times a week until "broken". A man with an intense erythema (E) on any part of his body 24 hours after his first

exposure in the suit was withdrawn from the test and a new man substituted in his place. This was called a "strike" on the suit. Three "strikes" in succession, or following each other closely, constituted a "break".

11. At the end of the tests, samples from several different areas of each suit were analyzed for active chlorine content.

12. The suits were not laundered until after they were "broken". Between exposures they were folded and kept in the laboratory. After all the suits "broke", three suits from the aqueous and three from the solvent + ZnO groups were laundered. New men, dressed in these suits, were given one exposure at CT 600 (10 γ H/l. for 60 min.) and at 90°F. and 65% R.H.

C. Results

13. Table I gives the summarized results obtained in the "suit-break" tests. In the Appendix, Tables IX through XI give condensed physiological readings after each exposure for the three types of suits, Table XII gives the active chlorine content of the suits after the "breaks" and Table XIII gives the active chlorine content of the suits after laundering and one more exposure.

TABLE I

"Suit Break" Tests

Conditions of Exposure: H at CT 1200 (60 min.); 90°F,65% R.H.

Impreg. Syst.	Suit No.	No. of Exp.	mg.Cl+/cm.² Before	mg.Cl+/cm.² After	Loss Per Exp.
Solvent	1	25 (1 strike)		.08	
	2	30 (2 strikes)		.07	
	3	29 (2 strikes)		.08	
	4	25		.06	
	5	28 (2 strikes)		.08	
		Av. 27+	.34	.07	.010
Aqueous Suspension	6	53		.20	
	7	53		.25	
	8	45		.22	
	9	53		.26	
	10	41		.30	
		Av. 49	.76	.25	.010
Solvent+ZnO	11	41		.20	
	12	33		.12	
	13	29		.15	
	14	37		.10	
	15	36		.12	
		Av. 35	.44	.14	.009

14. None of the men exposed in the suits which were laundered had an intense erythema on any part of the body 24 hours after the exposure at CT 600 (i.e., no "strikes" occurred for any of these suits after they had been "broken" and laundered).

D. Discussion

15. It is apparent from the results obtained that the differences in the total number of exposures required to "suit-break" the three different types of

impregnated clothing are due mostly to the differences in initial active chlorine content. In the order of the greatest amount of protection given by the suits are the aqueous, solvent + ZnO and plain solvent impregnation, and this is also the order of initial chlorine content.

16. It is particularly noteworthy that the loss of active chlorine content per exposure was constant for the three types of impregnation. It has been found in other tests (not reported here) that the loss of active chlorine in tests of this nature is due not only to reaction with H but also in large measure to the four hour period of wear following each exposure. It was shown in NRL Report No. P-2343, "Tropical Wearing Trials of Protective Clothing", that the aqueous type lost active chlorine faster than the other types under tropical conditions, but, due to its higher initial loading, the percentage drop was essentially the same for all three types. It appears, therefore, that the three types of impregnation may be considered as comparable in the loss of active chlorine due to exposure and wear.

17. Examination of the data presented in Table IX through Table XI in the Appendix shows that, in general, as the number of exposures increases, the leakage of H vapor through the clothing also increases. This is particularly true towards the end of each series and is undoubtedly related to the decreased active chlorine content of the suits, since it has been shown (unpublished data) that the total leakage through aqueous impregnated cloth, as measured chemically and physiologically, is essentially the same for the first four exposures as for the succeeding four exposures.

18. It can be seen from Table XII in the Appendix that on the average, the amount of active chlorine lost for the different parts of a suit was in the following decreasing order: elbow, knee, back, shoulder, seat and crotch. At the end of the tests, the difference in active chlorine content between the elbow and back (including shoulders) was small for the

solvent and solvent + ZnO type suits but was considerable for the aqueous suits. The "strikes" on the solvent and solvent + ZnO suits were due almost entirely to burns of the back whereas for the aqueous suits the "strikes" on back and arms were about evenly divided. These results are to be expected in view of the difference in chlorine loading and the greater susceptibility of the skin of the back over that of the arms (as demonstrated in NRL Report No. P-2579 in tests with men wearing no protective clothing).

19. The active chlorine content of the three types of suits after they were "broken" confirms the conclusions given in NRL Report No. P-2597 that a higher reimpregnation level is desirable for the aqueous than for the solvent types. It can be seen from Table I that the average loading at the "break" was 0.08 - 0.14 mg.Cl+/cm.^{2} for the solvent types and o.25 mg.Cl+/cm.^{2} for the aqueous type. In NRL Report No.P-2597, it was recommended that for the solvent types a value of 0.15 mg.Cl+/cm.^{2} and for the aqueous a value of 0.20 mg.Cl+/cm.^{2} be considered as the reimpregnation level for worn CC-2 impregnated clothing.

20. In spite of the increased loss of active chlorine of the suits which were laundered and re-exposed after they had "broken", the fact that no "strikes" occurred at CT 600 indicates that the protection given by these suits was not impaired by the laundry treatment.

Part II - "MAN BREAK" TESTS

A. Introductory

21. In view of the results obtained in the "suit-break" tests it was obvious that the leakage of H vapor through one layer of CC-2 impregnated Arnzen cloth is sufficient to produce serious burns long before the total protective capacity of the suit is exhausted. Furthermore, a very large number of exposures are necessary to "break" a suit. Accordingly, a different method of evaluating protective clothing was established. This was called the "man-break" method of testing, and it gives results which are more significant in regard to the protection afforded any one individual.

22. The impregnation systems used in these series of tests were the same as those described in Part I of this report. In the 1-1/2 and 1-3/4 layer tests, the protective shorts and skivvies used were all impregnated by the aqueous-suspension process. Two typew of protective shorts were used, standard Navy issue Nainsook and Cooper-type rib-knit. In the tests prior to 1 May 1944, the suit jumpers were secured with buttons part way down the front and around the hood. In later tests the jumpers had no buttons and the hoods were secured by means of a drawstring.

23. No active chlorine contents or losses are listed for these tests, since it was found that the loss of active chlorine during the few exposures given any one suit was usually less than the variations found in analyses due to the inherent uneven impregnation of the clothing. The analytical results, therefore, would not be significant.

B. Procedure

24. Each man exposed in the chamber was equipped with at least the following:

(a) Navy diaphragm mask, Mark III or IV (with CC-2 impregnated sleeves on the hose connecting tubes).

(b) Impregnated Arnzen protective suits.

(c) Two pair of impregnated socks.

(d) One pair of wool elbow length gloves.

(e) Overshoes (Arctics).

(f) Protective Ointment, S-330 (Applied to face and neck).

25. The following additional items were also used:

(1) 1-layer tests - Plain standard issue underwear (unimpregnated).

(2) 1-1/2 layer tests - Plain standard issue undershirts (unimpregnated) and either Nainsook or Knit shorts impregnated by the aqueous suspension process.

(3) 1-3/4 Layer tests - Knit shorts and standard issue undershirts (T-shirts) impregnated by the aqueous suspension process.

(4) Minimum protection test --In this test, no gloves were used and the sleeves were secured at the wrists with twine. The hoods were thrown back and impregnated watch caps worn on the head. Oxford shoes were used in place of the overshoes. S-330 ointment was applied liberally to all exposed areas, i.e., neck, ears, face, hands and wrists.

26. The "man-break" tests were conducted as follows: The subjects, always dressed in the same suits and accessories, were given successive daily exposures to H vapor in the chamber at CT 1200 (20 γ H/l. for 60 min.) and at 90°F, 65% R.H., and 2-2.5 m.p.h. wind velocity. The clothing was worn for four hours after each exposure. The men were examined and read by the medical officer before each exposure, and each subject was withdrawn from the test when he had incurred a reading of E (intense erythema) or greater on any part of his body. The successive daily exposures were continued until all the men had "broken" or were withdrawn by the medical officer for other reasons. The average number of exposures tolerated was used as the criterion of

protection afforded during a particular test.

27. The intense erythema endpoint of a "man break" very seldom incapacitates the subjects in the tests. Since it was desirable to estimate better the significance of this endpoint in relation to production of casualties and determine how many more exposures could be tolerated, several men in the 1-3/4 layer tests were subjected to additional exposures after they had "broken". The end point in this case was pin-point vesication on any part of the body.

28. A further test was carried out to determine whether the standard amount of protection could be reduced. The men were dressed as outlined previously for the "minimum protection" test and were given one standard exposure. Two groups of men were used, the first group had had no previous exposures, the second group had had one previous exposure dressed in standard 1-1/2 layer protection.

C. Results

(1) 1-layer Tests.

29. The three different systems of impregnation listed in Part I of this report were studied by means of one layer tests. One test each of the solvent and solvent + ZnO systems and 6 tests of the aqueous system were carried out. The results are summarized in Table II; more complete data are given in Tables XIV [(a) through (h)], XVII and XX in the Appendix.

TABLE II

One Layer "Man-Break" Tests

Conditions: H at CT 1200 (60 min.); 90°F, 65% RH.

Impregnation System	No. of Men	No. of "Breaks"	Av. No. of Exp. Tolerated
Solvent	7	6	7.3+
Solvent+ZnO	6	6	6.7
Aqueous	42	35	3.8+

30. The solvent, solvent + ZnO and one of the aqueous tests were run concurrently. The average number of exposures for the aqueous test in this group was 4.1.

31. Of special importance in the one-layer tests are the reactions sustained on the genitalia. In NRL Report No. P-2579, it was shown that in basic tests (no protective clothing), reactions on the scrotum and penis often develop slowly. In one layer tests, therefore, a man may "break" on some other part of the body and yet sustain severe genital burns at a later date. Of the 55 men in the one-layer tests, 19 had either scaling, crusting or ulceration of the scrotum or penis when they returned from leave approximately 8 - 15 days after the last exposure (See Table XX in the Appendix).

(2) 1-1/2 Layer Tests

32. Only the aqueous system of impregnation was studied by means of 1-1/2 layer tests. Most of these tests were actually used as controls in studying other factors in protection. A total of 13 tests was carried out, in two of which the men wore Nainsook shorts and in the others knit shorts. The results are summarized in Table III; more complete data are given in Tables XV /[a) through (m)7, XVIII and XXI in the Appendix.

TABLE III

1-1/2 Layer "Man-Break" Tests

Conditions: H at CT 1200 (60 min.); 90°F, 65% RH.

Impregnation System	Type of Shorts	No. of Men	No. of "Breaks"	Ave.No. of Exp. Tolerated
Aqueous	Nainsook	12	9	3.2+
"	Knit	69	58	4.5+
	Totals	81	67	4.3+

33. No significance can be attached to the difference in results between the Nainsook and knit shorts given in the Table above since none of the men in the Nainsook shorts "broke" solely on the area covered by the shorts. The difference is due, therefore, to the normal variations found in this type of test. The reasons for adopting the knit type of shorts over the Nainsook were discussed in NRL Report No. P-2343.

34. None of the 81 men in the tests had scaling, crusting or ulceration of the genitals when they returned from leave 8 - 15 days after the last exposure. Only two of the men had readings of erythema with edema or greater of the genitals 48 hours after the last exposure (See Table XXI in the Appendix).

(3) 1-3/4 Layer Tests

35. Two tests were carried out using 1-3/4 layers. One was with solvent + ZnO and the other with aqueous impregnated suits. The plain solvent suits were not tested because the protection given in the one layer tests was comparable for the two solvent systems. The results are summarized in Table IV; more detailed data are given in Tables XVI [(a) and (b)], XIX and XXII in the Appendix.

TABLE IV

1-3/4 Layer "Man-Break" Tests

Conditions: H at CT 1200 (60 min.); 90°F, 65% RH.

Impregnation System	No. of Men	No. of "Breaks"	Av.No. of Exp. Tolerated
Solvent+ZnO	8	8	8.5
Aqueous	9	9	6.6

36. The data in the table above show again that, as in the one layer tests, the solvent + ZnO type of impregnation gave better protection than the aqueous type, but the difference was not as

pronounced in the 1-3/4 layer tests.

37. Of the 17 men tested, only one developed a crusted lesion on the genitalia. This man received 6 exposures and was dressed in an aqueous type suit. (See Table XXII in the Appendix).

(4) Vesication Endpoint Test

38. Five of the men from the 1-3/4 layer tests were given additional exposures after they had "broken". These additional exposures were continued until pin-point vesication resulted. The results are summarized in Table V; more detailed data are given in Table XXIII in the Appendix.

TABLE V

Vesication Endpoint "Man-Break"

Conditions: H at CT 1200 (60 min.); 90°F, 65% RH.

Impreg. System	No. of Men	No.of "Breaks" (To Pin-point Vesication)	No.of Previous Exposures	No.of Add. Exp. Tol.*	Av.Add. Exp.Tol.
Solvent+ZnO	3	3	7,9,7	3,2,2	2.3
Aqueous	2	1	9,9	2,1+**	1.5+
Total	5	4	Av. 8.2		2.0+

* All men were withdrawn from test when numerous pin-point vesicles resulted.

** Was withdrawn from test before vesication was produced.

39. The data given in Table V show that an additional two exposures were required to produce pin-point vesication after the intense erythema "man-break". No significance can be attached to the difference in results between the two types of impregnation systems because of the small number of men used in the test.

(5) Minimum Protection Test

40. The results obtained with the two groups in the minimum protection test are summarized in Table VI. More complete data are given in Table XXIV [(a) and (b)] in the Appendix.

TABLE VI

Minimum Protection Test

Conditions: H at CT 1200 (60 min.); 90°F, 65% RH. Neck, edges of face, ears, hands and wrists covered only by S-330 Protective Ointment.

Group	No. of Exp. Given	No. of Men	No. of "Breaks"
No previous exp.	1	8	2
1 previous exp. in std. 1-1/2 layer test	1	5	2

41. The data in Table VI show that 4 out of 13 men "broke" on one exposure. In view of this, and of the moderate erythemas sustained by all but one of the remaining men, no further exposures were given.

D. Discussion

42. The average number of exposures tolerated for the aqueous suits was 3.8+ for the one layer tests and 4.3+ for the 1-1/2 layer tests. The differences between the two is small, largely because most of the "breaks" occur on the back, which is protected in both tests by a single layer. This is borne out further by the fact that 6.6 exposures were tolerated in the 1-3/4 layer test in which the back and upper arms were protected by 2 layers. However, in view of the slowness of development of lesions of the genitalia (as shown in NRL Report No. P-2579), and in view of the importance of genital lesions in producing casualties, the numerical value

for exposures tolerated by men in 1 and 1-1/2 layers gives only a partial measure of the protection afforded. Thus, in the 1 layer tests, 35% of the men ultimately developed crusted or ulcerated lesions of the genitals whereas in the 1-1/2 layer tests none of the men did. The importance of giving additional protection to this vulnerable area of the body, therefore, is evident.

43. The results of the vesication end-point test carried out on the men in the 1-3/4 layer tests indicate that the number of exposures required to give an intense erythema in a "man-break" test is on the order of 80% of that required to produce pin-point vesication. In this particular test no men sustained lesions as severe as those of the men with severe genital burns in the one layer tests. Thus, in a 1 layer "man-break" test a large percentage of the men may approach or reach a casualty stage after the test is completed, whereas in 1-1/2 and 1-3/4 tests, in which the genitals are protected, an additional number of exposures would be required to produce casualties. The increased total protection afforded in the 1-1/2 and 1-3/4 layer tests is again emphasized.

44. The results of the minimum protection test showed that under the exposure conditions used, the amount of protection in the standard method of dress cannot be reduced significantly without impairing the protection afforded to a considerable degree. This applies particularly to the neck, ears and face. It is apparent that the ointment will give considerable protection to the neck but that it is not comparable to that given by the impregnated clothing. It is not known whether ointment alone would be adequate under less severe conditions of exposure. In the tests carried out here the men were sweating profusely, and this tends to break the continuity of the ointment film on the skin. The test did not determine whether the ointment would be sufficient to replace the gloves since only one exposure was given and no significant burns of the hands or wrists occurred.

45. The 1 and 1-3/4 layer tests showed that, under the conditions used, the solvent types of impregnated clothing offered greater protection than the aqueous type. In the two series of tests the average number of exposures tolerated for the solvent + ZnO suits was respectively 2.6 and 1.9 exposures greater than the aqueous suits tested concurrently. The greater leakage of H vapor through the aqueous clothing has also been confirmed in chemical tests (unpublished data).

46. The "man-break" tests indicated that the solvent suits give better individual protection than the aqueous suits, whereas the "suit-break" tests indicate greater total protection for the aqueous type. The Navy, at present, is impregnating clothing by the aqueous process only. This is due primarily to the much greater ease of production by the aqueous process, and the fact that higher initial loadings of active chlorine are obtained.

47. In basic tests (no protective clothing) it was shown that under constant conditions of exposure, the severity of burns is proportional to the CT of exposure. This is not true for protective clothing "man-break" tests, since it has been observed repeatedly that the severity of burns does not increase proportionately to the number of exposures, but rather that the increase in severity tapers off with increasing number of exposures. This indicates a greater leakage of H vapor through the clothing during the first exposures than in succeeding exposures, a fact which has been demonstrated by chemical means (unpublished data). This also means that the endpoint in a "man-break" test is actually approached much more gradually than if the leakage of H vapor were constant for each exposure, and it accounts in part for the considerable variation in number of exposures tolerated in the tests in the 1-1/2 layer series.

48. The number of tests carried out is too

small to permit a statistical evaluation of the seasonal variations for the 1-1/2 layer tests under constant chamber conditions. However, an examination of the data indicates that a greater number of exposures were tolerated during hot weather than during cool weather, although it was demonstrated in NRL Report No. P-2579 that skin is more susceptible to H vapor in hot weather than in cool weather. A possible explanation for this is that the men are sweating actively during the hot weather, and also, because of the high relative humidity, the suits become quite wet before the men are exposed. In cool weather when the men are not sweating visibly, the suits are dry and remain so during the initial part of each chamber exposure. Chemical and chamber tests (unpublished data) have shown that the leakage of H vapor is greater through dry impregnated cloth, and are therefore consistent with the observed lower protection in the chamber tests carried out in cool weather.

SUMMARY AND CONCLUSIONS

1. Two types of tests of protective clothing have been described in this report. The first type, called "suit-break" tests, consists of repeated exposures of the same suit until it no longer affords suitable protection for one exposure to H vapor under standard conditions (CT 1200 (60 min.), 90°F, 65% R.H.) The second type, called "man-break" tests, consists of successive daily exposures under standard conditions of one individual in the same suit until intense erythema is produced.

2. Three types of impregnated suits were tested as "suit-breaks". The solvent type averaged 27+ exposures (CT 32,400), the solvent + ZnO type averaged 35 exposures (CT 42,000) and the aqueous type averaged 49 exposures (CT 58,800). The total protection given was approximately proportional to the initial active chlorine content of the three types of suits, which were 0.34, 0.44 and 0.76 mg./cm.^{2} respectively.

3. The final average active chlorine content of the suits after the "suit-break" was 0.07 - 0.14 mg./cm.^{2} for the solvent types and 0.25 mg./cm.^{2} for the aqueous type. These values are in reasonable agreement with the recommended values of 0.15 and 0.20 mg.Cl+/cm.^{2} for the reimpregnation level of solvent and aqueous impregnated suits, respectively, as given in NRL Report No. P-2597.

4. The overall loss of active chlorine per exposure was practically constant at 0.009 - 0.010 mg./cm.^{2}/exposure for the three types of impregnated clothing in the "suit-break" tests.

5. After the "suit-break" tests, laundering did not impair the residual protection as demonstrated by one further exposure at CT 600 (60 min.) of aqueous and solvent + ZnO suits.

6. The "man-break" tests of impregnated clothing were conducted as 1 layer (plain underwear), 1-1/2 layer (CC-2 impregnated shorts) and 1-3/4

layer (CC-2 impregnated shorts and undershirts).

7. In 1 and 1-3/4 layer "man-break" tests the solvent + ZnO type gave protection for approximately 2 exposures more than the aqueous type. In the 1 layer tests the solvent gave slightly greater protection than the solvent + ZnO.

8. A comparison of the 1, 1-1/2 and 1-3/4 layer tests, using aqueous type suits, showed an average of 3.8+, 4.3+ and 6.6 standard exposures tolerated respectively. In the 1 and 1-1/2 layer tests, most of the "breaks" occurred on the back and shoulders which in both cases are protected by only one layer of impregnated cloth.

9. The most significant difference between the 1 and 1-1/2 layer tests was the delayed severe reactions of the genitals in the one layer tests. Of 55 men, 19 had crusted or ulcerated lesions of the penis or scrotum 8 - 15 days after the last exposure, whereas of the 81 men in the 1-1/2 layer tests, none suffered crusted or ulcerated lesions. Although 1 layer protection offers reasonably good protection against H vapor, repeated exposures would lead to a much higher percentage of casualties than the use of 1-1/2 layer protection. From a casualty production standpoint the value of protective shorts, therefore, is evident.

10. A "man-break" test in which the exposures were extended beyond the intense erythema endpoint of a 1-3/4 layer test showed that the number of exposures required to produce intense erythema was 80% of that required to produce pin-point vesication.

11. A test in which the neck was protected only by S-330 ointment showed that, under the conditions employed, the ointment does not give protection comparable to that given in the standard manner of dress.

RECOMMENDATIONS

1. In NRL Report No. P-2597 it was recommended that a reimpregnation level of 0.15 mg.Cl+/cm.^{2} for solvent type impregnated suits and of 0.20 mg.Cl+/cm.^{2} for the aqueous type, be adopted. The results given in this report substantiate the above recommendation.

2. It is recommended that, in the event of chemical warfare, personnel in danger areas be supplied with CC-2 impregnated shorts in addition to the protective suits, the shorts to be impregnated by any readily available method, and that CC-2 impregnated rib-knit type protective shorts be adopted for more general distribution.

3. It is recommended that S-330 Protective Ointment not be considered as equivalent to the present hood for protectiom of the neck and adjacent areas, but that it be used if standard design protective clothing is not available.

4. It is recommended that unused solvent and solvent + ZnO types of impregnated clothing be considered as offering slightly greater protection against H vapor than the unused aqueous type suits for frequent exposures of one individual, but that the overall protection, including partially degraded suits, be considered equivalent for the three types.

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APPENDIX

TABLE VII

Legend - Body Areas

Abbr.	Area	Abbr.	Area
aaf	anterior axillary folds	lum	lumbar region
aar	anterior arms	oint	area covered by ointment
abd	abdomen	paf	posterior axillary folds
af	axillary folds	par	posterior arms
ale	anterior legs	pen	penis
ar	arms	ple	posterior legs
ash	anterior shoulders	pop	popliteal fossae
athi	anterior thighs	psh	posterior shoulders
ax	axillae	pthi	posterior thighs
bt	buttocks	sc	scapulae
C_7	7th cervicular region	scr	scrotum
cf	cubital fossae	sh	shoulders
cl	clavicles	th	thorax
dh	dorsum of hands	thi	thighs
dth	dorsal thorax	umar	upper medial arms
el	elbows	vth	ventral thorax
fa	forearms	wr	wrists
igf	intergluteal folds		
il	iliac crest		
ing	inguinal region		
kn	knees		
le	legs		
lth	lateral thorax		

TABLE VIII

Legend - Severity of Burns

O = no reaction

E-? = trace

E- = mild erythema (for "suit-break" tests, a mild to moderate erythema).

E° = moderate erythema

E = intense erythema (for "suit-break" tests a moderate to intense erythema)

E+ = papular erythema

NPV = numerous pin-point vesicles

V = vesicle

NV = numerous vesicles

sc = scaling

ul = ulceration

cr = crusting

P_1 = mild pigmentation

P_2 = moderate pigmentation

P_3 = intense pigmentation

TABLE IX

Physiological Readings

Solvent Suits - "Suit-Break" Tests

Date	Exp. No.	Most Severe 24 Hour Reading for Man in Suit No. 1	2	3	4	5
9/21/43	1	0	0	0	E th	0
9/22	2	E th	0	0	E th	0
9/24	3	0	0	0	E dth	0
9/27	4	E-? th	E-?dth	E-? dth	E dth	E-? dth
9/28	5	E- dth	E- dth	0	E dth,ar	E- dth
9/30	6	E-dth,ar	0	E- dth	E dth	0
10/2	7	0	E- dth, thi	E- dth	E dth	E- dth
10/5	8	E th	E- dth	0	allergy	E th
10/19	9	* E- dth	* 0	* 0	* 0	*E- dth,ar
10/20	10	E-? dth	0	E-? dth	0	0
10/21	11	E- dth	E- sh	0	0	0
10/22	12	E dth,ar	0	allergy	V cf	E dth
10/26	13	* 0	** E th	* 0	* 0	* 0
10/27	14	0	* E- dth	E dth	E- dth	0
10/28	15	0	E- dth	0	0	E- dth
11/2	16	* 0	* 0	* 0	* 0	* 0
11/4	17	E laf	0	E le	0	E- sh
11/5	18	0	E- dth	E- dth	0	0
11/8	19	* 0	* 0	** E dth	* 0	** E dth

TABLE IX (Cont'd.)

Physiological Readings

Solvent Suits - "Suit-Break" Tests

Date	Exp. No.	Most Severe 24 Hour Reading for Man in Suit No. 1	2	3	4	5
11/9/43	20	E- dth,ar	0	*E- dth	E-? dth	*E-dth,ar
11/10	21	E dth	E-? dth	E dth	E-? dth	E dth
11/12	22	* 0	E- dth	* 0	* 0	* 0
11/16	23	*E- sh	* 0	* E-? dth	** E sh	*E-? dth
11/17	24	*E- dth	E- dth	E- dth	** E dth	E-? dth
11/18	25	** E dth	E sh,ar	E dth	** E sc	E- dth
11/23	26		* 0	*E-? sc		** E dth
11/25	27		0	E- dth		* E- dth
11/26	28		E dth	-		-
12/1	28		-	** E ar		**E dth,ar
12/1	29		** E sh	-		
12/2	29		-	** E dth		
12/2	30		** E dth			

* Signifies a new man started in suit.

** Signifies a "strike", i.e., a reading of E after first exposure of a new man.

TABLE X

Physiological Readings

Aqueous-Suspension Suits - "Suit-Break" Tests

Date	Suit Exp. No. & Most Severe 24 Hour Reading for Man in Suit No. 6	7	8	9	10
9/21 43	1. 0	1. 0	1. 0	1. 0	1. E- dth
9/22	2. E-dth	2. 0	2. 0	2. E- dth	2. E dth
9/24	3. 0	3. 0	3. 0	3. 0	3. E dth
9/27	4. E dth	4. 0	4. 0	4. E- dth	4. E- dth
9/28	5. E-dth	5. 0	5. 0	5. 0	5. E- dth
9/30	6. E-dth	6. E- dth	6. E-? dth	6. E dth	6. E-? dth
10/2	7. E-dth	7. E- dth	7. E- dth	7. E dth	7. E- dth
10/5	8. E th, le	8. 0	8. E- dth	8. E- dth	8. E dth
10/19	9. *E-dth	9. * 0	9. * 0	9. *E- dth	9. *E- dth
10/20	10. *0	10. 0	10. E-dth	10. E- dth	10. 0
10/21	11. 0	11. E dth	11. E-?dth	11. E dth	11. E- dth,ar
10/22	12. E dth ar	12. E dth, ar	12. E dth,cf	12. E dth	12. E dth
10/26	13. *0	13. *0	13. * 0	13. *0	13. *E-? vth
10/27	14. E dth	14. E dth	14. E dth,le	14. E- dth	14. E- dth,ar
10/28	15. E dth	15. E dth	15. * 0	15. E dth	15. E dth,ar
11/2	16. *0	16. *0	16. *0	16. *0	16. * 0
11/4	17. E dth ar	17. E dth	17. E-dth,ar	17. E-dth,ar	17. E- sh
11/5	-	-	18. E dth	-	-

TABLE X (Cont'd.)

Physiological Readings

Aqueous-Suspension Suits - "Suit-Break" Tests

Date	Suit Exp. No.& Most Severe 24 Hour Reading for Man in Suit No. 6	7	8	9	10
11/8/43	-	-	19.** E ar	-	-
11/9	18.*E-th ar	18* 0	20.E dth,ar	18.* 0	18.* E- dth
11/10	19.E- th ar	19. 0	21.E dth,ar	19.E th,ar	19. E- dth
11/12	20.* 0	20.E dth, ar	22.** E vth	20.* 0	20.* 0
11/16	21.*E-sh	21.*E-sh	23.*E-dth,ar	21.* E- sh	21.* E- dth
11/17	22.E-dth	22.E-sh,ar	24.*E-dth,ar	22. E ar	22. E cf
11/18	23.E-dth ar	23. E dth	25. E dth	23. E dth	23. E dth,ar
11/23	24.* 0	24.* 0	26.*E-dth,ar	24.* E dth	24.* E dth,ar
11/25	25.E-dth	25. E- ar	27. E- dth	25. E cf	25. E- dth
11/26	26.E-dth	26.E sh,ar	28. 0	-	-
12/1	27.*E dth	27.* 0	29.* 0	26.* E- dth	26.* E-? sh
12/2	28. E- dth	28. E- dth	30. E- dth	27. E dth	27. E dth
12/3	29. E-? dth	29. E dth	31. E- dth	28.*E- le dth,	28.* E- dth
12/4	30. E-? dth	30. E dth	32. E- dth	29. E dth	29. E- dth
12/7	31.*E- dth,cf	31.*E- dth cf	33.* E dth, ar	30.**E dth, ar	30.* E- dth
12/8	32.E- af	32. E- ar	34. E- dth	31.**E dth	31. E- dth
12/9	33.E-dth	33. E ar	35. E dth	32.* 0	32. E dth
12/14	34.*E-sh	34.* 0	36.* E- sh	33. E-? sh	33. E- scr

TABLE X (Cont'd.)

Physiological Readings

Aqueous-Suspension Suits - "Suit-Break" Tests

Date	Suit Exp. No.& Most Severe 24 Hour Reading for Man in Suit No. 6	7	8	9	10
12/15 43	35.E- dth	35.E- dth	37. E- dth	34. E sc,sh	34. E sc, sh
12/16	36. E dth	36.E sc, sh	38.E dth,cf	35. E dth,cf	35. E dth
12/21	37.*E-? dth	37.* 0	39.*E-? sh	36.* 0	36.* 0
12/22	38.E dth	38.E- dth	40.E dth	37. E dth	37. E dth,ar
12/28	39.* 0	39.*E-dth	41.**E dth	38.** E dth	38.** E dth
12/29	40.E- dth	40.E- dth	42.* E- dth	39.* E- dth	39.** E dth
12/30	41. E dth	41. E sh, ar	43. E sc	40. E sc	40.* E- dth
1/4 44	42.*E-dth	42.**E sc ar	44.**E sc, ar	41.* E- ar	41.** E dth,af, cf
1/5	43. E dth	-	45.**E sc, sh	42. E sc	
1/11	44.*E-dth	43.*E-dth		43.* E- sc	
1/12	45.**E dth	44. E dth		44. E- dth	
1/25	46.*E- sc	45.*E-?sc		45.* E- dth	
1/26	47.**E ar	46.**E dth,cf		46.* E dth	
1/27	48. E dth ar	47.E sh, ar		47. E sh, ar	
2/1	49.*E-dth	48.**E dth		48.* E- sc	
2/2	50. E ar	49. E dth		49. E ing	
2/3	51.**E ar	50. E cf		50. V ar	
2/4	52.**E ar	51.**E cf		51.** E ar	
2/7	53.**E dth	52.**E cf		52.** E cf	

TABLE X (Cont'd.)

Physiological Readings

Aqueous-Suspension Suits - "Suit-Break Tests"

Date	Suit Exp. No.& Most Severe 24 Hour Reading for Man in Suit No. 6	7	8	9	10
2/9 44		53.**E cf		53.**NPV sc	
Suits Laundered, One More Exposure Given at CT 600 (1 hr.)					
2/23	-	54.* E-dth ar	46.* E° sc	54.* E- dth, le,ar	

* Signifies a new man started in suit.
** Signifies a "strike" i.e., a reading of E after first exposure of a new man.

TABLE XI

Physiological Readings

Solvent + ZnO Suits - "Suit-Break" Tests

Date	Exp. No.	Most Severe 24 Hour Reading for Man in Suit No. 11	12	13	14	15
10/26/43	1	*E- dth	* 0	* 0	* 0	* 0
10/27	2	E- dth	0	E-? dth	E dth	0
10/28	3	0	E dth	E- dth	E dth	E-? dth
11/2	4	* 0	* 0	* 0	* 0	* 0
11/3	5	E-? kn	0	E- sh	0	0
11/4	6	E- ax	E- dth	E- sh	0	0
11/5	7	0	E dth	E- sh	0	E- dth
11/9	8	* 0	* 0	* E- dth	* 0	*E-? sh, ar
11/10	9	E- dth, ar	E-? le	E dth	E- dth	E- dth
11/12	10	E-? dth	E- dth,le	*E- dth	E dth	E dth
11/16	11	* 0	* 0	* 0	* E-? sh	* 0
11/17	12	0	0	E dth	E- dth	0
11/18	13	E- dth	E- dth	E dth	E dth	E-? dth
11/23	14	* E-? dth	* 0	* E- dth	* 0	* 0
11/24	15	E- dth, cf	E dth	E-? sh	0	E- dth, cf
11/25	16	E- dth, cf	E- dth,ar	E- dth,cf	E- dth,cf	E- dth, cf
12/1	17	* 0	* 0	* 0	* 0	* 0
12/2	18	0	E- dth	E- dth	E- dth	E- sh,sc
12/3	19	0	E- dth,ar	E- dth,ar	E- dth,ar	0

TABLE XI (Cont'd.)

Physiological Readings

Solvent + ZnO Suits - "Suit-Break" Tests

Date	Exp. No.	Most Severe 24 Hour Reading for Man in Suit No. 11	12	13	14	15
12/4/43	20	E- dth,ar	E dth	E dth,ar	E- dth,ar	E-? dth
12/ 7	21	* O	* E- dth	* E- dth	*E- dth	* E- dth
12/ 8	22	E- dth	E dth	E-dth,ar	E- dth	E cf,dth
12/ 9	23	E dth	E dth	E dth	E sc,sh	E+ dth
12/14	24	*E le	* E- sh,sc	* E- sc	E- dth	* E- dth
12/15	25	E-? bt	E dth	E sc	E af	E- dth
12/16	26	E- dth	E dth	E dth	E dth	E sh,sc
12/21	27	* O	** E dth	** E sc	* O	*E-? dth
12/22	28	E sc	** E sc	** E dth	E dth	E dth,cf
12/28	29	* E-? dth	* O	** E dth	*E- ar	*E-? sc,sh
12/29	30	E- dth	E- dth		E- sc,sh	E- dth
12/30	31	E dth	E dth		E ar,af	E dth
1/4/44	32	*E- dth	** E dth		*E- dth	*E- dth
1/5	33	E dth	E dth		E dth	E dth
1/11	34	*E- dth			** E dth	** E dth
1/12	35	E dth			E sc	** E dth
1/25	36	*E- dth			** E sc, cf	** E cf
1/26	37	** E dth			** E dth	
1/27	38	E sc				

TABLE XI (Cont'd.)

Physiological Readings

Solvent + ZnO Suits - "Suit-Break" Tests

Date	Exp. No.	Most Severe 24 Hour Reading for Man in Suit No. 11	12	13	14	15
2/1/44	39	** E cf				
2/2	40	** E sc				
2/3	41	** E ar,sc				
	Suits Laundered, One More Exposure Given at CT 600 (1 Hr.)					
2/23	-	* E° ar			*E- sc,dth	*E° dth

* Signifies a new man started in suit.
** Signifies a "strike" i.e., a reading of E after first exposure of a new man.

TABLE XII

Cl+ Content After "Suit-Breaks"

Impreg. System	Suit No.	No. of Exps.	mg. Cl+/cm.² Shoulder	Elbow	Back	Crotch	Seat	Knee	Av.
Solvent	1	25	.04	.03	.07	.10	.15	.06	.08
	2	30	.05	.04	.08	.12	.09	.02	.07
	3	29	.06	.02	.10	.13	.10	.06	.08
	4	25	.03	.05	.06	.09	.12	.03	.06
	5	28	.08	.07	.05	.12	.13	.03	.08
	Av.	27	.05	.04	.07	.11	.12	.04	.07
Aqueous Suspension	6	53	.23	.09	.27	.28	.23	.11	.20
	7	53	.33	.09	.37	.37	.24	.10	.25
	8	45	.24	.12	.28	.32	.21	.12	.22
	9	53	.33	.14	.21	.31	.29	.27	.26
	10	41	.40	.17	.26	.43	.31	.22	.30
	Av.	49	.31	.12	.28	.34	.26	.16	.25
Solvent + ZnO	11	41	.13	.08	.13	.32	.32	.24	.20
	12	33	.14	.14	.09	.13	.11	.08	.12
	13	29	.17	.15	.11	.23	.11	.13	.15
	14	37	.15	.06	.07	.16	.14	.04	.10
	15	36	.13	.06	.08	.13	.17	.13	.12
	Av.	35	.14	.10	.10	.19	.17	.12	.14

TABLE XIII

Cl+ Content of "Broken" Suits After Laundering and One Exposure

Impreg. System	Suit No.	Area	mg.Cl+/cm.^{2} Before Laund.	After Laund. + 1 Exp.	Cl+ Loss
Aqueous Suspension	7	Elbow	.09	.06	
	8	"	.12	.05	
	9	"	.14	.09	
		Av.	.12	.07	.05
Solvent + ZnO	11	Elbow	.08	.04	
	14	Knee	.04	.03	
	15	Elbow	.06	.05	
		Av.	.06	.04	.02

TABLE XIV

Single Layer "Man-Breaks"

Suits in tests from January to April 1944 had button hoods; those tested later had drawstring hoods.

* * * * *

TABLE XIV a

Date Started - 1/18/44 (Concurrent with XIV b and XIV c).

Impregnation - Solvent

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
9	E+ cf E dth,ar,paf E° bt	E+ cf E ar,sh,paf
8	E+ ing E athi E° dth,scr,pen	E ing,thi E° dth,bt,cf,scr,pen
5	E dth,ar,oint,bt	E dth,ar,sh,bt
4	E pen,scr,sc,sh, ar,bt,thi,le, paf	E dth,ar,thi,ing,bt E° cf,aaf
5	E scr E° bt,thi,le,dth	E scr E° bt,le,thi
10*	E+ oint E° scr	E cf E° oint,scr
10	E scr E° oint,cf,aaf, ar,sc,dth,pen, thi	E thi,ing,dth,sh,bt E° ar

Av. 7.3+

* In this and all subsequent tables, signifies a man withdrawn from test for reasons other than a "break".

TABLE XIV b

Date Started - 1/18/44 (Concurrent with XIV a and XIV c).

Impregnation - Solvent + ZnO

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
6	E dth,sh,ar,bt,thi	(11 days) Ulcer.scr.; E+ scr; pig. body
8	E sc,paf,ing,thi E° scr,pen,cf	E dth,paf,bt E° ar,cf,ing,thi,scr
6	E cf E° dth,sc,ax,aaf, scr	Pigmenting rapidly
8	E ing,scr E° pen,sc	E dth,af,ar,cf,ing,scr, pen,bt
5	E+ dth,sh,ar,paf E° cf,bt	E sc,cf,bt,thi E° sh,ar
7	E dth,af,ar,cf, scr,ing,bt,pop	E ing,pen,scr,thi,se, paf,ar,bt,pop

Av. 6.7

TABLE XIV c

Date Started - 1/18/44 (Concurrent with XIV a and XIV b).

Impregnation - Aqueous Suspension

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E dth,sh,ar,ax,aaf, le,thi,ing	(72 hr.) E+ ing,thi, bt,le E dth,sh,paf
5	E dth,sh,ar,paf,le, scr,bt E° thi,ing,aaf	E dth,sh,ar,bt,thi, scr,ing
6	E dth,sh,ar,aaf,thi	No Readings
4	E+ scr E aaf,sh,th,pen,ing, ar	E+ ing E dth,sh,ar,af,scr
2	E scr	(96 hr.) E scr,ing,ax, bt E° oint,af,cf,thi
4	E af,dth,sh,cf, bt,thi,le,ar, pen,scr,ing	E dth,sh,af,cf,scr,bt E° ne,ing,thi
5	E dth,sh,af,ax,cf, scr E° ing,abd,thi,bt	E th,sh,ar,ax,paf,thi, abd E° bt

Av. 4.1

TABLE XIV d

Date Started - 2/29/44

Impregnation - Aqueous Suspension

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
2	E scr,sc,dth,ar E° cf	E scr,sc,paf E° aaf,cf,ar,sh,dth,thi, le
3	E paf E° cf,aaf,sc,dth, pop	E aaf,sh,ar,sc,dth E° cf,ing,thi,le
4	E ing,af,sc E° cf,sh,ar,dth, pen,thi,bt,le	E aaf,ax,ing,sc,sh E° pen
2	E sc E° aaf,th,ar,thi, le	E pen,sc,dth,paf E° sh,vth,aaf,cf,ar,scr, ing,thi,bt,pop
3*	E° scr,pen,st, dth,ar,aaf,thi kn,pop	E sc E° cf,dth,ar,sh,scr,pen, thi,le
2	E sc,paf E° cf,ar,sh,pop, th	E se,paf E° cf,ar,sh,th,bt,thi,le
3*	E° scr,pen,sc	E° pen,cf,aaf,sh,ar,sc
3*	E° scr,pen,aaf, sc,ar	E° aaf,sh,sc,dth,pen, ing,thi

Av. 2.8+

TABLE XIV e

Date Started - 3/21/44 (Concurrent with XV b and XV c).

Impregnation - Aqueous Suspension

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E sc E° cf,ar,dth,thi	E° aaf,sc,dth,thi,pop, le,kn
5	E sc,dth,scr E° ar,bt,thi	E° sh,ar,th,thi,sc
2	E sc,dth	E sc,dth E° sh,ar,cf,bt,pthi
5*	E° scr,ing,pen, dth,sc,ar	E sc,paf,dth E° sh,ar,thi
5*	E° scr,pen,dth, sc,ar,bt,abd	E° sc,dth,thi
5*	E° scr,pen,th,sh, ar,ax,lth	E° sh,sc,ar,dth,lth,thi

Av. 4.2+

TABLE XIV f

Date Started - 4/25/44 (Concurrent with XV f).

Impregnation - Aqueous Suspension

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E ash,sc,dth E° cf,ar,oint,bt, pop,le,thi,scr	E sc E° scr,sh,ar,cf,th,bt, thi,le,ing
6	E ing,thi,sc E° scr,ash,aaf	E+ sc E sh,ar,oint E° scr,bt
6*	V hand (accident)	V hand E° cf,bt
7	E bt E° cf,ash,aaf,sc, dth,thi,le,pop, lth	E bt E° ash,aaf,ar,cf,ax,sc. lth,thi
3	NPV scr (probably not H)	E° scr,sc
3	E pen E° scr,ing,thi	E thi,ing E° ne,ash,aaf,sc,bt, thi,pop,le,scr, pen

Av. 4.8+

TABLE XIV g

Date Started - 8/1/44 (Concurrent with XV j).

Impregnation - Aqueous Suspension

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E scr,pen E° oint,sc,bt	E scr,pen E° oint,sc,bt
4	E scr E° oint,sc,sh,thi,pop,le	E scr E° oint,sh,sc,pop,le
4	E scr E° oint,bt,sc	E scr E° sc
3	E scr	E scr,ing,thi,kn E° st,lth,bt,sc,pop
3	E scr E° cf,sc,dth	NPV cf E scr E° sh,oint,sc,dth
4	E scr E° oint,vth	E° oint,scr,thi,kn,bt
3	V pen E scr E° sh,ar	V pen E+ scr E° sh,thi,le,kn
4	E scr E° sh,pop	E scr,sc E° pen

Av. 3.6

TABLE XIV h

Date Started - 10/17/44

Impregnation - Aqueous Suspension

The first exposure was at CT 600 (10 γ H/l for 60 min.), the remainder at CT 1200 (20 γ H/l for 60 min.). It has since been found that with protective clothing there is little difference in man-breaks at CT 600 and at CT 1200 if the exposures are for 60 min. Therefore, this test is included without making a correction in the number of exposures.

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E ash,aaf,ing,pen, scr,kn,cf,sc,dth, bt,el,thi	E ash,aaf,th,cf,ing, pen,thi,kn,sc,bt E° ax,scr,pop
4	E ing,thi,kn E° oint,ax,cf,lth	E ing,thi,kn,ax,cf, lth E° ash,vth,oint
4	E ash,ing,kn,sc, dth E° vth,ax,scr,el,bt	E ash,vth,ax,th,cf, ing,kn,sc,paf E° pen,scr,oint,el,bt
4	E ax,lth,ing,sc,dth E° ash,vth,bt	E ash,ax, th,ar,ing, sc,paf E° scr
3	E sc E° ash,ar,dth,oint, el,bt	E ash,ar,thi,kn,bt,sc, dth,paf E° el,pop,lth
4	E+ scr E ing,thi E° sc,dth,pop	E ing,thi E° scr,sc,dth
4	E sh,aaf E° cf,sc,paf	V wr E ash,af,ar,cf,thi, ing,sc,dth E° ax,bt,pop

Av. 3.9

TABLE XV

1-1/2 Layer "Man-Breaks"

All suits and shorts impregnated by the aqueous suspension process. Suits in tests in March and April 1944 had buttoned hoods; those tested later had draw-string hoods.

* * *

TABLE XV a

Date Started - 3/14/44

Nainsook Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E th,aaf,sh,sc E° thi,bt,cf,ar	E th,aaf,sh,cf,ar,sc
3	E aaf E° cf,th,sc	E cf,paf E° sh,sc,ar,dth,thi,kn
4	E ash,vth,lth,sc E° scr,dth,ar, thi,kn,le	E aaf,sh,ar,lth,sc E° dth,le,thi

Av. 3.7

TABLE XV b

Date Started - 3/21/44 (Concurrent with XIV e and XV c).

Nainsook Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E sc,ing E° cf,aaf,ash,dth, thi,pop	E sc,dth,ash,ar,thi,pop E° ing
5*	(E- only)	E° ar,cf,sh,vth,sc
3*	V hand E ing E° ar,ash,th,sc, thi,le	V hand (palm and dorsum) E° ar,sh,sc,dth,bt, pthi,ing
4	E sc,dth	E° pen,scr,cf,ax,th, oint,sc
3	E sc,dth E° ax	E sc E° dth,sh,ar
2	E C_7 E° vth,sc	E sc E° vth,dth
3*	V palm E° cf,sc,dth, thi,le	V palm E° cf,sc,dth,thi, pop,scr
2	E sc E° dth	E sc,dth,sh,aaf,cf E° pthi,le
2	E sc,dth E° scr,thi,oint	E sc,dth E° sh,lth,pthi

Av. 3.0+

TABLE XV c

Date Started - 3/21/44 (Concurrent with XIV e and XV b).

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
2	E sc,dth E° scr,vth,sh,ar,lth	E ash,ar,cf,sc,dth E° lth,thi,le
3	E ash,aaf,ar,sc,dth E° thi	(No Readings)
4	E sc,dth E° ash,cf,pop,thi	E° thi,le,sc,dth,sh
3	E sc,dth E° scr,oint,sh,ar,pop	(No Readings)
2	E sc E° aaf,ash,ar,dth	E thi E° cf,ar,sc,dth,pop
2	E sc,dth E° sh,ne,cf	E vth,sh,ar,ax,aaf E° sc,dth,pen,thi,le
3*	E° scr,sc,dth	(No Readings)

Av. 2.7+

TABLE XV d

Date Started - 3/28/44

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E sh E° scr,cf,sc,th	E° th,sc
2	E sh,paf E° oint,th,ar, aaf,sc	E sc,dth
3	E cf E° ax,aaf,ar,sc	E cf E° af
3	E sc E° dth	E° sc,dth

Av. 2.8

TABLE XV e

Date Started - 4/11/44

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E ax,dth,sc,paf, lth,cf E° sh	E sh,ar,dth,lth,sc,pop E° thi,le
5*	E° sc,dth	E° sc,dth,ar
5	E ash E° th,sc,ar	E sh,lth,sc E° vth,dth,ar
3	E sc E° dth,ax,pop,kn, sh,aaf,cf	E+ sh,ar E dth,sc,lth,ax,paf E° cf,thi,pop

Av. 4.3+

TABLE XV f

Date Started - 4/25/44 (Concurrent with XIV f).

Knit Shorts.

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
8	E sc,dth E° kn,ash,lth,aaf, ar,cf,oint,thi, pop	(No Reading)
6	E sc E° sh,aaf,lth,pop	E ash,sc E° lth,ax,dth,bt
7*	E° cf,ash,sc,dth	E° cf,ash,sc,dth
3	NPV scr E° sc,dth	NPV (with scaling) scr E° sh,aaf,sc
7	E sc E° sh,ar,aaf,th	E sc,dth E° sh,ar,lth,thi,pop,le
3	E dth E° scr,thi,le,vth, lth,aaf,sc,bt	E ash,aaf,lth,sc,dth E° thi,pop,le,scr
7	E sc,dth E° ash,cf,aaf,lth, le	E af,dth,sc E° ash,lth,bt

Av. 5.9+

TABLE XV g

Date Started - 5/2/44

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E scr,oint E° sc,dth,bt, thi,le	E+ scr,oint E° sh
5	E oint,scr E° thi,pop,le	E° oint,scr,bt,pen
5	E+ athi E sc,dth,thi, pop,le E° ne,sh,ar	E+ dth E ash,ax,aaf,sc,lth,thi, pop,le E° bt
6*	E° sc,bt,kn, oint	E° oint

Av. 5.0+

TABLE XV h

Date Started - 5/9/44

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
6	E lth,ax,sc E° le,thi,scr, af,ash	E ash,aaf,sc E° scr,dth,cf
8*	E° sh,sc,bt, thi,le	NPV oint E° sh,ar,sc,dth,pop, le (15d. V le)
7	E ing E° scr	E scr
5	E scr E° sh,vth,cf	E scr,cf,thi,le E° ash,sc,dth
3	E scr E° pen,sc	E vth,dth,sc E° scr,ash,aaf,bt, thi,kn

Av. 5.8+

TABLE XV 1

Date Started - 5/16/44

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
6	E oint,aaf,sc,dth E° sh,kn	E oint,vth,sc,dth, paf,ar E° scr,pen,kn,le
6	E sc,dth E° oint,paf,scr,sh	E° scr,sc,dth
6	E scr,oint (with scaling) E° thi,kn	E° oint,scr
6*	V chin E° scr	V chin
8	E scr E° sh,th,cf,sc, thi,le	E cf,ar,sh,sc,dth
4	E sc,dth	E dth
8*	E° sc,dth,thi,kn	E° sc,dth

Av. 6.3+

TABLE XV j

Date Started - 8/1/44 (Concurrent with XIV g).

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E scr	E scr E° oint,sh,pen
5*	E° oint,scr,sc, dth,thi,le	E° sc,dth,thi,le
4*	E oint E° scr,pen,sc	E oint,thi,le E° scr,vth
5*	E oint E° scr,sh	E° sc,dth,oint,scr,kn
4*	E° ar,scr,pen, kn	E oint,sh,pen,sc E° cf,scr,el (72 hrs. V sc).
5	E sh,pop,oint E° scr,sc	E° sc,dth
5	E sc,scr E° thi,le	E sh,scr,sc (72 hrs. NPV sc)
5	E scr,pen E° sh,sc,ne	E scr E° sh

Av. 4.5+

TABLE XV k

Date Started - 10/3/44

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
5	E ash,af,cf,thi, kn,sc,dth,pop E° ar	E ash,af,ar,cf,thi,kn, sc,dth,pop,le
6	E sc,dth,paf E° ash,thi,kn, pop	E sc,dth,paf E° ash,thi,kn,pop
3	E sc E° ash,ar,cf,dth, thi,pop,le	E ash,th,sc,paf E° ar,cf,scr,thi,kn, el,pop,le (13 d. V ash)
4	E sc,dth E° cf,thi,kn,el, pop	E ax,thi,kn,sc,dth,pop
3	E sc E° ash,aaf,ar,cf, thi,kn,ar,pop, le	E ash,aaf,cf,ar,sc,dth E° scr,thi,kn,el
3	E sc,dth E° ash,aaf,cf,thi, kn,ar,pop,le	E sc,dth E° ash,aaf,ar,cf,thi, kn,el,pop
4	E ash,ar,cf,sc, dth,pthi,pop E° oint,vth,pen, scr,athi,kn	E ash,aaf,th,cf,sc,pthi, pop E° athi,kn,scr

Av. 4.0

TABLE XV 1

Date Started - 10/31/44

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E sc,sh E° ax,thi,kn,pop, dth	E athi,kn,sc,th,af,pop, ax,sh,ar
3	E pop E° ash,thi,kn, oint,sc,dth	E pop E° oint,st,kn,psh,paf
5	E ash,aaf,lth, cf,st,le,sc, pop E° kn,dth	E cf,pop,sh,af,ax,ar, th,sc E° kn
4	E+ pop E thi,le,ax,af, kn	E+ sc,dth,psh E ash,aaf,ax,ar,cf, thi,kn,le,pop E° oint
5	E psh,sc,dth,pop E° oint,ash,aaf, kn	E kn,le,sc,dth,psh,pop E° oint,aaf,cf
5	E sh,ar,cf,ax, pop,athi,kn,sc, dth E° pthi,vth,el	E sh,aaf,cf,ax,thi,kn, sc,dth,pop
5	E aaf,ash,ar,thi, kn,le,pop E° oint,psh,sc, dth	E ash,aaf,ax,th,thi,kn, le,sc,pop E° ar
5	E sh,ar,sc,dth E° thi,kn,le,pop	E sh,dth E° ar,thi,kn,pop

Av. 4.4

TABLE XV m

Date Started - 11/21/44

Knit Shorts

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E pop	E pop E° ax
3	E psh,sc,dth E° oint,ax,cf,ar	E cf,ax,psh,sc,dth,paf E° oint,ar,pop
3	E ax E° cf,psh,sc,dth	E ax E° cf,kn,psh,sc,dth
3	E ax	E ax E° athi,kn,psh,sc,dth
7	E pop E° cf,thi,kn,oint, psh,sc,dth,ar	E+ pop E sh,cf,thi,kn,le E° oint,sc,dth
3	E psh,sc,dth,paf E° oint,cf,ar	E ax,psh,sc,dth,paf E° cf,ar
5	E ax,cf E° oint,psh,pop	E ax,ash E° oint,athi,kn,le,psh
3	E ax,paf E° oint,psh,sc, dth	E ax,left psh, sc,paf E° ash,right psh,sc,paf

Av. 3.9

TABLE XVI

1-3/4 Layer "Man-Breaks"

All suits had buttoned hoods.

* * *

TABLE XVI a

Date Started - 1/25/44 (Concurrent with XVI b).

Impregnation - Solvent + ZnO Suits; aqueous suspension undershirts and shorts.

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
6	E+ cf E ar E° dth,sc	E+ cf E ar E° thi,dth
8	E cf E° ar,athi	NPV pop E+ cf E° ar,thi,kn,le
10	E ar E° cf	E ar,thi E° cf
7	E+ cf E ar	(Given additional exposures)
9	E cf,ar E° dth,athi	(Given additional exposures)
7	E cf,ar E° sc,dth,bt,thi	(Given additional exposures)
11	E cf E° ar,thi,dth,vth, oint	E+ cf E dth,sh,ar
10	E+ cf E ar,oint,vth,sh	E+ oint,sh,ar,cf,sc, thi,kn (allergic type reaction).

Av. 8.5

TABLE XVI b

Date Started - 1/25/44 (Concurrent with XVI a).

Impregnation - Aqueous suspension suits, undershirts and shorts.

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
5	E ar,cf	E+ cf E ar,paf
9	E cf,ar E° athi,kn,ne	(Given additional exposures)
5	E+ cf E ar,scr	E cf E° ar,sc,pthi
9	E cf,ar	(Given additional exposures)
6	E+ cf E ar E° thi,kn	E+ cf,ar E pthi,le E° pop,athi
8	NPV cf E ar,el E° sc,dth,pthi	NPV cf E+ ar E aaf E° dth
6	E cf,ar E° pthi,pop	E+ cf E ar
5	E sh,ar,cf E° dth	E° cf,ar,sh,sc,dth
6	E+ cf E thi,le	E cf E° ar,thi,kn,pop,le (11 d. V cf,pop)

Av. 6.6

TABLE XVII

Breaks per Day on One Layer "Man-Break" Tests

Date Started	Impreg. System	No. of Men	No. of Men Broken on Day No. - 1	2	3	4	5	6	7	8	9	10	No. of Breaks	Av. No. of Exps. Tolerated
1/18/44	Solvent	7				1	2			1	1	1,1*	6	7.3 +
1/18/44	Solvent + ZnO	6					1	2	1	2			6	6.7
1/18/44	Aqueous	7		1	1	2	2	1					7	4.1
2/29/44	"	8		3	1,3*	1							5	2.8 +
3/21/44	"	6		1	1		1,3*						3	4.2 +
4/25/44	"	6			2	1		1,1*	1				5	4.8 +
8/ 1/44	"	8			3	5							8	3.6
10/17/44	"	7			1	6							7	3.9
Total	Aqueous	42		5	9,3*	15	3,3*	2,1*	1				35	3.8 +

* Man withdrawn from test for reasons other than a "break".

TABLE XVIII

Breaks per Day on 1-1/2 Layer Aqueous "Man-Break" Tests

Date Started	Shorts Type	No. of Men	No. of Men Broken on Day No.- 1	2	3	4	5	6	7	8	No. of Breaks	Av. No. of Exps. Tolerated
3/14/44	Nainsook	3			1	2					3	3.7
3/21/44	"	9		3	2,2*	1	1*				6	3.0 +
3/21/44	Rib-Knit	7		3	2,1*	1					6	2.7 +
3/28/44	"	4		1	3						4	2.8
4/11/44	"	4			1	1	1,1*				3	4.3 +
4/25/44	"	7			2			1	2,1*	1	6	5.9 +
5/ 2/44	"	4				1	2	1*			3	5.0 +
5/ 9/44	"	5			1		1	1	1	1*	4	5.8 +
5/16/44	"	7				1		3,1*		1,1*	5	6.3 +
8/ 1/44	"	8			1	2*	3,2*				4	4.5 +
10/ 3/44	"	7			3	2	1	1			7	4.0
10/31/44	"	8			2	1	5				8	4.4
11/21/44	"	8			5	1	1		1		8	3.9
Totals		81	7	23,3*		11,2*	14,4*	6,2*	4,1*	2,2*	67	4.3 +

* Man withdrawn from test for reasons other than a "break".

TABLE XIX

Breaks per Day on 1-3/4 Layer "Man-Break" Tests

Date Started	Impreg. System	No. of Men	No. of Men Broken on Day No. - 1	2	3	4	5	6	7	8	9	10	11	No. of Breaks	Av. No. of Exps. Tolerated
1/25/44	Solvent + ZnO	8						1	2	1	1	2	1	8	8.5
1/25/44	Aqueous	9					3	3		1	2			9	6.6

TABLE XXI

1-1/2 Layer Aqueous Tests - Penile and Scrotal Reactions Only

XVa-Nain. 3/14/44				XVb - Nain. 3/21/44				XVc - Knit 3/21/44				XVd - Knit 3/28/44				XVe - Knit 4/11/44				XVf - Knit 4/25/44				XVg - Knit 5/2/44			
Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.
4	E°	0	0	3	0	0	0	2	E°	0	0	3	E°	E-	0	4	0	0	P_1	8	0	0	0	4	E	E+	0
3	0	0	0	5*	0	0	0	3	0	0	0	2	E-	E-	0	5*	E-	E-	0	6	E-	0	0	5	E	E°	0
4	E°	E-	0	3*	0	0	0	4	E-	0	0	3	E-	0	0	5	0	0	P_3	7*	0	0	0	5	0	0	0
				4	E-	E°	0	3	E°	0	0	3	0	0	0	3	0	0	P_3	3	NPV	NPV	0	6*	E-	E-	0
				3	0	E-	0	2	0	0	0									7	E-	0	0				
				2	0	0	0	2	E-	0	0									3	E°	E°	0				
				3*	E-	E°	0	3*	E°	E°	0									7	E-	0	0				
				2	0	0	0																				
				2	E°	0	0																				

TABLE XXI Continued on Next Page.

TABLE XXI (Cont'd.)

1-1/2 Layer Aqueous Tests - Penile and Scrotal Reactions Only

XVh - Knit 5/9/44				XVi - Knit 5/16/44				XVj - Knit 8/1/44				XVk - Knit 10/3/44				XVl - Knit 10/31/44				XVm - Knit 11/21/44			
Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.	Exp.	24	48	xd.
6	E°	E°	0	6	0	E°	0	3	E	E	0	5	0	0	0	3	0	0	0	4	0	0	0
8*	0	E-	0	6	E°	E°	0	5*	E°	E-	0	6	0	0	0	3	0	0	0	3	E-	E-	0
7	E°	E	E	6	E	E°	0	4*	E°	E°	0	3	0	E°	0	5	0	0	0	3	0	0	0
5	E	E	0	6*	E°	0	0	5*	E°	E°	0	4	0	0	0	4	0	0	0	3	0	0	0
3	E	E°	0	8	E	E-	0	4*	E°	E°	E-	3	E-	E°	0	5	0	0	0	7	0	0	0
				4	E°	E-	0	5	E°	E-	0	3	0	0	0	5	0	0	0	3	0	0	0
				8*	E-	0	0	5	E	E	E-	4	E°	E°	0	5	0	0	0	5	0	0	0
								5	E	E	0					5	0	0	0	3	0	0	0

* Man withdrawn from test for reasons other than a "break".

The men in each test are in the same order as those in the indicated test in Table XV. Each test lists the number of exposures given and the scrotal or penile reactions at 24 and 48 hrs. after the last exposure and the reactions when the men returned from leave (xd.) 8 - 15 days later. The type of shorts and the date the test was started are also given.

TABLE XXII

1-3/4 Layer Tests - Penile and Scrotal Reactions Only

XVIa - Solv.+ZnO 1/25/44				XVIb - Aqueous 1/25/44			
Exp.	24	48	xd.	Exp.	24	48	xd.
6	0	0	0	5	E-	E-	0
8	0	0	0	11	0	E°	
10	E-	0	0	5	E	E-	0
10	E°	E		10	E-	E-	
11	E-	E	0	6	0	0	0
7	E°	0	0	8	0	0	0
11	0	0	0	6	0	0	0
10	E°	0	0	5	E-	E-	0
				6	E-	E-	cr

The men in each test are in the same order as those in the indicated test in Table XVI. Each test lists the number of exposures given and the scrotal or penile reactions at 24 and 48 hrs. after the last exposure and the reactions when the men returned from leave (xd.) 8 - 15 days later. The type of impregnation and the date the test was started are also given.

TABLE XXIII

Vesication Endpoint "Man-Break"

Men from 1-3/4 layer tests (See Tables XVI a and XVI b).

Impreg. System	No. of Previous Exposures	Readings (24 hrs. after additional exposure number) 0	1	2	3
Solvent + ZnO	7	E+ rcf E lcf,ar	E+ rcf E lcf,ar, athi,kn E° sc	E+ cf,ar E° athi	NPV rcf E+ lcf,ar E° athi,scr, oint
	9	E cf,ar E° dth, athi	E+ cf E ar E°thi,oint dth,pop	NPV cf,ne E+ ar E° dth,sh le,thi	
	7	E cf,ar E° sc,dth bt,thi	E+ cf E ar E° athi,ne dth	NPV cf E+ ar	
Aqueous	9	E cf,ar E° athi, kn,ne	E+ ne E° cf,ar, paf,thi, kn,pop	NPV ne E+ cf E ar E° scr,dth pop	
	9	E cf,ar	E cf E° ar,oint thi,kn	Sick, was withdrawn from test	

TABLE XXIV

Minimum Protection Tests

* * * * *

TABLE XXIV a

Date Started - 4/4/44

No previous exposures.

No. of Exposures Given	Readings (Hours after Last Exposure) 24	48
1	E ne,ar E° face*, dth,sh	E° ne,face,dth,sh,ar
1	(No readings of E° or greater)	(No readings of E° or greater)
1	E° ne	E ne
1	E° ne	E° ne
1	E° ne	E ne E° ar
1	E ne,ears,cl E° dh	E ne,ears,face E° cl
1	E° ne	E° ne
1	Q (No readings of E° or greater)	E° ne,face,cf

* Readings recorded as "face" represent the area of the face not covered by the gas mask.

TABLE XXIV b

Date Started - 4/6/44

Men had had one previous exposure on 4/4/44 dressed in standard 1-1/2 layer protection.

No. of Exposures Given	Readings (Hours after Last Exposure) 24	48
1	E° ne,face*	No 48 hour readings recorded
1	E° face,dth,sc, sh,ar	"
1	E ne E° dth,sh,sc,ar, cf,af	"
1	E° ne,dth,sc,sh, ar	"
1	E ne	"

*Readings recorded as "face" represent the area of the face not covered by the gas mask.

DISTRIBUTION

Bu Ships	17
Bu Med	2
OR&I	2
CNO	2
CO, Naval Unit,EA	1
CWS, Tech. Div.	4
CWS, Med. Div.	1
CWS, Med. Div. EA	1
NDRC	4
NRC, Wash. D. C.	2