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CHAMBER TESTS WITH HUMAN SUBJECTS XI. EVALUATION OF MODIFIED AQUEOUS CC-2 IMPREGNATION SYSTEMS

By

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Report No. P-2602

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ABSTRACT

This report describes the results of an investigation to evaluate, by means of chamber tests, the protection afforded by Navy protective clothing impregnated with various modifications of the aqueous CC-2 impregnation system.

In tests of binder modifications, it was found that:

(a) The low CP (25%) binder impregnation system provides protection equal to or greater than the 75% CP system.

(b) Pretreatment with an organic solvent solution of CP before impregnation with a low CP (25%) binder system does not result in improved protection as compared to regular low CP (25%) impregnation.

(c) Clothing impregnated by a system using mineral oil as binder and Aresklene as dispersing agent provides slightly less protection than clothing impregnated by the 75% CP system.

Tests on the effect of variation of ZnO content in the low CP (25%) system indicated that up to at least 25% ZnO, the protection provided is not affected by the amount of ZnO present.

Investigation of modified methods of application showed that:

(a) Clothing prepared from piece-goods impregnation provides slightly greater protection than 75% or 25% CP system clothing.

(b) Clothing impregnated by the Field Set (Light Weight Simplified) exhibits an unusually high degree of protection.

(c) In a preliminary test, Laboratory impregnation of Arnzen clothing by the CWS Foam Process did not result in increased protective capacity as compared with the low CP (25%) system.

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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-77-2(Dz), Serial 811 of 17 December 1940.

B. Statement of Problem

2. The purpose of this investigation was to evaluate, by means of chamber tests, the protection afforded by various modifications of the aqueous CC-2 impregnation system.

3. Included in the investigation were studies of binder modifications, stabilizer modifications and modified methods of application.

C. Known Facts Bearing on Problem and Theoretical Considerations.

4. The original Navy aqueous process for impregnation of protective clothing was based upon the following formulation: CC-2 + 25% ZnO + 75% CP (chlorinated paraffin) + 3.75% PVA (polyvinyl alcohol) + 9% dye. In this formula the percentage values represent percentage based on the weight of CC-2. The ZnO acts as a stabilizer to prevent degradation of the cloth by neutralizing HCl resulting from any decomposition of the CC-2 and CP. The CP serves as a binder. It binds the CC-2 to the fabric and also furnishes a medium for the reaction of CC-2 and H. The PVA is a dispersing agent used in the preparation of a stable, uniform impregnation bath.

5. The various modifications of the aqueous process which have been studied in this investigation have been designed to improve the CC-2 protective clothing in one or more of the following respects:

(a) Protection against H vapor. Since this is the primary purpose for which CC-2 impregnated

clothing has been developed, it represents the most important consideration in improvement of the clothing characteristics. Thus, improvements in other respects must not be accompanied by a decrease in H vapor protection.

(b) Stability. This refers to stability of both the CC-2 on the clothing and the clothing itself during wear, storage, and laundering.

(c) Method of application. This pertains to methods of both impregnation and reimpregnation. Improvements in this respect are designed to improve the ease and efficiency of impregnation, the uniformity of impregnation, and the texture ("hand" or "feel") of the impregnated clothing.

(d) Availability and cost of materials. This involves substitution, wherever possible, of materials which are more readily available and less expensive.

The specific nature of the intended improvements represented by each of the modifications evaluated in this study is described in detail in the section of the report describing each modification and the experimental results obtained in its evaluation.

D. Previous Work Done at this Laboratory.

7. This is the eleventh of a series of reports on "Chamber Tests with Human Subjects" in which the results obtained in the evaluation of various protective devices against the effects of persistent chemical warfare agents are reported.

8. The following NRL reports describe the work done at this Laboratory in the development of the original aqueous impregnation process and some of the modifications with which this report is concerned:

(a) NRL Report No. P-2000, "Progress Report on Protective Clothing," dated 20 February 1943.

(b) NRL Report No. P-2055, "Aqueous Impregnating Systems of Chlorinated Paraffin and Impregnite S-145", dated 12 May 1943.

(c) NRL Report No. P-2297, "A Study of Chlorinated Paraffin as the Binding Agent for Protective Clothing Impregnated by the Aqueous Process", dated 27 May 1944.

(d) NRL Report No. P-2406, "Wearing Trials of Protective Clothing at Camp Lejeune, N.C.", dated 13 November 1944.

(e) NRL Report No. P-2463, "Impregnation of Protective Clothing in the Piece Goods", dated February 1945.

(f) NRL Report No. P-2521, "Stabilizers for Permeable Protective Clothing", dated 3 May 1945.

EXPERIMENTAL

A. Procedure for Chamber Tests

9. The operation of the NRL chamber is described in detail in NRL Report No. P-2208, dated 22 December 1943. The general procedure for conducting chamber tests is also described in this report.

10. The chamber tests involved in the present investigation were conducted as 1-1/2 layer "man break" tests. In these tests each man exposed in the chamber was supplied with the following protective equipment:

(a) Navy diaphragm mask, Mark III or IV (with CC-2 impregnated sleeves on the hose connecting tubes.)
(b) CC-2 impregnated Arnzen suit.
(c) CC-2 impregnated rib-knit shorts.
(d) Standard Navy undershirt (skivvy shirt - unimpregnated).
(e) CC-2 impregnated cotton socks (2 pair).
(f) CC-2 impregnated elbow-length wool gloves.

(g) Overshoes (Arctics).
(h) Protective Ointment (S-330-NC- III) for face and neck.

11. The subjects were given successive daily exposures to H vapor in the chamber under the following conditions:

(a) CT = 1200 (60 min.)
(b) Temperature = 90+ 0.2°F.
(c) Relative Humidity = 65+ 3%.
(d) Wind Velocity = 2 - 2.5 m.p.h.

12. The clothing was worn by the subjects for 4 hours after a chamber 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" i.e., reached a reading of E or greater. The average number of exposures tolerated was used as the basis for evaluating the protection afforded by the clothing.

B. Original (75% CP) Aqueous System.

13. The original aqueous impregnation system, represented by the formula: CC-2 + 25% ZnO + 75% CP + 3.75% PVA + 9% dye, has been evaluated in a large number of chamber tests under the conditions used in this investigation. The data obtained in these tests are given in Table I. The detailed individual data for these tests (cf Tables XI through XXIV in Appendices I & II) as well as for all subsequent tests are given in the Appendices. These data include the readings of each subject at 24 and 48 hours after the last exposure. Summarized data showing breaks per day for the different variables studied are presented in Tables XXIV, XLI, XLV, and LVI.

Table I

Original (75% CP) Aqueous System

Test Started	No. of Men	No. of Breaks	Av. No. of Exposures Tolerated
3/21/44	7	6	2.7+
3/28/44	4	4	2.8
4/11/44	4	3	4.3+
4/25/44	7	6	5.9+
5/ 2/44	4	3	5.0+
5/ 9/44	5	4	5.8+
5/16/44	6	5	6.3+
8/ 1/44	8	4	4.5++
10/ 3/44	7	7	4.0
10/31/44	8	8	4.4
11/21/44	8	8	3.9
Totals	68	58	Av. 4.5+

14. As shown in Table I, 11 chamber tests, using a total of 68 men (58/68 broken) gave a combined average of 4.5+ exposures tolerated for the original aqueous impregnation system. This value, in addition to that obtained in concurrent control tests, is used as a basis for comparison in the evaluation of most of the modified systems.

C. Binder Modifications.

15. In the original aqueous impregnation system, chlorinated paraffin (75% of the CC-2) was used as the binding agent. Binder modifications evaluated in this investigation included (a) reduction of the CP content to 25% of the CC-2, (b) pretreatment of the cloth with CP before applying the CC-2, and (c) substitution of mineral oil for the CP.

(1) Low CP (25%) System

16. Laboratory tests have shown that the use of 75% CP results in a considerable build-up of CP on the clothing on successive impregnations, (cf. NRL Report No. P-2297). The primary purpose involved in the study of a low CP (25%) system of impregnation was to reduce this undesirable "build-up". However,

clothing impregnated by this formulation has been shown to exhibit equivalent laundering resistance, with no decrease in stability toward storage and weathering, as compared to the higher (75%) CP system. In addition, reduction of the CP content results in a saving in materials.

17. The initial tests on low CP binder modification consisted of a series of arm chamber tests in which preliminary data were obtained on the effect of variation in CP content and on a CP premix formulation.* These tests were conducted as arm chamber "man break" tests under exactly the same conditions as used for large chamber tests, i.e., successive daily exposures at CT 1200 (60 min.) at 90°F and 65% R.H. with 2 m.p.h. wind velocity. The operation of the NRL arm chamber is described in NRL Report No. P-2219, "Chamber Tests with Human Subjects III; Design, Operation and Calibration of a Chamber for Exposing Forearms to H Vapor", dated 22 January 1944.

18. In these tests the following aqueous formulations were evaluated:

(a) CC-2 with 25% CP.
(b) CC-2 with 50% CP.
(c) CC-2 with 75% CP.
(d) CC-2 premix formulation.

In conducting the tests, sleeves impregnated by the above formulations were worn underneath a 75% CP system CC-2 impregnated protective jumper. In dressing the subjects, standard impregnated woolen gloves were pulled over the sleeve, rolled back to the wrist and then taped. The sleeves of the jumper

* This formulation is described in detail in NRL Report No. P-2297. The process consists of wetting out the CC-2 and stabilizer in chlorinated paraffin which has been diluted sufficiently with a solvent such as tetrachloroethylene. The entire mix is then emulsified and used in the same manner as the regular aqueous process.

were folded back and taped so that a 3" strip of the cloth to be tested was left uncovered. The clothing was worn for 4 hours after each exposure and the successive daily exposures were continued until each man had incurred a reading of E on the test area 24 hours after exposure. The results of this test are shown in Table II (See also Table XXV in Appendix III.).

Table II

Arm Chamber Tests on Variation in CP Content and Premix Formulation

Test Started	CP	No. of Men	No. of Breaks	Av.No. of Exposures Tolerated
2/9/44	75%	3	3	5.7
2/9/44	50%	3	1	7.0+
2/9/44	25%	3	2	7.0+
2/9/44	Premix	3	1	6.0+

19. The data in Table II indicated that the 25 and 50% CP systems were as good as, and possibly better, than the 75% CP and the premix systems with regard to protective capacity.

20. Following these preliminary arm chamber tests a number of large chamber tests have been conducted using clothing impregnated by the low CP (25%) formula: CC-2 + 25% ZnO + 25% CP + 2.5% PVA + 9% dye, and the results obtained in these tests are given in Table III (See also Tables XXVI through XXXVI and Table XLI in Appendix III.).

Table III

Low CP (25%) System

Test Started	No. of Men	No. of Breaks	Av. No. of Exposures Tolerated
4/11/44	9	3	4.8++
11/ 7/44	7	7	6.6
11/14/44	8	8	4.4
11/21/44	8	8	3.8
3/27/45	4	4	4.3
4/30/45	8	8	8.1
5/15/45	15	14	7.9+
5/30/45	8	8	8.8
6/ 5/45	7	7	6.3
Totals	74	67	Av. 6.1+

20. The data in Table III show that in 9 chamber tests, involving 74 men (67/74 broken), a combined average value of 6.1+ exposures tolerated was obtained. This represents an increase over the 75% CP system (Table I).

21. The tests on 4/11/44 and 11/21/44 were accompanied by concurrent control tests with clothing impregnated by the 75% CP system. The results of these tests have been shown in Tables I and III but are reproduced in Table IV for comparative purposes.

Table IV

Concurrent 75% and 25% CP System Tests

Test Started	Impregnation System	No. of Men	No. of Breaks	Av.No.of Exposures Tolerated
4/11/44	75% CP	4	3	4.3+
4/11/44	25% CP	9	3	4.8++
11/21/44	75% CP	8	8	3.9
11/21/44	25% CP	8	8	3.8

22. These tests do not show as significant an improvement as indicated by the combined average values from Tables I and III. However, it may be seen that in the test on 4/11/44 only 3 of 9 men wearing suits impregnated by the low CP system had "broken" at the time the test was discontinued, as compared with 3 of 4 men wearing suits impregnated by the 75% CP system. The difference, therefore, is greater than indicated by the actual values shown. In the test on 11/21/44 no difference between the two impregnation systems is indicated. It has been concluded on the basis of all tests that the use of the 25% CP impregnation system provides protection equal to or greater than that given by the 75% CP system.

(2) Pretreatment with CP.

23. It has previously been indicated (cf. NRL Report No. P-2597 "Chamber Tests with Human Subjects VIII. Evaluation of Worn CC-2 Impregnated Clothing") that worn solvent type clothing gives considerably more (about 100%) protection after

aqueous reimpregnation by the Field Set, M-1, than does worn aqueous type clothing reimpregnated in the same manner. It was considered possible that this increased protection might be due to the more uniform distribution of CP on the solvent type clothing than on the aqueous type.

24. In order to test this hypothesis, suits were prepared in the laboratory by the following process. Ten suits were soaked in a 3-1/2% solution of CP in Solvesso, wrung by hand, and tumbler dried. (This represented a pretreatment with CP and was designed to give a uniformity of CP distribution comparable to that of solvent type clothing.). These 10 pretreated suits and 10 untreated suits were then impregnated in a low CP (25%) aqueous bath containing 7-1/2% CC-2.

25. Chamber tests of the pretreated and untreated suits were conducted in the standard manner, and the results obtained are given in Table V. (See also Tables XXXVII, XXXVIII, and XLI, in Appendix III).

Table V

Pretreatment with CP

Test Started	Impregnation Method	No. of Men	No. of Breaks	Av.No.of Exposures Tolerated
4/17/45	Pretreatment	7	5	10.1+
4/17/45	Untreated	8	7	10.4+

26. The data in Table V show that the pretreatment with CP did not lead to any increase in protective value as compared with the untreated suits. Both groups of suits exhibited an abnormally high degree of protection, but it is believed that this can be attributed to a difference resulting from laboratory rather than plant impregnation technique. It was concluded on the basis of this test that uniformity of CP distribution is not the contributing factor in the higher protection afforded by reimpregnated solvent type clothing, and that a pretreatment with CP does not represent any improvement in the

aqueous impregnation system.

(3) Mineral Oil System

27. In laboratory work designed to improve the ease of emulsification in the preparation of aqueous system impregnation baths, it was found that the following formulation possessed advantages in this respect: CC-2 + 15% ZnO + 50% mineral oil + 10% Aresklene + 9% dye. Since this modification produced no significant changes in the wearing, storage, or laundering characteristics of the clothing impregnated by this system, it was considered as representing a possible substitute for the CP process, providing the protective value was not decreased. Accordingly, chamber tests were conducted on clothing impregnated by the mineral oil system with the results shown in Table VI. (See also Tables XXXIX, XL and XLI in Appendix III).

Table VI

Mineral Oil System

Test Started	Impregnation System	No. of Men	No. of Breaks	Av.No.of Exposures Tolerated
8/1/44	Mineral Oil	8	8	3.9
8/1/44	75% CP	8	4	4.5++

28. The data in Table VI show that the protection afforded by the mineral oil system impregnation is somewhat inferior to that afforded by the 75% CP. The value obtained for average number of exposures tolerated (3.9) is less than that obtained for the concurrent control group (4.5++) and is also less than the combined average value (4.5+) for the 75% CP impregnation system (cf Table I). On the basis of these data, which indicate that mineral oil is probably not as satisfactory a binding agent as CP, it was concluded that, if CP becomes unavailable, mineral oil can be used as a substitute with no large sacrifice in protection.

D. Stabilizer Modifications.

29. Zinc oxide (25% of the CC-2) is used

in the aqueous impregnation system as the stabilizing agent. In this investigation the only stabilizer modification studied consisted of an evaluation of the effect of variation in the ZnO content of the impregnated clothing.

(1) Variation in ZnO Content.

30. For the study of the effect of variation in ZnO content, three groups of suits were impregnated in the laboratory by the low CP (25%) aqueous system. Group I contained no ZnO, Group II, 10% ZnO, and Group III, the standard 25% ZnO. Chamber tests conducted with subjects wearing this clothing gave the results shown in Table VII. (See also Tables XLII through XLV in Appendix IV.).

Table VII

Variation in ZnO Content

Test Started	ZnO Content (% of CC-2)	No. of Men	No. of Breaks	Av. No. of Exposures Tolerated
6/5/45	0	7	7	6.4
6/5/45	10 (11.7)*	8	8	6.5
6/5/45	25 (27.7)*	7	7	6.3

* By Analysis

31. From the results given in Table VII it is evident that, within the range of 0 to 25%, the ZnO content of clothing impregnated by the low CP (25%) system has no influence on the protective value of the clothing. The average number of exposures tolerated for the 0 and 10% ZnO suits are in good agreement with that obtained for the 25% controls, and all the values are in good agreement with the combined average value of 6.1+ for the low CP (25%) system. (cf Table III). These data lead to the conclusion that the determination of the optimum stabilizer (ZnO) content of CC-2 clothing impregnated by the aqueous process can be based on a consideration of the amount necessary to secure adequate stabilization under the most adverse conditions of storage or use.

E. Modified Methods of Application

32. Modified methods of aqueous impregnation considered in this investigation were: (a) impregnation in the piece-goods, (b) Field Set (Light Weight Simplified) impregnation, and (c) foam process impregnation.

(1) Piece-Goods Impregnation

33. NRL Report No. P-2463 gives a complete description of the work conducted by this Laboratory on impregnation of protective clothing in the piece-goods. This process consisted of treatment of Arnzen cloth with 75% CP aqueous impregnation suspension (CC-2 + 25% ZnO + 75% CP + 3.75% PVA + 9% dye) using standard textile finishing equipment, followed by the manufacture of protective garments from the impregnated piece-goods. Potential advantages to be obtained in the use of piece-goods impregnation were as follows:

(a) Greater latitude in formulation,
(b) Improved uniformity of impregnation.
(c) Economy in the use of chemicals, reduced labor costs, and expanded production facilities.

34. Chemical evaluation of clothing prepared from piece-goods impregnated cloth has shown that the laundering resistance, and storage stability are equal to that of 75 and 25% CP aqueous impregnated suits. Wearing tests have indicated comparable Cl+ retention and a reduced tendency to become soiled.

35. The evaluation of the protective characteristics of piece-goods impregnated clothing conducted in this study consisted of three chamber tests with concurrent control tests. Two of these tests were "man-break" tests at the standard conditions. The third, however, was a "screening" man break test at CT 6000 (60 min.). The data obtained in these tests are presented in Table VIII. (See also Tables XLVI through LI and LVI in Appendix V.).

Table VIII

Piece-goods Impregnation

Test Started	Method Of Application	CT	No. of Men	No. of Breaks	Av.No.of Exposures Tolerated
4/25/44	Piece-goods	1200	4	1	6.3++
4/25/44	Standard (75% CP System)	1200	7	6	5.9+
3/27/45	Piece-goods	1200	6	6	4.8
3/27/45	Standard (25% CP System)	1200	4	4	4.3
3/ 5/45	Piece-goods	6000	2	2	5.5
3/ 5/45	Standard (25% CP System)	6000	8	8	4.6

36. As indicated by the data in Table VIII clothing prepared from piece-goods impregnated cloth provides a slight but consistent increase in protection as compared to the 75% CP and low CP (25%) aqueous system impregnations. This greater protection can probably be attributed, at least in part, to the more uniform distribution of impregnite on the piece-goods clothing.

(2) Field Set (Light Weight Simplified).

37. The Field Set, LWS, has been developed by the NDRC as a method for both impregnation and reimpregnation of protective clothing in the field. The formulation used in this process is: CC-2 + 10% ZnO + 25% CP + 10% Aresklene + 9% dye. The clothing is impregnated by hand using the bath made from the packaged ingredients contained in the kit. The method is designed as an emergency or semi-emergency method for field use where plant impregnation facilities are not available.

38. The evaluation of the protection given by clothing impregnated with the Field Set was carried out by means of a standard chamber test with a concurrent control test using low CP (25%) impregnated clothing. The results of the tests are given in Table IX. (See also Tables LII, LIII and LVI in Appendix V.).

Table IX

Field Set (Light Weight Simplified) Impregnation

Test Started	Method Of Application	No. of Men	No. of Breaks	Av. No. of Exposures Tolerated
3/27/45	Field Set, LWS	5	3	10.6+
3/27/45	Low CP (25%)	4	4	4.3

39. It may be seen that the clothing impregnated by means of the Field Set exhibited an unusually high degree of protection as compared with the low CP (25%) control clothing. It is considered possible that this high protective capacity is associated with the use of Aresklene instead of PVA as the dispersing agent in the formulation of the impregnating bath rather than with the method of application. Indirect evidence in support of this hypothesis has been obtained in chamber tests of 75% CP aqueous system clothing reimpregnated with the Field Set, M-1, which differs from the Field Set (Light Weight Simplified) only in the use of PVA as the dispersing agent. (cf. NRL Report No. P-2597, "Chamber Tests with Human Subjects, VIII Evaluation of Worn CC-2 Impregnated Clothing"). In these tests, the reimpregnated clothing provided normal protection (4.0 exposures tolerated). However, conflicting evidence was obtained in the evaluation of clothing impregnated by means of the mineral oil system (cf. page 10). In the tests of this impregnation system, which involves the use of Aresklene as dispersing agent, the protective capacity of the clothing was found to be slightly inferior to that of 75% CP clothing.

40. It was considered desirable on the basis of the high degree of protection afforded by the Field Set clothing to conduct chamber tests of clothing impregnated in the plant with the same formula. However, up to the present time, it has not been possible to arrange a plant trial to prepare clothing using Aresklene instead of PVA as the emulsifying agent.

(3) Foam Process Impregnation.

41. The CWS at Edgewood Arsenal has recently

developed a modified aqueous impregnation process called the "Foam Process". This process is based upon the application of the calculated quantity of impregnating suspension to the clothing as a foam. The calculated amount for one batch of clothing is added to the impregnator together with a small amount of foaming agent such as Duponol, Aresklene, or Nacconol. As the clothing is tumbled, the suspension is converted into a foam which rises and permeates the clothing. When the process is complete, there is little or no liquid remaining in the machine, and the clothing is removed and tumbler dried. The proposed advantages in the use of this impregnation process are:

(a) Elimination of the possibility of depletion of the bath and preferential absorption.

(b) All types of clothing may be impregnated with the same suspension concentration.

(c) Production of a smoother, softer, less irritating surface.

(d) Improved laundering resistance.

42. In addition to the above advantages of the foam process, chamber tests at Edgewood Arsenal have indicated that suits impregnated by this method provide greater protection against H vapor than regular Army M-2 clothing.

43. The results of a preliminary chamber test conducted at this Laboratory in connection with the evaluation of the foam process, are shown in Table X. (See also Tables LIV through LVI in Appendix V). The suits used in this test were standard Navy Arnzen suits impregnated in the laboratory by the foam method as described.

Table X

Foam Process-Impregnation

Test Started	Method of Application	No. of Men	No. of Breaks	Av. No. of Exposures Tolerated
5/18/45	Foam Process	6	5	6.3+
5/18/45	Low CP (25%)	15	14	7.9+

44. The data obtained in this test are not in agreement with those reported by the CWS. The average number of chamber exposures tolerated by the subjects wearing foam process suits was less than the value obtained in the concurrent control test with suits impregnated by the low CP (25%) system. However, the value (6.3+) is very close to the combined average value (6.1+ - Table III) for the low CP (25%) system. Thus, on the basis of this test, foam method impregnation of Arnzen clothing does not result in an increased protective capacity as compared with the low CP (25%) system. In order to secure a more extensive evaluation of the foam process, however, it is planned, with the cooperation of the CWS, to conduct further chamber tests of Arnzen clothing impregnated by the foam process at the Edgewood Arsenal M-2 plant. Tests using these suits will eliminate any variations which might be attributed to laboratory rather than plant impregnation.

SUMMARY AND CONCLUSIONS

1. Chamber tests have been conducted to evaluate the protection afforded by various modifications of the aqueous CC-2 impregnation system. Binder modifications, stabilizer modifications and modifications in the method of application were studied.

2. The original Navy aqueous impregnation system (CC-2 + 25% ZnO + 75% CP + 3.75% PVA + 9% dye) was used as the basis for comparison in most of the tests of modified systems reported here. It was found that in standard 1-1/2 layer "man break" tests as carried out at this Laboratory, clothing impregnated by this system provides protection for a combined average of 4.5+ chamber exposures.

3. In the tests of binder modifications it was found that:

(a) The low CP (25%) aqueous impregnation system (CC-2 + 25% ZnO + 25% CP + 2.5% PVA + 9% dye) provides protection equal to or greater than the 75% CP system - giving a combined average of 6.1+ chamber exposures tolerated.

(b) Pretreatment of clothing with an organic solvent solution of CP before impregnation with a low CP (25%) formulation does not result in an increase in protection as compared to regular low CP (25%) system clothing.

(c) Clothing impregnated by a mineral oil system (CC-2 + 15% ZnO + 50% mineral oil + 10% Aresklene + 9% dye) provides slightly less protection (average of 3.9 exposures tolerated) than clothing impregnated by the 75% CP system.

4. The tests on stabilizer modifiaations, consisting of a study of the effect of variation of ZnO content, showed that within the range studied (0 to 25% ZnO), the protection afforded by low CP (25%) system clothing is independent of the amount of ZnO present.

5. The investigation of modified methods of application produced the following results:

(a) Clothing prepared from piece-goods impregnation provides slightly greater protection than standard system clothing (75% or 25% CP).

(b) Clothing impregnated by the Field Set (Light Weight Simplified) using the formulation: CC-2 + 10% ZnO + 25% CP + 10% Aresklene + 9% dye, provides an unusually high degree of protection (average of 10.6+ exposures tolerated) as compared with low CP (25%) control clothing.

(c) Laboratory impregnation of Arnzen clothing by the CWS Foam Process does not result in an increase of protection as compared with the low CP (25%) system.

RECOMMENDATIONS

1. As a result of the experimental work reported in NRL Report No. P-2297, "A Study of Chlorinated Paraffin as the Binding Agent for Protective Clothing Impregnated by the Aqueous Process", dated 27 May 1944, it was recommended "that the present procedure for impregnated clothing by the aqueous process be modified to reduce the amount of chlorinated paraffin binder from 75% to 25% by weight of the CC-2". This recommendation was subsequently adopted and the present standard Navy impregnation system is the low CP (25%) system. The results obtained in the more extensive evaluation of this system described in this report substantiate the above recommendation.

2. It was recommended in NRL Report No. P-2463, "Impregnation of Protective Clothing in the Piece-goods", dated February 1945, "that impregnation of cloth in the piece-goods be adopted in the event that present plant capacity be required for reimpregnation". The results of the present investigation lend emphasis to this recommendation.

3. It is recommended that the mineral oil impregnation system be used as a substitute system in the event that CP is unavailable.

4. It is recommended that a stabilizer (ZnO) content up to 25% of the CC-2 be considered as having no deleterious effect on the protective characteristics of aqueous process CC-2 impregnated clothing.

5. It is recommended that the Field Set (Light Weight Simplified) be considered as satisfactory for field impregnation and reimpregnation from the standpoint of the protective value of the resulting clothing.

6. It is recommended that the use of Aresklene as an emulsifying agent in the aqueous impregnation process be investigated in plant trials.

7. It is recommended that, pending further tests, the CWS Foam Process of impregnation be considered of no advantage over the present standard Navy process.

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Medical Group

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C. F. Adams, Cox. - Volunteer Personnel
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The subjects participating in these tests were volunteer personnel from NTC, Bainbridge, Maryland.

Appendix I

Table XI

Physiological Readings - Legend

Symbol	Reaction
E°	Moderate Erythema
E	Intense Erythema
E+	Papular Erythema
NPV	Numerous Pin-point Vesicles
V	Vesicle
NV	Numerous Vesicles

Readings of mild and questionable erythema are not included since they are not considered significant in tests of this nature.

Table XII

Body Areas - Legend

Abbreviation	Area	Abbreviation	Area
aaf	anterior axillary folds	le	legs
aar	anterior arms	lth	lateral thorax
ab	abdomen	lum	lumbar
ale	anterior legs	paf	posterior axillary folds
ar	arms	par	posterior arms
ash	anterior shoulders	pen	penis
athi	anterior thighs	ple	posterior legs
ax	axillae	pop	popliteal spaces
bt	buttocks	psh	posterior shoulders
C_7	7th cervical	pthi	posterior thighs
cf	cubital fossae	sc	scapulae
cl	clavicles	scr	scrotum
dh	dorsum of hands	uab	upper abdomen
dth	dorsal thorax	ulth	upper lateral thorax
el	elbows	umar	upper medial arms
fa	forearms	umthi	upper medial thighs
igf	intergluteal folds	uvth	upper ventral thorax
il	iliac crest	vth	ventral thorax
ing	inguinal	wr	wrist
kn	knees		

Appendix II

Detailed Physiological Data for

Tests on Original Aqueous Impregnation System

Table XIII

Test No. 1a - Original (75% CP) System

Date Started: 3/21/44

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,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,cf	E vth,sh,ar,ax,aaf E° sc,dth,pen,thi,le
3*	E° scr,sc,dth	No readings

Av. 2.7+

* Indicates, in this and subsequent tables, subject withdrawn from test for reasons other than a "break".

Table XIV

Test No. 1b - Original (75% CP) System

Date Started: 3/28/44

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° 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

Test No. 1c - Original (75% CP) System

Date Started: 4/11/44

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,pop E° cf,thi,pop

Av. 4.3+

Table XVI

Test No. 1d - Original (75% CP) System

Date Started: 4/25/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
8	E sc,dth E° kn,ash,lth,aaf, ar,cf,thi,pop	No readings
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 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 XVII

Test No. 1e - Original (75% CP)System

Date Started: 5/2/44

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

Av. 5.0+

Table XVIII

Test No. 1f - Original (75% CP)System.

Date Started: 5/9/44

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	E° sh,ar,sc,dth,pop,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° pe,sc	E vth,dth,sc E° scr,ash,aaf,bt, thi,kn

Av. 5.8+

Table XIX

Test No. 1g - Original (75% CP)System

Date Started: 5/16/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
6	E aaf,sc,dth E° sh,kn	E vth,sc,dth,paf,ar E° scr,pen,kn,le
6	E sc,dth E° paf,scr,sh	E° scr,sc,dth
6	E scr E° thi,kn	E° scr
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 XX

Test No. 1h - Original (75% CP)System

Date Started: 8/1/44

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

Av. 4.5++

Table XXI

Test No. 1i - Original (75% CP) System

Date Started: 10/3/44

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
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,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,le,pop
4	E ash,ar,cf,sc, dth,pthi,pop E° vth,pen,scr, athi,kn	E ash,aaf,th,cf,sc,pthi, pop E° athi,kn,scr

Av. 4.0

Table XXII

Test No. 1j - Original (75% CP) System

Date Started: 10/31/44

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,sc, dth	E pop E° kn,psh,paf
5	E ash,aaf,lth,cf, 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
5	E psh,sc,dth,pop E° ash,aaf,kn	E kn,le,sc,dth,psh,pop E° 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° 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 XXIII

Test No. 1k - Original (75% CP) System

Date Started: 11/21/44

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

Av. 3.9

Table XXIV

Tests on Original (75% CP) Aqueous System

Date Started	No. of Men	No. of Men Broken On Day 1	2	3	4	5	6	7	8	No. of Breaks	Av. No. Exps. Tolerated
3/21/44	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	6				1		3		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
Total	68		4	20,1*	8,2*	14,3*	6,1*	4,1*	2,2*	58	Av. 4.5+

Appendix III

Detailed Physiological Data for Tests on Binder Modification

Table XXV

Test No. 2a - Arm Chamber Tests on Variation in CP Content and Premix Formulation

Date Started: 2/9/44

Subject No.	CP	No. of Exposures Tolerated	Av.	Readings (Hours after Last Exp.) 24	48
1	75%	4		E	E
2	"	6		E	E•
3	"	7		E	E
			5.7		
1	50%	7+		E•	E•
2	"	7		E	E
3	"	7+		E•	E
			7.0++		
4	25%	7		E	E
5	"	7		E	E
6	"	7+		E•	E
			7.0+		
4	Pre-mix	5		E	E
5	"	6+		E•	E-
6	"	7+		E•	E
			6.0++		

Table XXVI

Test No. 2b - Low CP (25%) System

Date Started: 4/11/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
5*	E° aaf	No Readings E° or Greater
5*	No Readings E° or Greater	No Readings E° or Greater
5*	E° sc,dth	No Readings E° or Greater
5*	E° sc	No Readings E° or Greater
5*	No Readings E° or Greater	No Readings E° or Greater
5*	No Readings E° or Greater	E° sc,dth
5	E sc	E° sc
4	E scr,aaf,ax E° dth,sc,sh	E° ash,aaf,th,cf,sc,pop, le
4	E dth,sc,sh E° cf,ar,ax,lth	E° sh,lth,ax,sc,dth

Av. 4.8++

Table XXVII

Test No. 2c - Low CP (25%) System

Date Started: 11/7/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
5	E psh,sc,dth	E psh,sc,dth,lum
13	E ax E° psh,sc,pop	E ax,paf
5	E sh,th,ax,sc, lum,paf,pop	E sh,aaf,th,ax,cf,sc,lum E° kn
5	E ax,cf,psh,sc E° ash,lum,pop	E cf,psh E° ash,ax,th,kn,sc,pop
11	E psh,ar,pop,ax E° cf,thi,kn, il,le	E cf E° par
5	E psh,sc,dth,lum E° pop	E psh,sc,dth,lum E° aaf
2	E psh,dth,sc E° ash	E psh,sc,dth E° ash,cf

Av. 6.6

Table XXVIII

Test No. 2d - Low CP (25%) System

Date Started: 11/14/44

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

Av. 4.4

Table XXIX

Test No. 2e - Low CP (25%) System

Date Started: 11/21/44

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

Av. 3.8

Table XXX

Test No. 2f - Low CP (25%) System

Date Started: 3/27/45

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

Av. 4.3

Table XXXI

Test No. 2g - Low CP (25%) System

Date Started: 4/30/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
6	E psh,sc,ax,ash E° umar,cf,aaf,lth, dth,pop	E cl,ash,umar,ax,ulth,psh, sc,dth E° aaf,paf,pop
12	E ash,umar,cf,athi, kn,ale,psh,par,el, C_7,sc,dth,lum, pthi,pop,ple	E ash,aar,umar,vth,uab,cf, athi,kn,ale,pthi,ple pop,bt E° psh,sc,dth,par,el
9	No Readings (Sick Bay)	E aar,cf,athi,kn,ale) paf,pop) 72 E° umar,fa,dh,wr,psh) par,el,sc,dth,) hrs. pthi,ple)
10	E pop,ple E° aar,cf,athi,kn, ale,psh,sc,dth	E cf,pop E° aar,athi,kn,ale,paf, sc,dth,ple
8	E ax E° athi,kn,ale,pop	E ax,pop E° athi,kn,ale,paf,psh, C_7, sc,pthi,ple
8	E pop E° umar,cf,kn,paf, psh,el,sc,pthi, ple	E pop E° umar,aar,cf,athi,kn, ale,paf,psh,el,sc,dth, pthi,ple
4	E ash,umar,aar,cf, ax,lth,vth,athi, kn,ale,paf,psh, el,sc,dth,pthi, pop,ple E° par	E ash,umar,aar,cf,ax,lth, athi,kn,ale,paf,psh,par, el,sc,dth,pthi,pop, ple
8	E pop E° athi,kn,ale,paf, psh,sc,dth,pthi, ple	E kn,pop E° umar,cf,ax,ulth,athi, ale,paf,psh,el,sc,dth, pthi,ple

Av. 8.1

Table XXXII

Test No. 2h - Low CP (25%) System

Date Started: 5/15/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
7	E pthi,pop E° cf,kn,paf,psh, par,el,sc,dth, igf,ple	E pthi,pop E° athi,kn,ale,psh,el,sc, dth
7	E cl,athi,kn,ale, pthi,pop E° ple	E cl,athi,kn,ale,pthi,pop, ple E° el
3	E ash,aar,cf,athi, kn,pthi,pop E° umar,ulth,uvth, ale,psh,par,el, C_7,sc,dth,ple	E ash,aar,uvth,athi,kn, ale,pthi,pop E° umar,cf,paf,psh,par,el, C_7,sc,dth,ple
6	E psh,sc,dth E° umar,aaf,ax,lth, athi,kn,ale,paf, el,pthi,pop,ple	E umar,ax,ulth,athi,kn,ale, paf,psh,sc,dth,pop E° aar,cf
7	E ax,pthi,pop,athi, kn E° aar,cf,lth,ale, paf,psh,el,sc, dth,ple	E umar,ax,ulth,athi,kn,ale, pthi,pop,ple E° ash,aar,cf,aaf,lth,paf, psh,el,sc,dth
6	NV psh E° athi,kn,ale,pop	NV psh E kn,pop E° athi,pthi,ple
7	E athi,kn,pthi,pop E° umar,aar,cf, ulth,ale,paf, psh,el,sc,dth, ple	E athi,kn,ale,pthi,pop E° umar,aar,cf,ax,ulth,paf, psh,el,sc,dth,ple
7	E cf,kn,paf,psh,sc, dth,pop E° ash,umar,aar,aaf lth,athi,ale,el, pthi,ple	E cf,kn,paf,psh,el,sc,dth E° ash,umar,aar,ax,lth,vth, athi,ale,pthi,pop,ple

(Continued on following page)

Table XXXII (Cont'd.)

Test No. 2h - Low CP (25%) System

Date Started: 5/15/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
10	NV psh E° ash,umar,cf,ax, ulth,athi,kn, ale,paf,el,sc, dth,pthi,pop, ple	NV psh E uvth,pthi,pop,ple E° ash,umar,cf,aaf,ax, lth,athi,kn,ale,paf, el,sc
10	E cf,psh E° aar,athi,kn, ale,paf,sc,dth	E cf,dh,wr,athi,kn,ale, psh,pthi,pop E° paf,el,C_7,sc,dth,ple
10*	E° athi,kn,ale, paf,psh,sc,dth	E° athi,kn,ale,pop
10	E paf,psh,sc,pthi, pop E° kn,dth,ple	E paf,sc,dth,pthi,pop E° ax,athi,kn,ale,psh, ple
10	E athi,kn,ale,psh, pop E° cf,el,sc,dth, pthi,ple	E athi,kn,ale,psh,pop E° cf,el,pthi,ple
8	E pthi,pop E° athi,kn,ale, el,ple	E pthi,pop E° athi,kn,ale,ple
10	NV psh E° cf,kn,pthi,pop	NV psh E pthi,pop E° cf,athi,kn,ale,ple

Av. 7.9+

Table XXXIII

Test No. 2i - Low CP (25%) System

Date Started: 5/30/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
10	E aaf,ax,paf,sc E° cf,psh,dth, pthi,pop,ple	E paf,sc E° cf,aaf,ax,psh,el,dth, pthi,pop
10	E kn,el,pop E° athi,ale,psh, sc,dth,pthi, ple	E kn,el,pop E° athi,ale,pthi,ple
8	E cf,pop E° kn	E cf,pop E° kn,el
8	E pop E° umar,ax,kn, ale	E umar,ax,athi,kn,ale,pop E° aar,cf,paf,psh,par,el, sc,pthi,ple
8	E cf,kn,pop E° ale,psh,el, C_7,sc,dth	E cf,kn,pop E° aar,ale,psh,el,sc,dth, ple
9	E cf,kn,pop E° ash,vth,athi, ale,el	E cf,kn,pop E° umar,athi,ale,el
10	E kn E° umar,aar,cf, athi,el,pthi, pop,ple	E° umar,aar,kn,paf,psh, el,sc,dth,pthi,pop
7	E pop E° cf,kn	E cf,pop E° kn,psh,el,sc

Av. 8.8

Table XXXIV

Test No. 2j - Low CP (25%) System

Date Started: 6/5/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
8	E cf,kn,pop E° umar,lth,athi, paf,psh,el,sc, dth,pthi,ple	E kn,pop E° athi,ale,paf,psh,el, sc,dth,pthi,ple
4	E ash,psh E° cf,kn,el,sc,dth, pop	E psh E° cf,athi,kn,ale,el, sc,dth,pthi,pop
8	E kn,pop E° cf,athi,paf,psh, el,sc,dth,pthi, ple	E kn,pthi,pop E° athi,paf,psh,sc,dth
6	E pop E° cf,athi,kn,ale, paf,psh,el,sc, dth,ple	E kn,paf,psh,sc,pop E° umar,cf,athi,ale,el, dth,ple
5	E paf,psh,sc,dth E° athi,kn,ale, par,el,pthi,pop, ple	E kn,pop E° aar,athi,ale,paf,psh, el,sc,dth,pthi,ple
7	E cf,ax,ulth,athi, kn E° ash,aaf,psh,sc, dth,pthi,pop	E ash,umar,aar,aaf,ax, lth,athi,kn,paf,psh, sc,dth,pthi,pop E° ale,el,ple
6	E kn,ale,pthi,pop, ple E° ash,umar,aar, athi,paf,psh, par,el,sc,dth, cf	E athi,kn,ale,pthi,pop,ple E° ash,umar,aar,cf,psh, par,el,sc,dth

Av. 6.3

Table XXXV

Test No. 2k - Concurrent Control Test for Low CP System

75% CP Aqueous System

Date Started: 4/11/44

This test was conducted concurrently with Test No. 2b (Table XXVI). The data are presented in Table XV as Test No. 1c. (Original - 75% CP - Aqueous System). The average number of exposures tolerated was 4.3+ (3/4 men broken).

Table XXXVI

Test No. 21 - Concurrent Control Test for Low CP System

75% CP Aqueous System

Date Started: 11/21/44

This test was conducted concurrently with Test No. 2e (Table XXIX). The data are presented in Table XXIII as Test No. 1k. (Original - 75% CP - Aqueous System). The average number of exposures tolerated was 3.9 (8/8 men broken).

Table XXXVII

Test No. 3a - Pretreatment with CP

Date Started: 4/17/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure)	
	24	48
6	E pop	E pop E° kn
10	E kn,pop E° athi,ale,psh, sc,dth,pthi, ple	E kn,ale,pop E° athi,psh,sc,dth, pthi,ple
7	E dh,wr,athi,kn, pthi,pop,ple E° ale,psh,sc,dth	E+ dh,wr E athi,kn,ale,pthi,pop, ple E° psh,sc,dth
15*	E° cf,athi,kn,ale, psh,par,el,sc, dth,pthi,pop, ple	E° athi,kn,ale,psh,C_7, sc,dth
15*	E° cf,athi,kn,ale, pthi,pop,ple	E° cf,athi,kn,ale,pop
11	E psh,sc,dth	E psh,sc,dth
7	E kn,pop E° ax,lth,athi, ale,paf,psh, sc,dth,pthi, ple	E umar,athi,kn,ale,pthi, pop,ple E° cf,psh,sc,dth

Av. 10.1+

Table XXXVIII

Test No. 3b - Control Test for Pretreatment with CP Laboratory Aqueous System Impregnation (25% CP)

Date Started: 4/17/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
11	E umar,cf,paf E° ax,athi,kn,ale, psh,sc,dth,pthi, pop,ple	E umar,cf,paf,psh,sc,dth E° ax,athi,kn,ale,pthi, pop,ple
12	E kn,ale,pthi,pop E° aar,cf,athi,psh, sc,dth,ple	E cf,pthi,pop E° athi,kn,ale,psh,sc, dth,ple
10	E cf,kn E° umar,athi,ale, paf,psh,sc,dth, pthi,pop,ple	E ash,aar,cf,fa,lth,vth, uab,athi,kn,psh,sc, par,el,C_7,dth,lum E° umar,ale,paf,pthi, pop,ple
9	E umar,athi,kn,ale, psh,sc,dth,pthi, pop E° ash,aar,cf,ple	E umar,athi,kn,pthi,pop E° cf,ale,psh,sc,dth,ple
8	E umar,cf,athi,kn, paf,psh,pop E° aaf,lth,ale,sc, dth,pthi,ple	E umar,cf,lth,athi,kn, ale,paf,psh,pthi,pop, ple E° ash,aaf,sc,dth
15*	E° cf,athi,kn,ale, par,el,pthi,pop, ple	E° cf,athi,kn,ale,pthi, pop
10	E kn E° cf,athi,ale,par, el,pthi,pop,ple	E kn E° athi,ale,par,el,pthi, pop,ple
8	E athi,kn,ale E° umar,aar,lth,psh, sc,dth,pthi,pop, ple	E athi,kn,ale,psh,sc,dth, pop E° pthi,ple

Av. 10.4+

Table XXXIX

Test No. 4a - Mineral Oil System

Date Started: 8/1/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E cl E° sh	E scr E° sh
3	E scr,bt E° vth,ar	E scr
3	E sh,sc,ar E° vth,scr	E+ sh,sc
4	E scr E° pen,sc,dth	E scr,sc E° sh,pen
4	E scr,thi,kn E° vth,sc,dth, pop	E ash,thi,kn,sc,dth E° cf,ar
4	NV vth,sh,cf,sc, psh E scr E° pen,thi,kn, le,el	No Readings (Sick Bay)
5	E scr,thi,kn E° sc,le,pop	E thi,kn,pop E° le
5	E ash,thi,kn, sc,dth,cf, scr,bt E° cf,ar,pop, vth,aaf	E cf,sh,ar,thi,kn,sc, bt,pop

Av. 3.9

Table XL

Test No. 4b - Control Test for Mineral Oil System

75% CP Aqueous System

Date Started: 8/1/44

This test was conducted concurrently with Test No. 4a (Table XXXIX). The data are presented in Table XX as Test No. 1h. (Original-75% CP - Aqueous System). The average number of exposures tolerated was 4.5++ (4/8 men broken).

Table XLI

Tests on Binder Modifications

Date Started	No. of Men	Binder Modification	No. of Men Broken on Day No. - 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	No. of Breaks	Av. Exp. Tolerated
4/11/44	9	Low CP (25%)				2	1,6*											3	4.8 + +
11/ 7/44	7	" " "		1			4						1		1			7	6.6
11/14/44	8	" " "			1	6				1								8	4.4
11/21/44	8	" " "			3	4	1											8	3.8
3/27/45	4	" " "				3	1											4	4.3
4/30/45	8	" " "				1		1		3	1	1		1				8	8.1
5/15/45	15	" " "			1			2	5	1		5,1*						14	7.9 +
5/30/45	8	" " "							1	3	1	3						8	8.8
6/ 5/45	7	" " "				1	1	2	1	2								7	6.3
Totals	74		1	1	5	17	8,6*	5	7	10	2	9,1*	1	1	1			67	
																		Av.	6.1 +
Concurrent Standard 75% CP System Control Tests for Low CP System Tests																			
4/11/44	4	None (75% CP)			1	1	1,1*											3	4.3 +
11/21/44	8	None (75% CP)			5	1	1		1									8	3.9

Continued on following page

Table XLI (Cont'd.)

Tests on Binder Modifications

Date Started	No. of Men	Binder Modification	No. of Men Broken on Day No. - 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	No. of Breaks	Av. Exp. Tolerated
4/17/45	7	Pretreatment with CP						1	2			1	1				2*	5	10.1 +
**4/17/45	8	**None								2	1	2	1	1			1*	7	10.4 +

** Concurrent Laboratory Aqueous System (25% CP) Control Test for Pretreatment with CP Test

8/ 1/44	8	Mineral Oil			3	3	2											8	3.9
** 8/ 1/44	8	**None			1	2*	3*											4	4.5 + +

** Concurrent 75% CP Aqueous System Control Test for Mineral Oil System Test

Appendix IV

Detailed Physiological Data for Tests on Stabilizer Modifications

Table XLII

Test No. 5a - Variation in ZnO Content
No ZnO

Date Started: 6/5/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
6	E pop E° cf,athi,kn,el, pthi,ple	E pop,ple E° umar,cf,athi,kn,ale, el,pthi
6	E paf,sc,dth E° kn,psh,el,pthi, pop,ple	E psh,sc,dth,kn E° cf,athi,el,pthi,pop
8	E psh,sc E° ash,aar,cf,ax, athi,kn,ale,el, dth,pthi,pop, ple	E psh,sc,dth E° ash,umar,aar,cf,athi, kn,ale,el,pthi,pop,ple
6	E umar,cf,ulth, paf E° kn,psh,el,sc, dth,pop	E umar,cf,lth,paf,psh, sc,dth,pop E° ax,kn,el,pthi,ple
7	E paf,sc E° athi,kn,ale, el,pthi,pop, ple	E paf,sc E° athi,kn,el,pop,ple
5	E ax,athi,paf,sc, dth E° ash,aar,cf,kn, psh,el,pthi, pop,ple	E ash,aar,cf,athi,kn,paf, psh,sc,dth,pthi,pop,ple E° umar,ax,par,el
7	E kn,paf,psh,sc, dth E° ash,umar,aar,cf, aaf,ax,lth,athi, ale,el,pthi,pop, ple	E umar,athi,kn,ale,paf,psh, sc,dth,pthi,pop E° aar,cf,ax,lth,el,ple

Av. 6.4

Table XLIII

Test No. 5b - Variation in ZnO Content
10% ZnO

Date Started: 6/5/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
8	E kn,ale,pop E° cf,athi,psh,el, sc,dth,pthi,ple	E kn,ale,pthi,pop,ple E° cf,athi,el
7	E cf,pop E° umar,athi,kn, ale,paf,psh,par, el,C_7,sc,dth, pthi,ple	E cf,kn,paf,el,pop E° lth,athi,ale,psh,par, sc,dth
6	E psh,sc,dth E° ash,athi,kn,par, el,pthi,pop,ple	E psh,sc,dth E° ash,athi,kn,ale,par, el,pthi,pop,ple
7	E ash,psh,pop E° umar,athi,kn, ale,paf,el,sc, dth,pthi,ple	E ash,kn,paf,psh,el,pop E° aar,athi,ale,sc,dth, pthi,ple
4	E paf,psh,sc,dth, el E° umar,aaf,cf, ulth,kn,pthi, pop,ple	E lth,paf,psh,el,sc,dth E° aar,cf,kn,pthi,pop,ple
6	E uvth,psh,sc,dth E° umar,ax,lth,kn, el,pthi,pop,ple	E ash,uvth,kn,psh,sc,dth E° aar,cf,ax,lth,athi,el, pthi,pop,ple
7	E cf,kn,el,sc,pthi, pop E° cl,ash,aar,vth, psh,dth	E cf,uvth,el,pop E° cl,ash,aar,athi,kn,psh, par,C_7,sc,dtn,pthi
7	E umar,cf,athi,kn, paf,psh,sc,dth E° ash,aar,ax,lth, ale,el,pthi,pop, ple	E cf,ax,athi,kn,ale,paf, psh,sc,dth,pthi,pop E° ash,aar,aaf,lth,el,ple

Av. 6.5

Table XLIV

Test No. 5c - Concurrent Control Test for Variation in ZnO Content - Low CP System (25% ZnO)

Date Started: 6/5/45

This test was conducted concurrently with Test Nos. 5a and 5b (Tables XLII and XLIII). The data are presented in Table XXXIV as Test No. 2j (Low CP System). The average number of exposures tolerated was 6.3 (7/7 men broken).

Table XLV

Tests on Stabilizer Modifications

Date Started	No. of Men	Stabilizer Modification	No. of Breaks on Day No. 1	2	3	4	5	6	7	8	No. of Breaks	Av.Exp. Tolerated
6/5/45	7	No ZnO					1	3	2	1	7	6.4
6/5/45	8	10% ZnO				1		2	4	1	8	6.5
**6/5/45	7	None (25% ZnO)				1	1	2	1	2	7	6.3

** Concurrent Low CP (25%) System Control Test

Appendix V

Detailed Physiological Data for Tests on Modified Methods of Application

Table XLVI

Test No. 6a - Piece-goods Impregnation

Date Started: 4/25/44

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
4	E sh,sc	E lth,ar,sc,dth E° sh
7*	E° sh,sc	No Readings
7*	E° bt,pop	No Readings
7*	E° sc	No Readings

Av. 6.3++

Table XLVII

Test No. 6b - Piece-goods Impregnation

Date Started: 3/27/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
3	E athi,kn,psh,sc, dth,pthi,pop,ple E° ash,umar,aar,cf, ax,lth,ale,par, el	E ash,aar,cf,aaf,ax, lth,athi,kn,ale,paf, psh,par,el,sc,dth,pthi, pop,ple
4	E umar,paf,pop E° cf,ulth,athi,kn, psh,sc,dth,pthi, ple	E umar,ax,ulth,athi,kn, paf,psh,sc,dth,pop E° cf,ale,par,el,pthi, ple
4	E ash,aar,cf,ax, lth,athi,kn,paf, psh,sc,dth E° ale,par,el,pthi, pop,ple	E+ athi E ash,umar,aar,cf,ax, lth,kn,ale,paf,psh, par,el,sc,dth,pthi, pop,ple
3	E ash,aar,aaf,lth, vth,psh,sc,dth E° cf,ax,athi,kn, ale,par,el	E ash,aar,cf,lth,vth, athi,kn,ale,paf,psh, sc,dth E° ax,par,el,pthi,pop, ple
6	E athi,kn,ale,pthi, pop,ple E° aar,cf,psh,sc,dth	E aar,cf,athi,kn,ale, psh,sc,dth,pthi,pop, ple E° ash,par,el
9	E ax,dth E° aaf,lth,athi,kn, ale,paf,psh,sc, pthi,pop,ple	E psh,sc,dth E° cf,aaf,ax,ulth,athi, kn,ale,paf

Av. 4.8

Table XLVIII

Test No. 6c - Piece-goods Impregnation

CT 6000 (60 min.)

Date Started: 3/5/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure)	
	24	48
6	E umar,athi,kn,paf, psh,sc,pop E° ash,aar,cf,ale, C_7,dth,pthi,ple	E ash,umar,cf,aaf,kn, paf,psh,sc,pop E° lth,athi,ale,el,dth, pthi,ple
5	E ash,cf,paf,psh,sc, dth E° umar,aar,ax,lth, athi,kn,ale,el, pthi,pop,ple	E ash,umar,aar,cf,aaf,lth, vth,athi,kn,ale,paf, psh,sc,dth,pthi,pop, ple E° el

Av. 5.5

Table XLIX

Test No. 6d - Concurrent Control Test for Piece-goods Impregnation - 75% CP Aqueous System

Date Started: 4/25/44

This test was conducted concurrently with Test No. 6a (Table XLVI). The data are presented in Table XVI as Test No. 1d (Original-75% CP-Aqueous System). The average number of exposures tolerated was 5.9+ (6/7 men broken).

Table L

Test No. 6e - Concurrent Control Test for Piece-goods Impregnation - Low CP (25%) System

Date Started: 3/27/45

This test was conducted concurrently with Test No. 6b (Table XLVII). The data are presented in Table XXX as Test No. 2f (Low CP System). The average number of exposures tolerated was 4.3 (4/4 men broken).

Table LI

Test No. 6f - Concurrent Control Test for Piece-goods Impregnation - Low CP (25%) System

CT 6000 (60 Min.)

Date Started: 3/5/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
6	E paf,psh,sc,dth E° ash,umar,aar,cf, lth,athi,kn,pthi, pop,ple	E ash,umar,cf,lth,athi, kn,ale,psh,sc,dth, pthi,pop E° el,ple
3	E psh,sc,dth E° C_7	E paf,psh,sc,dth E° ash,umar,aaf,lth,vth
3	E psh,sc,dth	E ash,psh,sc,dth E° cf
5	E paf,psh,sc,dth, pop E° C_7,pthi,ple	E+ pop E athi,kn,paf,psh,sc, dth,pthi,ple E° cf,ale
5	E athi,pop E° cl,ash,lth,kn, ale,paf,psh,C_7, sc,dth,pthi,ple	E+ pop E lth,athi,kn,ale,paf, psh,sc,dth,pthi,ple E° cl,umar,cf,C_7
5	E psh,sc,dth,pop E° ax,lth	E ax,paf,psh,sc,dth E° ash,cf,athi,kn,ale, pthi,pop,ple
4	E paf,psh,sc,dth, igf E° cf,athi,kn,el	E ash,paf,psh,sc,dth E° cf,ax,athi,kn
6	E paf,psh,sc,dth, pop E° umar,athi,kn, pthi,ple	E psh,sc,dth E° umar,ax,paf,pop

Av. 4.6

Table LII

Test No. 7a - Field Set

(Light Weight Simplified) Impregnation

Date Started: 3/27/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
9	NPV sc	NV sc,psh E umar,par,el,dth
11	NV psh,sc E aar E° athi,kn,pop	NV psh,C7 E° aar,cf
11*	E° dh,wr,athi,kn, psh,par,el,pthi, pop,ple	No Readings
11*	E° cf,fa,athi,kn	No Readings
11	E aar,cf E° athi,kn,psh,sc	No Readings

Av. 10.6+

Table LIII

Test No. 7b - Concurrent Control Test for Field Set (Light Weight Simplified) Impregnation Low CP (25%) System

Date Started: 3/27/45

This test was conducted concurrently with Test No. 7a (Table LII). The data are presented in Table XXX as Test 2f (Low CP System). The average number of exposures tolerated was 4.3 (4/4 men broken).

Table LIV

Test No. 8a - Foam Process Impregnation

Date Started: 5/18/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
7*	No Readings E° or Greater	E° el,pop
7	NV psh E° ash,cf,aaf,athi, kn,ale,paf,par, el,sc,dth	NV cl,psh E° ash,cf,aaf,athi,kn, ale,paf,el,sc,dth, pthi,pop,ple
6	E ax E° athi,kn,ale,paf, psh,el,sc,dth, pthi,pop,ple	E ax E° ash,aar,cf,athi,kn, ale,psh,el,sc,dth, pthi,pop,ple
7	E ash,athi,kn,ale, paf,psh,sc,pop E° umar,aar,cf,ax, lth,par,el,dth, pthi,ple	E ash,athi,kn,ale,paf, psh,sc,dth,pop E° aar,cf,lth,vth,par, el,pthi,ple
5	E paf,psh,sc E° ash,aar,athi,kn, dth	E paf,psh,sc E° ash,umar,aaf,lth, athi,kn,ale,dth
6	E cl E° kn	E cl E° kn

Av. 6.3+

Table LV

Test No. 8b - Concurrent Control Test for Foam Process Impregnation - Low CP (25%) System

Date Started: 5/15/45

This test was conducted concurrently with Test No. 8a (Table LIV). The data are presented in Table XXXII as Test No. 2h (Low CP System). The average number of exposures tolerated was 7.9+ (14/15 men broken).

Table LVI

Tests on Modified Methods of Application

Date Started	No. of Men	Method of Application	No. of Men Broken on Day No - 1	2	3	4	5	6	7	8	9	10	11	No. of Breaks	Av. Exp. Tolerated
4/25/44	4	Piece-goods				1			3*					1	6.3 + +
3/27/45	6	"			2	2		1			1			6	4.8
3/ 5/45	2	"					1	1						2	5.5 (CT 6000)
Concurrent Control Tests for Piece-goods Impregnation Tests															
4/25/44	7	75% CP Aqueous			2			1	2,1*	1				6	5.9 +
3/27/45	4	Low CP (25%)				3	1							4	4.3
3/ 5/45	8	" " "			2	1	3	2						8	4.6 (CT 6000)
3/27/45	5	Field Set (LWS)									1		2,2*	3	10.6 +
**3/27/45	4	**Low CP (25%)				3	1							4	4.3 **
**Concurrent Control Test for Field Set (LWS) Impregnation Test															
5/18/45	6	Foam Process					1	2	2,1*					5	6.3 +
***5/15/45	15	***Low CP (25%)		1		2	5	1			5,1*			14	7.9+***

*** Concurrent Control Test for Foam Process Impregnation Test

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