[redacted]

Serial No. 8

Navy Department - Office of Research and Inventions

NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

FR-2695

* * *

CHEMISTRY DIVISION - PROTECTIVE CHEMISTRY SECTION

26 November, 1945

A SUMMARY OF WEARING TRIALS OF PERMEABLE PROTECTIVE CLOTHING

By

G. M. Gantz

Report No. P-2695

[redacted]

* *

Approved by:

W. C. Lanning - Head, Protective Chemistry Section

Dr. P. Borgstrom
Superintendent, Chemistry Division

Commodore H. A. Schade, USN
Director, Naval Research Laboratory

Preliminary Pages ---	a - c
Numbered Pages ------	21
Appendices ----------	2
Tables --------------	5
Distribution List ---	d

NRL Problem P-60
EHB

Unclass B

[redacted]

Serial No. 7

Navy Department - Office of Research and Inventions

NAVAL RESEARCH LABORATORY
WASHINGTON 20, D. C.

* * *

CHEMISTRY DIVISION - PROTECTIVE CHEMISTRY SECTION

26 November, 1945

A SUMMARY OF WEARING TRIALS OF PERMEABLE PROTECTIVE CLOTHING

By

G. M. Gantz

Report No. P-2695

[redacted]

* * *

Approved by:

W. C. Lanning - Head, Protective Chemistry Section

Dr. P. Borgstrom
Superintendent, Chemistry Division

Commodore H. A. Schade, USN
Director, Naval Research Laboratory

Preliminary Pages ---	a - c
Numbered Pages ------	21
Appendices ----------	2
Tables -------------	5
Distribution List ---	d

NRL Problem P-60
EHB

ABSTRACT

This report summarizes the results obtained in four small scale wearing trials of protective clothing carried out in 1942 and 1943. A wearing trial of six suits at the Washington Navy Yard in September 1942 was followed by a trial in March 1943 of thirty-five suits on board a destroyer operating out of Key West.

Two trials were run at Bainbridge Naval Training Station, one in June and the other in September 1943. In the first trial a comparison was obtained between CC-2 applied by the solvent process and the impregnites S-461 and S-330. The second trial at Bainbridge was conducted to gain a supply of protective clothing for evaluation in chamber tests.

These trials showed that CC-2 clothing would retain more than 0.15 mg.Cl+/cm.^{2} for a period of two to six weeks when worn for 8 hours a day, five days a week, depending upon the weather and the laundering procedure. No adverse effects on wear were caused by introduction of the stabilizer zinc oxide to impregnating systems. Evidence was obtained that the impregnite S-461 had a shorter life span than CC-2. The impregnite S-330 was at least equivalent to CC-2 in retention of chlorine during wear.

TABLE OF CONTENTS

INTRODUCTION

A. Authorization

1. This work was authorized under Project No. 547/41, "Maintenance, Bureau of Ships" dated 16 December 1940. The problems which were proposed for study were given in BuShips letter S-77-2(Dz), Serial 811, of 17 December 1940.

B. Statement of the Problem

2. This report is intended to summarize the results of several small scale wearing trials of permeable protective clothing. These trials were conducted under temperate and semi-tropical conditions. Therefore, no conclusive data with regard to irritation on wear can be expected. The data reported is valuable, however, from the standpoint of establishing values for the service life of protective clothing during wear.

C. Known Facts Bearing on the Problem

3. Wearing trials have been conducted by the CWS in this country and the British have conducted wearing trials in England and other parts of the British Empire. Results of the tests have indicated that the service life of protective clothing under different climatic conditions and conditions of wear could vary from one week to six or eight weeks. Numerous factors influence the effective life of protective clothing, such as the type of garment, the type of impregnite, the laundering conditions, the amount of exposure to direct sunlight, etc. Any new modification in protective clothing should, therefore, be tested in a wearing trial designed to evaluate that modification.

4. Many recent wearing trials have been conducted to establish the tolerance of protective clothing in the tropica. Since these have been reviewed in a separate report, NRL P-2343, no discussion will be presented here.

D. Theoretical Considerations.

5. The tactical and climatic conditions under

which gas warfare may commence or be used, cannot be predicted with any degree of certainty. Therefore, it is difficult to establish standards of effective service life of protective clothing. Standards can be based on the results of previous wearing trials or on the known service life of unimpregnated clothing under various conditions.

6. In the Southwest Pacific area, clothing may be expected to have a service life of one month in combat. In rear areas such as base depots, the service life is approximately six months. In intermediate areas, clothing will last for two to three months. Previous experience indicates that the effective life of protective clothing will be considerably less than the values given above. This is due to loss of impregnite rather than wear of the clothing.

7. Consideration of the life of protective clothing for the Navy adds additional factors. On shipboard, the life of protective clothing may be expected to be quite long. Even if a policy were established that tropical personnel wear protective clothing at battle stations, such wear would not be as severe as most combat operations by land forces. The wearing of protective clothing by Naval personnel in landing operations and construction battalions must be considered as severe as combat operations on land.

E. Previous Work Done at This Laboratory.

8. No work was done at this Laboratory previous to that described in this report. A summary of the wearing trial conducted at Key West, Florida, was prepared in the form of a Memorandum to the Director C-S77-2 dated 15 June 1943.

EXPERIMENTAL

I. Preliminary Trial at Washington Navy Yard September 1942.

A. Description of the Clothing

9. This wearing trial was conducted just after a

demonstration and trial of incorporating zinc oxide stabilizer in the hand impregnation of clothing by the solvent process. Six suits were included in the test. Two were impregnated by the solvent process without stabilizer, two were impregnated by the solvent process with zinc oxide stabilizer. The other two suits were impregnated with the impregnites S-461 and S-328 by the solvent process.

B. Conduct of the Trial.

10. The six garments were worn by enlisted personnel attached to the Passive Defense Section of the Potomac River Naval Command. The garments were worn for five days at such times as would not interfere with the duties of the men. At the end of the first week, the garments were laundered using a 15 minute wash in 0.2% soap solution at 60°C. The garments were then reissued and worn a second week. The garments were actually worn about 25 hours each week of which 25% of the time was spent outdoors.

C. Retention of Active Chlorine and Tensile Strength.

11. The retention of active chlorine for the garments worn in the trial is shown in Table I. Each garment was analyzed at eight different points.

Table I

Wearing Trials of Impregnated Arnzen Suits
(Washington Navy Yard, Sept. 18-Oct. 1, 1942)

Impregnite	Active Chlorine mg/cm.^{2} Original	Active Chlorine mg/cm.^{2} After 2 wks.wear,2 washes	% Retained
S-145 (DPU)	0.56	0.38	68
S-145 (DPU), 25% ZnO	0.52	0.47	90
S-328	0.88	0.76	86
S-461	0.94	0.22	23

12. All the garments were in serviceable condition at the end of the two weeks wear and two washes. Only the suit impregnated with S-461 had lost sufficient tensile strength to be detected by the thumb test.

[redacted]

D. Discussion of Results.

13. This test indicated that no unexpected hazard existed with regard to the use of zinc oxide as a stabilizer. The impregnite S-461 was judged to be inferior to either S-145 or S-328.

II. Trial Aboard a Destroyer at Key West, March 1943

A. Description of the Clothing.

14. The clothing worn in this trial consisted of thirty-five two-piece Navy protective suits divided into seven groups of five suits each. The seven groups were as follows:

(1) unimpregnated
(2) Standard S-145 (DPU) impregnated by solvent process
(3) Same as (2).
(4) S-145 (DPU) + 25% zinc oxide by solvent process
(5) Same as (4).
(6) S-145 (DPU) + 25% zinc oxide and khaki dye #3031, solvent process
(7) S-145 (DPU) + 25% zinc oxide and blue dye TLX-1, solvent process.

15. All of the impregnated garments were prepared by the Impregnating Plant, Naval Clothing Depot, Brooklyn. The hoods attached to the jumpers of the suits were cut off. Also the jumper was worn inside the trousers, contrary to normal practice, to facilitate performance of regular duties by the men wearing the protective garments.

B. Conduct of the Trial.

16. The clothing in this trial was worn by the crew of the USS Dahlgren, a destroyer in training service, operating from the Naval Operating Base, Key West, Florida. The men performed their regular duties while wearing the suits.

17. The protective clothing was worn for approximately eight hours each day while the ship was at sea and for five and one-half days each week. A daily log

was kept of each individual suit with regard to activity and degree of perspiration of the crew member wearing the suit, per cent of wearing time in sunlight, and any unusual conditions of wear. The weather data recorded each day included temperature, humidity, precipitation, wind velocity, percent of possible sunshine and character of the day. The weather data and the daily log of each suit is recorded in Tables I through VI of Appendix A.

18. At the end of each week of wear (five and one-half days), the suits were laundered in the Ships Service laundry using a 15-minute wash in water at 60°C containing 0.5% of mild soap. Each of the seven groups of clothing was laundered separately. Sampling was accomplished by withdrawing one suit each week from each group and cutting it in half. One half was laundered while the other half was not. These samples were returned to the Laboratory for inspection and analysis.

C. Retention of Active Chlorine and Tensile Strength.

19. The samples returned each week from Key West were analyzed for active chlorine and tested for tensile strength. These results were summarized and are shown in Table II. Complete data on losses of chlorine and tensile strength are given in Tables VII through X of Appendix A.

TABLE II

SUMMARIZED RESULTS OF WEARING TRIALS

KEY WEST, FLA. March 1943

No.	System	% of Active Chlorine Retained After					Tensile Strength (lbs. warp)			
		1 wk.	1 wash	2 wk.	2nd wash	3 wks.	1 wk	2 wk	3 wk	4 wk
1.	Unimpregnated	-	-	-	-	-	151	143	139	135
2.	S-145 (DPU)	-	-	14	11	14	-	147	130	124
3.	"	63	55	23	22	7	163	144	139	135
4.	S-145, 25% ZnO	57	39	23	15	4	164	151	130	136
5.	"	76	48	17	10	7	175	147	134	134
6.	S-145, 25% ZnO Khaki Dye	64	42	18	11	12	168	150	146	132
7.	S-145, 25% ZnO Blue Dye	63	41	12	7	8	171	148	144	139
	AVERAGE	65	45	18	13	8	165	147	137	132

[redacted]

20. It is apparent from the data in Table II that the suits had lost sufficient active chlorine to require reimpregnation at the end of the second week of wear. The laundering process at the end of the first week of wear caused a considerable loss of active chlorine but not as much as the week of wear itself. Only small losses in tensile strength were observed for these suits and all of them were serviceable at the end of the trial. The presence of zinc oxide stabilizer had no effect on the loss of active chlorine and only a slight effect in preventing loss of tensile strength.

D. Discussion of Results.

21. Upon the basis of active chlorine losses, this trial indicated that two weeks is the longest time protective clothing should be worn on shipboard. The average temperature of 78°F with relative humidity between 60 and 85% is representative of semi-tropical conditions. The high percentage of possible sunshine, 85% to 90%, coupled with the high losses for the shoulders of the suits illustrate the destructive action of sunlight upon CC-2. Since impregnite losses for armpit and crotch areas of the suits (Tables VII to IX in Appendix A) were much less than for other areas, any destructive action of perspiration was masked by the more destructive action of sunlight.

22. The zinc oxide analyses given in Table XI of Appendix A show that loss of this stabilizer was gradual over the wearing period. Even after the fourth week of wear and fourth laundering almost one half of the original zinc oxide content remained. The stabilizing action of zinc oxide on tensile strength losses is not outstanding primarily because unstabilized garments did not show a great loss.

23. The laundering procedure used in this trial was responsible for large losses of active chlorine. A milder washing formula is required which will not affect CC-2 but will remove gross dirt and perspiration. A measure of the losses due to laundering as separate from wearing, is shown in Table XII of Appendix A in which the hoods of the suits used in the wearing trial were laundered in the laboratory.

24. The results of a questionnaire filled out by men participating in this test is shown in Table XIV in Appendix A. The majority of the men thought the suits were comfortable while a few complained of size and warmth. Most of the men noticed an odor to the suits but only half of them reported it objectionable. There was no appreciable skin irritation during these trials though five men said the suits were itchy and one reported a rash on his leg.

III. Trial at Bainbridge NTS, June 1943.

A. Description of the Clothing.

25. The impregnated clothing worn in this trial consisted of forty-eight two-piece Navy protective suits divided into eight groups of six suits each. A ninth group was included of six two-piece Army protective suits made of March model carbon coated herringbone twill fabric. A set of underwear (nainsook drawers and cotton quartersleeve shirts) was included with each group of suits. The impregnations of the suits and underwear in each group is shown below:

(1) Solvent process CC-2, 15% ZnO; unimpregnated underwear.
(2) Aqueous process CC-2, 25% ZnO; unimpregnated underwear.
(3) Unimpregnated suits; solvent process 15% ZnO underwear.
(4) Unimpregnated suits; aqueous process 25% ZnO underwear.
(5) Aqueous process CC-2, 25% ZnO suits; solvent process 15% ZnO underwear.
(6) Aqueous process CC-2, 25% ZnO for both suits and underwear.
(7) Aqueous process S-461, 50% ZnO unimpregnated underwear.
(8) Aqueous process S-330, 10% ZnO; unimpregnated underwear.
(9) March model carbon coated HBT; unimpregnated underwear.

26. Both the solvent and aqueous process suits were impregnated at the Impregnation Plant, Naval Clothing

Depot, Brooklyn. The underwear was impregnated at this Laboratory as were the suits containing the impregnite S-330. The suits containing S-461 were impregnated by NDRC workers at the duPont Experimental Station according to the formula: 100 CC-2/20 ZnO/ 75 CP/5 PVA/10 Tamol NNO/5 $MnAc_2$.

B. Conduct of the Trial.

27. The clothing in this trial was worn by enlisted men undergoing their "boot camp" training. The regular training routine was adhered to since it was agreed that wearing of the protective clothing should not interfere with the training. A further agreement was made that clothing would be removed from any men suffering from skin irritations.

28. The protective clothing was worn for approximately eight hours a day for five days, Monday through Friday, during the three weeks of this trial. A log was kept of each suit with an estimate of activity of the men, the degree of perspiration, percent of wearing time in sunlight, and an entry of any unusual conditions of wear. A description of the activity of the men is given in Table II of Appendix B. In Table I of Appendix B is given the daily weather data collected during the trial.

29. At the end of each week, two suits and sets of underwear were withdrawn from each group and returned to the Laboratory. The remaining four sets of garments in each group were laundered at the Ships Service laundry. The unimpregnated and CC-2 impregnated suits were given a 15 min. wash in 0.06% Nacconal NR at 90°F. The carbon suits were washed separately in 0.2% Kalye-A at 140°F.

30. Each suit withdrawn from the trial was analyzed at seven different places: armpit, shoulder, elbow, waist, crotch, knee and seat. The underwear drawers were analyzed at the crotch and seat while the shirts were analyzed at the armpit, back, and waist. After the analyses the garments were laundered under the same conditions specified for Bainbridge and re-analyzed for active chlorine. In addition samples were taken out for

tensile strength measurements.

31. After laundering at the end of one week, the garments were reissued for five days of wear the following week.

32. During the trial the men were questioned regarding irritations from the clothing and on the third day of the first week all the men were examined by a medical officer for signs of dermatitis.

C. Retention of Active Chlorine and Tensile Strength.

33. Complete results on active chlorine analyses for the garments worn in this trial are given in Tables III through VIII of Appendix B. A summary of the data for the suits is given below in Table III.

Table III

Summarized Active Chlorine Losses for Wearing Trial at Bainbridge NTS, June 1943

System	Original mg.Cl+/cm.^{2}	% Cl+ Retained After 1st Wk	1st Wash	2nd Wk	2nd Wash	3rd Wk	3rd Wash
CC-2,solvent,ZnO	0.40	70	68	52	48	45	45
CC-2,aqueous,ZnO	0.58	72	64	61	56	52	51
CC-2,aqueous,ZnO	0.58	73	69	56	54	48	49
CC-2,aqueous,ZnO	0.58	78	70	52	48	60	53
S-461,aqueous,ZnO	1.68	74	42	21	6	16	12
S-330,aqueous,ZnO	0.96	83	81	49	48	60	58

34. The solvent process CC-2 impregnated suits lost a somewhat higher percentage of active chlorine than did the more heavily loaded aqueous process CC-2 suits. The interesting point is that both types of suits were above the reimpregnation level of 0.15 mg.Cl+/cm.^{2}, after the full three weeks of the test. This is in contrast to the results for the Key West trial and may be attributed, in part, to the much milder laundering procedure employed. The S-461 suits showed the greatest loss of any in the trial. Considerable losses were sustained in the launderings and this is characteristic of this impregnite. The behavior of the S-330 impregnated

suits indicated excellent chlorine retention against both wear and laundering for this impregnite.

35. The underwear worn in this trial was made of light weight fabric which did not take a high degree of impregnation. Consequently, the shirts and shorts reached a reimpregnation level of 0.15 mg.Cl+/cm.^{2} after about one week as indicated by the data in the table of Appendix B. It is evident, however, that better chlorine retention was shown by the solvent process of impregnation.

36. The tensile strength values shown in Table IX of Appendix B require little comment inasmuch as all the garments retained adequate strength. It is interesting to note that the unimpregnated suits showed lower strength values than the impregnated suits after the three weeks of the trial.

D. Irritation from the Clothing.

37. The skin irritation from wearing impregnated clothing encountered in this trial occurred during the first week. On the second day the men spent most of their time on the drill field in the suits. Two men wearing aqueous process CC-2 suits and one man with a carbon suit reported irritations. After another hard day on the drill field and obstacle course, several men complained of irritation and arrangements were made for examination of all men by a medical officer on the morning of the fourth day.

38. A summary of the skin irritations in the trial is shown in Table IV.

Table IV

Summary of Irritation Observed in Wearing Trial Bainbridge NTS, June 1943.

Date	System	Severity and Site of Irritation	Action
15 June	CC-2 aqueous, solvent underwear	not recorded	Suit withdrawn
15 June	CC-2 aqueous, aqueous underwear	not recorded	Suit withdrawn
15 June	Carbon suit, plain underwear	Mechanical Irritation	Suit transferred.
17 June	CC-2 solvent, plain underwear	mild, mesial aspect of mid thigh	Suit withdrawn
17 June	CC-2 aqueous, plain underwear	mild, groin, area 4 x 4 cm.	None
17 June	CC-2 aqueous, plain underwear	marked, groin	Suit withdrawn
17 June	CC-2 aqueous, solv. underwear	mild, mid-thigh	None
17 June	CC-2 aqueous, solv. underwear	irritation of June 15 aggravated	Withdrawn
17 June	CC-2 aqueous, aqueous underwear	mild, rt. anterior spine	None
17 June	CC-2 aqueous, aq. underwear	mild, rt. groin	None
17 June	CC-2 aqueous, aq. underwear	Papular rash, rt. side	None
17 June	S-461, plain underwear	severe, armpit, arms, groins, thigh	Suit withdrawn
17 June	S-461, plain underwear	moderate, inner aspect rt. thigh	Suit withdrawn
17 June	S-461, plain underwear	recovered from complaint of June 16	None
17 June	S-461, plain underwear	mild, inner aspect both thighs	None
17 June	S-461, plain underwear	mild, over both shoulders	None
17 June	Carbon suit, plain underwear	complaint of June 15 cleared up	-

Of the fifty-two men in the trial at the time of the medical examination, twelve had skin irritations. Of these, four cases were considered of sufficient severity to have their suits withdrawn from the test. It is doubtful if any of the cases of irritation were sufficient to affect the combat efficiency of the men since two of the men continued to wear their suits after they had been told they could remove them.

39. The greatest irritation occurred for those

suits impregnated with S-461. More cases of irritation were found for aqueous process suits than for solvent process suits. No irritation was observed for men wearing unimpregnated suits with impregnated underwear or for men wearing S-330 impregnated suits.

D. Discussion of Results.

40. In observing from this trial that both solvent and aqueous process CC-2 suits were still above the reimpregnation level after three weeks wear, it must be remembered that the clothing was worn for only eight hours a day and five days per week with about half the wearing time spent indoors. This would correspond to no more than six or seven days continuous wear with full time spent outdoors.

41. It is quite evident that the low temperature-synthetic detergent washing formula used in this trial is much better than the high-temperature-soap formula used in the Key West trial from the standpoint of retention of active chlorine.

42. The high chlorine losses observed for suits containing the impregnite S-461 indicate that this compound is not as suitable for protective clothing as CC-2 or S-330. This is confirmed by the higher incidence of irritation for the S-461 suits.

43. In view of the small number of suits involved and the mildness of the skin irritation, it is not possible to draw any conclusions regarding irritation by the clothing. It can be stated, however, that no marked differences in irritation were observed between impregnated suits worn with or without impregnated underwear.

44. The results obtained in this trial for the impregnite S-330 were very promising. However, later evidence was obtained to show that this compound did not show sufficient reactivity toward mustard gas (See NRL Report No. P-2300).

45. The evaluation of the carbon-coated suits worn in this trial has been described in NRL Report No. P-2322. Considerable loss of protective capacity was

observed for these suits during the three weeks of wear. This was due to mechanical loss of carbon as evidenced by blackening of undergarments and also to poisoning of the carbon, since dry cleaning of the suits restored a considerable part of their protective capacity.

IV. Trial at Bainbridge NTS, September 1943.

46. A second wearing trial was carried out at the Bainbridge Naval Training Station in September, October, and November of 1943. The purpose of the trial was to obtain a supply of protective suits worn and laundered to a reimpregnation level for subsequent chamber tests.

A. Description of the Clothing.

47. Five groups comprising a total of 110 suits were involved in the trials as follows:

(1) 25 suits, CC-2 solvent process impregnation, no stabilizer.
(2) 25 suits, CC-2 solvent process impregnation, 15% ZnO.
(3) 25 suits, CC-2 aqueous process impregnation, 25% ZnO.
(4) 25 suits, S-330 aqueous process impregnation, 10% ZnO.
(5) 10 suits, NDRC August model carbon coated herringbone twill.

All the suits, except those with carbon, were of the standard Navy two-piece design. Solvent process suits were prepared at the Impregnation Plant, Naval Clothing Depot, Brooklyn. The aqueous process CC-2 and S-330 suits were impregnated at this Laboratory in a Navy Portable Impregnation Plant. The carbon suits were standard two-piece Army combat garments as modified by the CWS for anti-gas use.

B. Conduct of the Trial.

48. The subjects in this trial were recruits assigned to the Outgoing Unit who had completed their

eight weeks basic training course. There was a frequent turnover of personnel in the Outgoing Unit with the result that frequent changes had to be made in the assignment of suits to the men.

49. The suits were worn for eight hours a day, five days a week, for five or six weeks. The men followed a regular training routine of infantry drill, physical conditioning, and class room instruction as well as assignment to working details for K.P. duty, policing grounds, wood-chopping, and ditch digging.

50. At the end of each five days of wear the suits were collected and laundered in the Ships Service laundry. The chemically impregnated suits were given three five minute washes in mild soap solution at 90-100°F, followed by rinsing, extracting, and drying. The carbon suits were washed separately for 15 minutes in 0.2% Kalye-A solution at 90°F. In order to preserve the effectiveness of the suits they were sampled at the pockets and pocket flaps. These samples were returned to this Laboratory for analysis.

51. Typical fall weather prevailed throughout the six weeks of this test. The temperature ranged from 50 to 90°F. The sunshine was moderate and rain was encountered on several days. Suits which became wet were air dried in the barracks. It was estimated that the men spent an average of 50% of the time outdoors. For the most part the men wore the protective clothing over their regular denim trousers and shirts.

C. Retention of Active Chlorine.

51. During the course of the trials it was found that analysis values obtained on pockets or pocket flaps were not always indicative of the true values for the suits. By an occasional analysis of a suit withdrawn from the test it was possible to estimate when to withdraw an entire group of suits from the test. The active chlorine values are summarized in Table V.

Table V

Retention of Active Chlorine for Suits in Wearing Trial, Bainbridge NTS, Sept. 1943

System	Original mg.Cl+/cm.^{2}	% Cl+ Retained after Week* 1	2	3	4	5	6
CC-2, Solvent	0.37	72	67	63	59	33	-
CC-2, Solvent, 15% ZnO	0.44	81	70	53	53	39	-
CC-2, aqueous, 25% ZnO	0.48	79	87	73	70	53	23
S-330, aqueous, 10% ZnO	0.63	39	59	49	43	42	-

*Samples were taken after laundering at the end of each week; underlined values refer to analyses for entire suits rather than to values for pockets or pocket flaps.

52. It was decided to remove the solvent and solvent stabilized suits from the trials after the fifth week. The aqueous process CC-2 and S-330 together with the carbon suits were withdrawn at the end of the sixth week.

53. It is quite evident that the suits worn in this trial under fall weather conditions retained their active chlorine for a longer time than suits worn under summer conditions as in the earlier trial at Bainbridge.

D. Discussion of Results.

54. The suits containing the impregnite S-330 worn in this trial were never used. Later work described in NRL Report No. P-2300 indicated that S-330 did not offer sufficient protection against mustard vapor to warrant further consideration as an impregnite for protective clothing.

55. The CC-2 clothing worn in this trial was tested against H vapor in a gas chamber. The results have been given in NRL Report No. P-2597, "Chamber Tests with Human Subjects VIII. Evaluation of Worn CC-2 Clothing", dated 5 September 1945. It was concluded in this report that a reasonable correlation existed between the active chlorine content of worn protective clothing and the

protective value. The level of 0.15 mg.Cl+/cm.^{2} (3% CC-2) was considered satisfactory for solvent impregnations but a value of 0.20 mg.Cl+/cm.^{2} (4% CC-2) was considered more satisfactory for aqueous process clothing.

56. An evaluation of the carbon clothing worn in this trial is described in NRL Report No. P-2322 and results of chamber tests on the clothing are given in Report No. P-2239. It was found that H vapor capacity of the suits as measured in the laboratory was decreased by the six weeks of wear. Chamber tests, however, showed that the protective value was nearly the same for the worn suits as for unworn suits of the same type.

SUMMARY AND CONCLUSIONS

1. Four wearing trials of permeable protective clothing carried out in 1942 and 1943 have been described. A trial of six suits impregnated by the solvent process was conducted for a period of two weeks at the Washington Navy Yard. The trial indicated that no unexpected hazard existed when zinc oxide was used as a stabilizer. A relatively high loss of chlorine was sustained by the suit containing the impregnite S-461.

2. A wearing trial of 35 suits of stabilized and unstabilized solvent process clothing was held aboard a destroyer operating out of Key West, Fla. The results indicated that the clothing required reimpregnation after the second week of wear and that appreciable loss of active chlorine was sustained in the laundering process used. No difference was found between the stabilized and unstabilized clothing.

3. A trial on fifty-four protective suits was conducted over a period of three weeks at the Bainbridge Naval Training Station in June 1943. Nine sets of clothing were issued including unimpregnated suits, both solvent and aqueous process CC-2 suits, S-330 impregnated suits, S-461 impregnated suits, and suits made from carbon coated herringbone twill fabric. Mild skin irritation was encountered during the first week of wear from the CC-2 and S-461 clothing. Both types of CC-2 clothing and the S-330 clothing retained more than the minimum level of active chlorine (0.15 mg.Cl+/cm.^{2}) after the three week period. The S-461 garments lost chlorine rapidly, especially in laundering.

4. The washing procedure employed in the Bainbridge trial involved a 15 minute wash and at 90°F. with a synthetic detergent. This procedure caused very little loss of active chlorine compared to the soap wash at 60°C employed in the Key West trials.

5. A second wearing trial was run at Bainbridge on one hundred and ten protective suits in the Fall of 1943. The purpose of this trial was to obtain a supply of worn garments for chamber tests. After five weeks of wear and five washes, the stabilized and unstabilized

solvent process clothing had nearly reached the reimpregnation level of 0.15 mg.Cl+/cm.^{2}. The aqueous CC-2 and S-330 suits were worn for a sixth week. The longer wearing time for the clothing in this trial is attributed to the milder weather conditions.

RECOMMENDATIONS

1. None. This report has been written for information only since larger and more recent wearing trials of permeable protective clothing have been described in previous reports.

ACKNOWLEDGMENT

Sincere appreciation is expressed to the Commandant, Naval Training Station, Bainbridge, Md., and to the Commandant, Naval Operating Base, Key West, Fla., for the excellent cooperation from the officers and men in their commands in carrying out the wearing trials described in this report.

The wearing trial at Key West was under the direct supervision of Dr. W. H. Taylor who was assisted during the first part of the trial by Mr. J. M. Davidson of the Bureau of Ships.

The wearing trial at Bainbridge in June 1943 was conducted by Lt. (jg) Kenyon J. Hayes, USNR and the second Bainbridge trial was conducted by Lt. (jg) Frank C. MeLeod, USNR.

Lt. Comdr. L. Eugene Daily (MC) USN, was instrumental in obtaining permission for the wearing trials at Bainbridge Naval Training Station.

APPENDIX A

A. Detailed Results of Key West Wearing Trial.

Various data were collected during and after the wearing trial of protective clothing aboard the Destroyer USS Dahlgren at Key West, Florida. This data is presented in several tables in this appendix for reference.

The first, Table I, gives the detailed daily weather observation collected during the trial. Tables II through V give the weekly log for the garments of each type of impregnation. Table VI gives a description of the activities and duties of crew members with regard to amount of manual labor, exposure to sunlight, salt spray, etc. Comparison of the distribution of the suits as shown in Tables II through V, with the activities shown in Table VI shows that a good randomization of the garments was obtained.

Tables VII, VIII, and IX show the percentage of active chlorine retained by the suits in each group both before and after laundering. The values are given for analyses at seven different positions on each garment. A comparison of the averages for each position shows the relative loss of active chlorine for different areas.

Table X gives the values for tensile strength determinations made at different positions on the garments after one, two, and three weeks wear. Relative losses for different areas of the suits can be seen in the averages of the columns. Averages of the rows shows the relative values for the different impregnating systems.

Zinc oxide analyses were made on some of the garments worn in this trial and the results are given in Table XI. It is apparent that after three weeks wear and the launderings about fifty percent of the zinc oxide originally present has been lost.

In an attempt to separate the two factors causing loss of active chlorine, a laboratory laundering was

carried out on the hoods of the suits sent to Key West for wear. The washing was done in household type washer using 0.5% soap solution at a temperature of 60°C. The results are given in Table XII. Comparison of the results in Table XII with those in Table VII shows that loss of active chlorine due to laundering was about the same for the garments in the trial and the detached hoods washed in the Laboratory.

At the end of the first week of wear a questionnaire was filled out by the men participating in the wearing trial. The form of the questionnaire is shown as Table XIII. The responses to the questionnaire were analyzed and are presented in Table XIV.

[redacted]

Table I

Weather Data During Wearing Trials
Key West Florida; March 3, 1943-March 25, 1943

Date	Temperature Max.	Min.	Mean	Total Precip.	Relative Humidity 1:00a	7:00a	1:00p	7:00p	Wind* Av.Vel.	Character** of Day
March 3	83	68	78	0	96	91	83	95	5	BC
4	75	59	67	0	79	78	80	73	5	B
5	78	62	73	0	75	90	70	-	3	BC-C
6 am.	79	75	77	0	82	82	-	-	3	BC
8	80	67	71	0	90	90	90	58	3	C-O
9	84	70	74	0	86	90	78	68	4	B
End of First Week of Wear. Percent of possible sunshine - 85										
11	88	72	80	0	78	86	58	72	3	BC
12	89	72	80	0	79	91	49	72	4	BC
13	90	77	85	0	87	71	66	55	4	BC-C
15	83	72	79	0	82	74	68	68	1	BC
16	83	75	79	0	78	86	75	69	2	BC
17	85	75	80	0	82	82	61	66	3	BC
End of Second Week of Wear. Percent of possible sunshine - 90										
19	83	76	80	0	87	70	76	71	3	BC
20	83	77	81	0	69	62	76	83	3	BC
22	77	73	75	0	86	82	86	61	5	C
23	75	63	68	0	64	74	63	50	6	B
24	79	65	72	0	66	70	58	58	4	BC
25	78	70	74	0	76	64	64	61	4	BC
End of Third Week of Wear. Percent of possible sunshine - 85										

* Scale of values
0 Calm
1 Light air, 1-3mph
2 Light breeze, 4-7 mph
3 Gentle breeze, 8-12 mph
4 Moderate breeze, 13-18 mph
5 Fresh breeze, 19-24 mph
6 Strong breeze, 25-31 mph

** Legend
B Blue sky, cloudless
BC Blue sky, detached clouds
C Sky mainly cloudy
O Overcast

[redacted]

Table II

Weekly Log of Wearing Trials
System: Unimpregnated Suits

Suit No.	Crew Member	Percentage of Wearing Time Spent Outdoors.	Degree of Perspiration	Remarks
	A. First Week of Wear			
1	Quartermaster striker	85	Average	
2	Deck hand	85	"	
3	Ship fitter	85	Above Average	
4	Deck hand	85	Average	
5	Gunners' striker	85	Above Average	
	B. Second Week of Wear			
2	Carpenters mate	75	Average	Worn four days
3	Deck hand	75	Average	" " "
4	Gunners' striker	75	Average	
5	Deck hand	75	Heavy	hard wear
	C. Third Week of Wear			
3	Deck hand	85	Average	
4	Carpenter	85	Average	
5	Torpedo man	85	Average	

[redacted]AL

Table III

Weekly Log of Wearing Trials
System: S-145 (DPU) Impregnation

Suit No.	Crew Member	Percentage of time spent outdoors.	Degree of Perspiration	Remarks
	A. First Week of Wear			
1	Torpedo-man	85	Average	3-½ days wear suit lost
2	Gunners' striker	85	Average	
3	Signal-man	85	Average	
4	Gunner	85	Average	
5	Carpenter	85	Average	
6	Gunners' mate	85	Average	
7	Quartermasters' striker	85	Average	
8	Deck hand	85	Average	
9	Torpedo-man	85	Average	
10	Gunners' mate	85	Average	
	B. Second Week of Wear			
2	Gunners' mate	75	Average	
3	Torpedo-man	75	Average	
4	Gunners' mate	75	Average	
5	Gunner striker	75	Average	Worn 4-½ days
7	Torpedo man	75	Average	
8	Torpedo man	75	Average	
9	Boatswain's mate	75	Average	
10	Torpedo man	75	Average	
	C. Third Week of Wear			
3	Fire Control man	85	Average	
4	Torpedo man	85	Average	Very Greasy
5	Quartermaster	85	Average	
8	Gunners' striker	85	Above Average	
9	Torpedo man	85	Average	
10	Torpedo man	85	Average	

[redacted]

Table IV

Weekly Log of Wearing Trials
System: S-145 (DPU) plus 25% ZnO

Suit No.	Crew Member	Percentage of Time Spent Outdoors	Degree of Perspiration	Remarks
	A. First Week of Wear			
1	Ship-fitter	85	Heavy	
2	Deck Hand	85	Below Average	
3	Gunners' Striker	85	Average	
4	Gunners' mate	85	Above Average	
5	Deck Hand	85	Average	
6	Torpedo man	85	Average	
7	Fire Control Striker	85	Average	
8	Deck Hand	85	Below Average	
9	Torpedo man	85	Average	
10	Torpedo man	85	Average	
	B. Second Week of Wear.			
2	Quartermaster	75	Average	
3	Torpedo man	75	Average	Worn 4-½ days
4	Quartermaster	75	Average	
5	Torpedo man	75	Average	
7	Gunners' mate	75	Average	
8	Fire Control man	75	Average	
9	Deck Hand	75	Average	
10	Torpedo man	75	Average	
	C. Third Week of Wear.			
3	Boatswain's mate	85	Average	Heavy duty
4	Gunners' mate	85	Average	Worn 4-½ days
5	Ship fitter	85	Average	
8	Deck Hand	85	Above Average	Heavy Duty
9	Fire Control man	85	Average	
10	Torpedo man	85	Average	

[redacted]

Table V

Weekly Log of Wearing Trials
System: S-145(DPU), 25% ZnO, plus dyes
Suits 1-5 Khaki dye; Suits 6-10, blue dye

Suit No.	Crew Member	Percentage of Time Spent Outdoors	Degree of Perspiration	Remarks
	A. First Week of Wear			
1	Gunners' mate	85	Average	
2	Boatswain's mate	85	Average	
3	Ship-fitter	85	Below Average	Worn 4-1/2 days
4	Boatswain's mate	85	Average	
5	Boatswain's mate	85	Average	Worn 4-1/2 days
6	Torpedo man	85	Average	
7	Boatswain's mate	85	Average	
8	Deck Hand	85	Average	
9	Deck Hand	85	Average	
10	Deck Hand	85	Heavy	
	B. Second Week of Wear			
2	Gunners' striker	75	Average	Worn 4-1/2 days
3	Ship fitter	75	Average	
4	Deck hand	75	Average	Salt water spray
5	Gunners' striker	75	Average	
7	Signal man	75	Average	
8	Gunners' striker	75	Average	
9	Deck hand	75	Average	
10	Fire Control man	75	Average	
	C. Third Week of Wear			
3	Quartermaster	85	Average	
4	Gunners' mate	85	Average	
5	Torpedo man	85	Average	
8	Deck hand	85	Average	
9	Deck hand	85	Above Average	
10	Gunners' striker	85	Average	

[redacted]

Table VI

Description of Activities and Duties of Crew Members

Designation	Duties	Remarks
1. Deck Hands and Boatswains' mates	Handle lines, anchors, small boats, painting, chipping paint, swabbing down decks.	Exposed to salt spray and water, dirtier than average, average exposure to sunlight.
2. Quartermasters and Signalmen	On bridge most of time, handle messages and flags.	Little manual labor, more than average exposure to sunlight, little exposure to water or spray.
3. Ship-fitters and carpenters	General repairing, plumbing and metal work, carpentry	Majority of work on topdeck, average exposure to sun, salt spray and water.
4. Gunners, Torpedomen, and Fire Control men	Handling of guns, ammunition, torpedos, range finders, depth charges, etc.	Operate topside as well as below decks in magazines; little manual labor except in hauling ammunition.
5. Strikers	Helpers and apprentices	More manual labor.

[redacted]

Table VII

Chlorine Retention For Suits in Key West Wearing Trial

System	% Cl+ Retained							
	shoulder	armpit	elbow	waist	crotch	seat	knee	Average
A. First week before laundering.								
S-145 (DPU)	--	--	--	--	--	--	--	--
	45	(113)	57	86	79	61	51	63
S-145(DPU) plus 25% ZnO	77	96	57	95	86	59	63	76
	32	57	35	75	92	59	48	57
S-134(DPU) plus 25% ZnO, khaki dye	56	83	49	98	67	59	37	64
blue dye	39	81	49	85	77	55	53	63
AVERAGE	50	79	49	88	80	59	50	65
B. First Week after Laundering.								
S-145 (DPU)	-	-	-	-	-	-	-	-
	32	69	49	64	53	44	72	55
S-145(DPU) plus 25% ZnO	31	39	25	38	61	41	38	39
	40	74	36	53	57	37	39	48
S-145 (DPU) plus 25% ZnO, khaki dye	27	47	35	54	47	38	45	42
blue dye	31	43	25	61	43	51	30	41
AVERAGE	32	54	34	54	53	42	43	45

[redacted]

Table VIII

Chlorine Retention for Suits in Key West Wearing Trial

System	% Cl+ Retained						
	shoulder	elbow	waist	crotch	seat	knee	Average
A. Second Week Before Laundering.							
S-145 (DPU)	1	3	28	36	3	12	14
	0	33	58	21	9	18	23
S-145(DPU) plus 25% ZnO	16	17	39	33	11	20	23
	7	10	35	16	19	17	17
S-145(DPU) plus 25% ZnO, khaki dye	18	17	39	15	13	7	18
blue dye	5	8	32	17	1	6	12
AVERAGE	8	15	39	23	9	13	18
B. Second Week After Laundering.							
S-145 (DPU)	1	2	27	22	4	11	11
	9	12	38	22	36	13	22
S-145 (DPU) plus 25% ZnO	3	9	26	34	10	9	15
	-	-	-	11	8	12	10
S-145 (DPU) plus 25% ZnO, khaki dye	13	13	9	13	11	9	11
blue dye	1	4	15	6	1	16	7
AVERAGE	5	8	23	18	12	12	13

Table IX

Chlorine Retention For Suits in Key West Wearing Trials

System	% Cl+ Retained						
	shoulder	elbow	waist	crotch	seat	knee	Average
A. Third Week Before Laundering							
S-145 (DPU)	24	7	34	15	4	3	15
	5	4	25	2	0	1	6
S-145 (DPU) plus 25% ZnO	3	5	12	1	1	2	4
	1	5	6	0	0	1	2
S-145 (DPU) plus 25% ZnO khaki dye	1	22	18	12	8	11	12
S-145 (DPU) plus 25% ZnO blue dye	3	11	27	2	3	1	8
AVERAGE	6	9	20	5	3	3	8
B. Third Week After Laundering.							
S-145 (DPU)	7	4	27	4	2	5	8
	0	0	17	1	1	0	3
S-145 (DPU) plus 25% ZnO	0	0	1	1	1	1	1
	0	1	0	0	1	0	0
S-145 (DPU) plus 25% ZnO, khaki dye	0	1	1	1	1	0	1
S-145 (DPU) plus 25% ZnO, blue dye	0	0	0	0	0	0	0
AVERAGE	1	1	8	1	1	1	2

[redacted]

Table X

Tensile Strength Values for Suits in Key West Wearing Trial

System	Tensile Strength (lbs. warp)* shoulder	elbow	waist	crotch	seat	knee	Average
A. First Week of Wear.							
Unimpregnated	157	154	155	151	156	135	151
S-145 (DPU)	-	-	-	-	-	-	-
	163	155	159	173	161	164	163
S-145 (DPU) plus 25% ZnO	149	168	169	163	158	177	164
	176	177	184	168	177	168	175
S-145 (DPU) plus 25% ZnO							
khaki dye	182	162	164	168	168	162	168
blue dye	178	173	142	175	174	177	171
AVERAGE	167	165	162	168	166	164	165
B. Second Week of Wear							
Unimpregnated	140	138	152	139	140	150	143
S-145 (DPU)	141	142	152	148	154	148	147
	142	155	157	132	137	141	144
S-145 (DPU) plus 25% ZnO	-	-	-	146	146	150	147
	149	151	157	146	152	152	151
S-145 (DPU) plus 25% ZnO							
khaki dye	154	161	159	138	147	142	150
blue dye	149	134	160	155	136	154	148
AVERAGE	146	147	156	143	145	148	147
C. Third Week of Wear							
Unimpregnated	118	147	161	136	126	145	139
S-145 (DPU)	131	143	135	115	122	136	130
	137	133	152	130	145	139	139
S-134 (DPU) plus 25% ZnO	127	139	129	124	143	119	130
	136	142	153	124	124	123	134
S-145 (DPU) plus 25% ZnO							
khaki dye	139	145	141	146	138	157	146
blue dye	142	150	165	134	127	148	144
AVERAGE	133	143	148	131	132	138	137

*The tensile strength determinations were made by the grab method. The original value for unimpregnated Arnzen cloth is 155 lbs., while impregnated Arnzen cloth has value of 165 lbs.

[redacted]

Table XI

Zinc Oxide Retention for Suits in Key West Wearing Trial

System	Original mg. ZnO/cm.^{2}	% Retained 2 weeks wear	% Retained 3 weeks wear
S-145 (DPU) plus 25% ZnO	.77	81	42
	.67	54	48
S-145 (DPU) plus 25% ZnO, khaki dye	.68	74	67

[redacted]

Table XII

Laundering of the Hoods of the Suits used in Key West Wearing Trial
(Washed in 0.5% soap at 60°C in laboratory)

System	Original mg.Cl+/cm.^{2}	% Cl+ Retained 1 wash	2 wash	3 wash	4 wash
S-145 (DPU)	.49	71	52	39	25
	.45	81	50	58	37
S-145 (DPU) plus 25% ZnO	.41	79	50	34	13
	.34	--	63	36	22
S-145 (DPU) plus 25% ZnO khaki dye	.36	75	45	24	6
blue dye	.39	81	54	37	12
AVERAGE		77	52	38	19

[redacted]

Table XIII

Evaluation by Wear of Protective Clothing

Name _____ Date _____

Place _____

1. Did you find the protective suit comfortable? _____
_____

2. a. Did you notice any odor? _____
b. Was it objectionable? _____

3. Did the suit produce any skin irritation? _____
_____

4. Would you be willing to wear one of these suits during a gas attack? _____

5. Remarks (Include any other pertinent information).

Table XIV

Analysis of Answers to Questionaire after one week of Wear.

System	Question 1 Comfort				Question 2 Odor				Question 3 Irritation		Question 4 Willing to wear in gas	
	Yes	No	Too hot	Too big	Yes	No	obj.	Not obj.	Yes	No	Yes	No
Unimpregnated	4	1	1	1	4	1	3	1	1	4	5	0
S-145 (DPU)	5	3	1	2	7	1	4	4	3	5	8	0
S-145 (DPU), 25% ZnO	7	3	1	2	8	2	4	4	0	10	10	0
S-145 (DPU), 25% ZnO, khaki dye	2	1	2	0	4	1	3	1	2	3	5	0
S-145 (DPU). 25% ZnO, blue dye	2	2	-	1	4	0	-	3	0	4	4	0
TOTAL	20	10	5	6	27	5	14	13	6	26	32	0

APPENDIX B

Detailed Results for Wearing Trial At Bainbridge NTS, June 1943

Detailed data collected during the wearing trial of protective clothing at Bainbridge NTS, during June 1943, is presented in this appendix for reference.

Table I gives the weather data for each day of the trial. Table II is a summary of the activities of men wearing the clothing and includes an estimate of the time they spent outdoors and the degree of perspiration for each day.

Active chlorine analyses on the suits in each impregnation group are shown in Tables III through VIII. Each value in these tables is an average for two suits. The data on suits after laundering refers to analyses made on suits after they had been laundered in the laboratory. Though the laboratory laundering condition was the same as used at Bainbridge, this does not mean that the same losses of chlorine would be sustained.

Table IX shows the tensile strength values for the suits after the third week of wear and the third wash.

[redacted]

Table I

Weather Data During Wearing Trials, Bainbridge NTS, June 1943

Date	Temp. 0730	Temp. 1330	Temp. 1930	Precip.	Rel. Humidity 0730	Rel. Humidity 1330	Rel. Humidity 1930	Wind* Av. Vel.	% Possible Sunshine	Character** of Day
14 June	-	85	78	0	-	56	63	2	95	BC
15 June	70	81	76	0	81	64	86	2	95	BC
16 June	75	87	85	0	86	63	62	1	80	V-BC
17 June	75	85	81	0	74	69	88	0	80	V-BC
18 June	73	84	82	0	91	60	80	1	80	V-BC
21 June	78	92	85	0	75	40	60	1	95	BC
22 June	77	91	87	0	79	55	67	0	80	V-BC
23 June	80	89	82	0	57	44	63	0-1	90	BC
24 June	69	83	84	0	100	80	76	0-1	60	F-BC
25 June	80	97	89	0	75	47	64	0-1	100	B
28 June	81	87	85	0	80	66	69	3	90	BC
29 June	76	80	82	Yes	91	96	88	0	0	O-R
30 June	66	69	65	0	71	51	52	3	80	BC
1 July	62	74	70	0	74	54	55	1	90	BC
2 July	67	75	73	0	71	47	57	0-1	85	BC

* Scale of Values
0 - Calm
1 - Light air, 1-3 mph
2 - Light breeze, 4-7 mph
3 - Gentle breeze, 8-12 mph

** Legend
B - Blue sky, cloudless
BC - Blue sky, detached clouds
F - Fog
O - Overcast
R - Continuous rain
V - Variable

[redacted]

Table II

Summarized Schedule of Activities for Wearing Trial at Bainbridge NTS, June 1943

Date	Activity		% Time Spent Outdoors	Degree of Perspiration
	AM.	PM.		
14 June	-	Classroom	5	Slight
15 June	Drilling	Drilling	66	Heavy
16 June	Classroom-Drill	Drill-Obstacle Course	45	Heavy
17 June	Classes	Rifle Drill	40	Moderate
18 June	Drill	Classroom	35	Moderate
21 June	Hike	Classes & Drill	60	Heavy
22 June	Classes	Drill	40	Heavy
23 June	Classes-Drill	Rifle Range Drill	45	Heavy
24 June	Drill	Classes	40	Moderate
25 June	Classes-Parade	Classes-Drill	40	Moderate
28 June	Drill	Drill	65	Heavy
29 June	Drill	Classes-Parade	50	Moderate
30 June	Classes-Drill	Hike	45	Moderate
1 July	Classes-Drill	Classes	20	Light
2 July	Service work	Service work	10	Light

Table III

Retention of Active Chlorine for Garments in Wearing Trial Bainbridge NTS
June 1943 After First Week of Wear

Suits	Original mg.Clf/cm.^{2}	mg.Clf/cm.^{2}							Average	% Clf Retained
		Armpit	Shoulder	Elbow	Waist	Crotch	Knee	Seat		
CC-2, solvent, 15% ZnO	0.40	0.31	0.27	0.27	0.35	0.27	0.24	0.25	0.28	70
CC-2, aqueous, 25% ZnO	0.58	0.50	0.34	0.42	0.52	0.39	0.39	0.37	0.42	72
CC-2, aqueous, 25% ZnO	0.58	0.43	0.38	0.39	0.47	0.46	0.43	0.40	0.42	72
CC-2, aqueous, 25% ZnO	0.58	0.49	0.40	0.41	0.57	0.49	0.43	0.41	0.46	79
S-461, aqueous, 50% ZnO	1.68	1.23	1.17	1.34	1.34	1.24	1.56	0.88	1.25	74
S-330, aqueous, 10% ZnO	0.96	1.21	1.03	0.80	0.92	0.48	0.46	0.62	0.79	82
Underwear										
CC-2, Solvent, 15% ZnO	0.23	0.21	(Back) 0.16		0.16	0.16		0.14	0.16	70
CC-2, aqueous, 25% ZnO	0.25	0.13	0.12		0.13	0.13		0.17	0.14	56

[redacted]

Table IV

Retention of Active Chlorine For Garments in Wearing Trial, Bainbridge NTS, June 1943
After First Week of Wear and First Wash
(Laundered for 15 min. in 0.06% Nacconal at 90°F.)

Suits	Original mg.Cl+/cm.^{2}	mg.Cl+/cm.^{2}							Average	% Cl+ Retained
		Armpit	Shoulder	Elbow	Waist	Crotch	Knee	Seat		
CC-2 solvent, 15% ZnO	0.40	0.25	0.26	0.25	0.33	0.29	0.28	0.25	0.27	68
CC-2, aqueous, 25% ZnO	0.58	0.42	0.32	0.38	0.47	0.36	0.28	0.32	0.37	64
CC-2, aqueous, 25% ZnO	0.58	0.42	0.38	0.42	0.43	0.40	0.36	0.38	0.40	69
CC-2, aqueous, 25% ZnO	0.58	0.42	0.31	0.40	0.52	0.39	0.45	0.37	0.42	72
S-461, aqueous, 50% ZnO	1.68	0.69	0.65	0.88	0.81	0.67	0.77	0.44	0.70	42
S-330, aqueous, 10% ZnO	0.96	0.88	1.21	1.01	0.79	0.26	0.36	0.34	0.69	72
Underwear										
CC-2, solvent, 15% ZnO	0.23	0.17	0.17 (Back)		0.18	0.15		0.12	0.16	70
CC-2, aqueous, 25% ZnO	0.25	0.07	0.08		0.07	0.11		0.10	0.09	36

Table V

Retention of Active Chlorine for Garments in Wearing Trial, Bainbridge NTS, June 1943
After Second Week of Wear

Suits	Original mg.Cl+/cm.^{2}	mg.Cl+/cm.^{2} Armpit	Shoulder	Elbow	Waist	Crotch	Knee	Seat	Average	% Cl+ Retained
CC-2, solvent, 15% ZnO	0.40	0.21	0.12	0.25	0.27	0.21	0.21	0.18	0.21	53
CC-2, aqueous, 25% ZnO	0.58	0.38	0.39	0.31	0.38	0.35	0.33	0.33	0.35	60
CC-2, aqueous, 25% ZnO	0.58	0.35	0.30	0.30	0.40	0.34	0.28	0.30	0.32	55
CC-2, aqueous, 25% ZnO	0.58	0.35	0.34	0.27	0.33	0.33	0.26	0.20	0.30	52
S-461, aqueous, 50% ZnO	1.68	0.51	0.24	0.33	0.35	0.57	0.32	0.17	0.36	21
S-330, aqueous, 10% ZnO	0.96	0.62	0.40	0.27	0.44	0.54	0.52	0.52	0.47	49
Underwear			(Back)							
CC-2, solvent, 15% ZnO	0.23	0.08	0.08		0.19	0.06		0.02	0.09	39
CC-2, aqueous, 25% ZnO	0.25	0.03	0.02		0.00	0.06		0.07	0.04	16

Table VI

Retention of Active Chlorine for Garments in Wearing Trial, Bainbridge NTS, June 1943
After Second Week of Wear and Second Wash
(Laundered for 15 min. in 0.06% Nacconal NR at 90°F)

Suits	Original mg.Cl+/cm.^{2}	mg.Cl+/cm.^{2}							Average	% Cl+ Retained
		Armpit	Shoulder	Elbow	Waist	Crotch	Knee	Seat		
CC-2, solvent, 15% ZnO	0.40	0.19	0.13	0.19	0.21	0.19	0.13	0.21	0.19	48
CC-2, aqueous, 25% ZnO	0.58	0.30	0.35	0.31	0.31	0.35	0.30	0.28	0.32	55
CC-2, aqueous, 25% ZnO	0.58	0.30	0.30	0.28	0.40	0.32	0.33	0.30	0.32	55
CC-2, aqueous, 25% ZnO	0.58	0.28	0.31	0.27	0.28	0.31	0.30	0.19	0.28	48
S-461, aqueous, 50% ZnO	1.68	0.08	0.27	0.06	0.02	0.14	0.04	0.00	0.07	4
S-330, aqueous, 10% ZnO	0.96	0.47	0.42	0.32	0.45	0.50	0.54	0.54	0.46	48
Underwear			(Back)							
CC-2, solvent, 15% ZnO	0.23	0.11	0.07		0.11	0.05		0.02	0.07	30
CC-2, aqueous, 25% ZnO	0.25	0.01	0.01		0.00	0.06		0.04	0.02	8

Table VII

Retention of Active Chlorine for Garments in Wearing Trial, Bainbridge NTS, June 1943
After Third Week of Wear

Suits	Original mg.Cl+/cm.^{2}	mg.Cl+/cm.^{2}							Average	% Cl+ Retained
		Armpit	Shoulder	Elbow	Waist	Crotch	Knee	Seat		
CC-2, solvent, 15% ZnO	0.40	0.23	0.13	0.19	0.25	0.20	0.15	0.12	0.18	45
CC-2, aqueous, 25% ZnO	0.58	0.36	0.26	0.34	0.32	0.31	0.26	0.29	0.31	53
CC-2, aqueous, 25% ZnO	0.58	0.33	0.28	0.29	0.30	0.31	0.26	0.27	0.28	48
CC-2, aqueous, 25% ZnO	0.58	0.52	0.33	0.33	0.30	0.34	0.33	0.35	0.36	62
S-461, aqueous, 50% ZnO	1.68	0.43	0.08	0.38	0.28	0.30	0.30	0.13	0.27	16
S-330, aqueous, 10% ZnO	0.96	1.10	0.68	0.77	0.81	0.28	0.17	0.25	0.58	60
Underwear			(Back)							
CC-2, solvent, 15% ZnO	0.23	0.07	0.06		0.10	0.04		0.02	0.06	23
CC-2, aqueous, 25% ZnO	0.25	0.02	0.01		0.01	0.04		0.02	0.02	8

[redacted]

Table VIII

Retention of Active Chlorine for Garments in Wearing Trial, Bainbridge NTS, June 1943
After Third Week of Wear and Third Wash
(Laundered for 15 min. in Nacconal NR at 90°F)

Suits	Original mg.Cl+/cm.^{2}	mg.Cl+/cm.^{2} Armpit	Shoulder	Elbow	Waist	Crotch	Knee	Seat	Average	% Cl+ Retained
CC-2, solvent, 15% ZnO	0.40	0.21	0.18	0.18	0.26	0.15	0.13	0.16	0.18	45
CC-2, aqueous, 25% ZnO	0.58	0.31	0.27	0.31	0.34	0.28	0.27	0.30	0.30	52
CC-2, aqueous, 25% ZnO	0.58	0.30	0.31	0.31	0.30	0.30	0.25	0.23	0.29	50
CC-2, aqueous, 25% ZnO	0.58	0.33	0.28	0.28	0.31	0.31	0.30	0.32	0.30	52
S-461, aqueous, 50% ZnO	1.68	0.19	0.18	0.42	0.13	0.25	0.27	0.10	0.20	12
S-330, aqueous, 10% ZnO	0.96	0.87	0.72	0.89	0.65	0.21	0.21	0.36	0.56	58
Underwear			(Back)							
CC-2, solvent, 15% ZnO	0.23	0.03	0.03		0.05	0.06		0.04	0.04	17
CC-2, aqueous, 25% ZnO	0.25	0.01	0.00		0.00	0.03		0.02	0.01	4

Table IX

Tensile Strengths of Garments in Wearing Trial Bainbridge NTS, June 1943
After Third Week of Wear and Third Wash

Suits	lbs. warp, brag samples Shoulder	Waist	Crotch	Seat	Average
CC-2, solvent, 15% ZnO	123	122	161	167	143
CC-2, aqueous, 25% ZnO	159	159	160	162	160
Unimpregnated	110	105	129	148	123
Unimpregnated	120	143	139	144	138
CC-2, aqueous, 25% ZnO	159	158	158	167	160
CC-2, aqueous, 25% ZnO	162	154	158	154	157
S-461, aqueous, 20% ZnO	150	143	149	150	148
S-330, aqueous, 10% ZnO	145	144	161	163	153
Underwear					
		(Back)			
CC-2, solvent, 15% ZnO		24		47	-
CC-2, aqueous, 25% ZnO		26		44	-

[redacted]