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CHEMISTRY DIVISION - PROTECTIVE CHEMISTRY SECTION

10 December 1945

CHAMBER TESTS WITH HUMAN SUBJECTS
XIX..STUDIES OF CLOTHING DESIGN

By
G. M. Gantz, W. H. Taylor,
H. W. Carhart
and
J.H. Heinen, Lt. (MC) USNR

- Report No. P-2729 -

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[redacted]

* * *

Approved by:

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Superintendent, Chemistry Division

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

Preliminary Pages..... a - c
Numbered Pages........ 21
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NRL Problem P-60

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NRL Problem P-60

ABSTRACT

This report describes the experimental procedures and results of chamber tests conducted primarily on modifications and new designs of Navy Protective clothing. A modified design of the Navy Protective suit was developed and found satisfactory which resulted in greater simplicity of manufacture as well as wear. Later a gas proof fly opening was designed, tested and recommended.

Special clothing submitted by the U.S.M.C. consisting of a modified form of their utility suit was found to have satisfactory protective value after impregnation with the field set, M-1. Detached hoods designed for use with these utility suits were also satisfactory. Marine Corps protective suits impregnated by the solvent process with $CaCO_3$ stabilizer were superior in protective value to the utility suits.

Several chamber tests were conducted on various types of socks, gloves and protective shorts.

Many designs and types of hoods were investigated in chamber tests in an effort to improve the design of the hood for both CC-2 impregnated and carbon-rayon protective clothing.

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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 report is to present the results of chamber tests with human subjects on special types and designs of protective clothing including suits, shorts, socks, gloves and hoods.

C. Known Facts Bearing on the Problem and Theoretical Considerations

3. In the course of conducting many chamber tests at this Laboratory a standardized procedure has been evolved for testing new items of clothing. Chamber conditions are maintained at 90°F. and 65% relative humidity. Subjects dressed in protective clothing (usually 1-1/2 layer) and masked, are exposed in the chamber for one hour each day. The subjects are examined for erythema or H vapor burns by a medical officer 24 hours after each daily exposure. Subjects are withdrawn from the test when they sustain an intense erythema (E) or more severe burn on any part of their body. The daily exposures are continued until all the men have been withdrawn from the test, though in some instances the tests have been stopped before all the men are withdrawn. The most convenient method of expressing protective value then becomes the average number of exposures tolerated by the subjects in a given test.

4. New types or designs of protective clothing such as suits, shorts, socks and gloves may be tested by the procedure outlined above and usually the item under test is run on one group in comparison with a control group wearing standard items of clothing.

5. There are many factors other than protective value to be considered in evaluating protective clothing items. It is important that the clothing be durable and comfortable on wear. These factors can be evaluated most satisfactorily in wearing trials. In evaluating certain designs such as the gas-proof fly it was felt necessary to conduct the chamber test with subjects exercising in such a way as to test the fly under many conditions including stooping, stretching and sitting. Certain other modifications of the standard chamber test procedure have been employed to evaluate special designs of protective hoods.

D. Previous Work Done at This Laboratory

6. This is the nineteenth of a series of reports on "Chamber Tests With Human Subjects". No prior formal report has been issued on chamber tests of special designs of protective clothing. The chamber employed in this investigation has been fully discussed in NRL Report No. P-2208, dated 22 December 1943. Many letter reports on chamber tests on modified items of protective clothing containing recommendations have been forwarded to the Bureau of Ships.

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EXPERIMENTAL

A. Description of Clothing and Procedures for Chamber Tests

(1) Modified Design of Protective Suits.

7. Through the combined efforts of this Laboratory and the Naval Clothing Depot, Brooklyn, a modified design of the Navy's protective suit was developed early in 1944. The aim in modifying the protective suit was to simplify both manufacture and wear of the suit.

8. The essential features of the new design suit are listed below:

(a) Complete elimination of buttons and buttonholes on jumpers. A wide neck band, 26 inches, and wide face opening in the hood, 28 inches, permit the jacket to be put on with the hood around the neck. The gas mask is put on and then the hood is pulled up over the head harness of the mask and drawn up snugly around the facepiece of the mask by means of a drawstring.

(b) Buttons on the shoulder straps are eliminated and the straps are tied through buttonholes in the bib of the trousers.

(c) The pockets on the jackets have been raised and the pocket on the trousers was made larger.

(d) Many other small changes were effected such as reinforcement of drawcord eyelets, lowering of ties on legs and cuffs, etc. The changes noted above greatly simplified the cutting and sewing operations in manufacture of the suits and facilitated expanded procurement required by the Navy. In addition, the changes greatly facilitated donning the suits. It was hoped that the changes would also improve the protective value of the suits.

9. The major change in the jumper was the elimination of the front opening. Therefore the first two chamber tests were conducted as single exposures without protective ointment in order to test specifically the protective value of the suits in the region of the neck. A third test was then run in which ointment was used and the subjects were given successive daily exposures. In these tests each man exposed in the chamber was supplied with the following protective equipment:

(a) Navy diaphragm mask, Mark III or IV.
(b) Aqueous CC-2 impregnated protective suit.
(c) Standard Navy issue undershirt and drawers, unimpregnated.
(d) CC-2 impregnated cotton socks, (2 pairs).
(e) CC-2 impregnated elbow-length wool gloves,
(f) Overshoes (Arctics).

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10. The subjects were given a single (or successive daily) exposure 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.

The operation of the NRL chamber is described in detail in NRL Report No. P-2208, "Chamber Tests with Human Subjects, I. Design and Operation of Chamber, II. Initial Tests of Navy Issue Protective Clothing Against H Vapor", dated 22 December 1943.

11. The clothing was worn by the subjects for four hours after each chamber exposure. The men were examined and read by the medical officer at 24 and 48 hours after the exposures. In the case of successive daily exposures the readings were made just before each chamber test 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. Successive daily exposures were continued until all the men had "broken", i.e., reached a reading of E or greater, although occasionally some tests were stopped before all the men had broken.

12. Control tests were run in conjunction with the modified design protective suits and consisted of standard design protective suits. This provided a direct method of assessing the protective value of the modification of the suit.

(2) U.S.M.C. Protective Suits.

13. Prior to 1945 the standard protective suit adopted by the Marine Corps was of the same design and the same fabric as the Navy's protective suit. Greatly increased procurement schedules resulted in consideration of a policy of utilizing the regular herringbone twill utility suits for gas protection. Minor modifications in the utility suit similar to those adopted by the CWS for the Army protective suit, would mean that every suit in the field and in reserve would be a potential protective suit and require only impregnation to be effective. It would be necessary to stockpile protective socks, gloves, hoods and shorts to complete the essential feature of the plan described.

14. At the request of the Plans and Policies Division of Headquarters, Commandant, U.S.M.C., this Laboratory conducted a series of tests on clothing furnished by the Marine Corps. The clothing worn in chamber tests consisted of three groups of eight suits each. The first group of suits were of modified utility suit design of herringbone twill. The eight detached hoods supplied with this group, designated as Type A, had a small face opening and were designed to be put on after the mask had been put on and adjusted. Four of the hoods were of herringbone twill and four were of Arnzen cloth. The second group of eight suits were the same as the first but the detached hoods, designed as Type B, had wide face openings and could be put on around the neck before the mask was put on. The Type B hoods were designed for use with hosetube type masks while the Type A hoods were for use with masks having the canister attached directly to the facepiece. The hoods and suits of both these two groups were impregnated by the field set process using M-1 sets.

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15. The third set of eight suits were of Navy design and made of Arnzen cloth. They had been impregnated by the solvent process at a CWS Z of I plant to contain 10% CC-2 with calcium carbonate stabilizer.

16. In addition to the suits and hoods described, the subjects were furnished with impregnated socks, shorts and gloves; masks, overshoes, and impregnated quarter sleeve shirts. No ointment was used. Repeated daily exposures to H vapor at 1200 CT, with four hours wear after exposures, were continued until all the men had a reading of E or greater on some part of the body. Particular emphasis was placed on readings in the region of the neck.

(3) Gas-Proof Fly.

17. During many wearing trials conducted by this Laboratory, it was noted that subjects would rip or cut the trousers to provide a fly opening. Consequently, a gas-proof fly was designed by this Laboratory and submitted to the Naval Clothing Depot for execution. NCD improved the design and made up several trousers containing the fly opening. The fly is made by cutting a vertical slip 4-1/2 inches long in the front seam of the trousers. A semi-circular flap is sewed to one side of the slit to provide protection on the under side of the opening. A one layer square of cloth, 5-1/2 inches on a side, is sewed over the slit on the outside of the trousers but the right edge of the square is left open. For gas to pass through this opening it must pass between the trousers and the outer square for a distance of 2-1/2 inches, go through the slip, and then travel for an inch or two in the opposite direction between the slit and the inner flap.

18. The chamber test of the gas-proof fly consisted of 7 men dressed in protective suits with the fly and seven men wearing suits without the fly. The first exposure was at 600 CT (20 γ H/1 for 30 min.) followed by successive daily exposures at 1200 CT. The clothing was worn for four hours after each exposure. During the exposures the men were required to perform the following exercises:

(a) Perform 6 knee bends to a squatting position and back.
(b) Walk about chamber for 5 minutes.
(c) Sit in squatting position for 5 minutes with knees drawn up.
(d) Repeat above sequence until exposure time is up.

Both groups of men in this test were dressed in the standard manner with masks, ointment on face and neck, overshoes, unimpregnated shirts and shorts, impregnated suits, socks and gloves. The suits for both groups were impregnated by the standard aqueous process (75% CP system) to contain approximately 0.5 mg. Cl+/$cm.^2$. A special record was kept of reactions in the pubic region.

(4) Socks, Gloves and Protective Shorts.

19. In the Fall of 1944 an imminent shortage of wool led the Navy Department to request the investigation of all-cotton socks to replace the cotton-wool socks as an item of protective clothing. The cotton-wool socks used

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for protective clothing meet the Federal Specification JJS-581A Class A Type 1, and contain 48% wool. Two types of all-cotton socks were tested as substitutes. One type was similar in construction and weight to the cotton-wool sock and met Federal Specification JJS-566 Type A, while the other socks were lighter in weight and conformed to the Specification JJS-566, Type B.

20. In the standard procedure for conducting chamber tests there is very little exposure of socks directly to H vapor and skin reactions on the feet or lower legs are very rare. However, the overshoes worn over the socks in chamber tests were contaminated with H vapor from repeated exposures in the chamber and would cause burns when unimpregnated socks were worn. The all-cotton socks were not given a special test but were subjected to repeated exposures in tests conducted for other purposes. For such tests, the feet and legs of the subjects were carefully examined to see if the special socks exhibited inadequate protection.

21. The first special test of protective gloves were on gloves woven from two-ply wool yarn, instead of three-ply yarn. During the imminent shortage of wool in 1944 two types of cotton protective gloves were tested. These gloves were made of a heavy cotton knit fabric napped on one side. One type had a six inch ribbed knit wristlet and was similar to the cotton glove used by the Chemical Warfare Service. The other type was similar but had a 12 inch woven fabric gauntlet with a channeled tiecord at the top for securing around the forearm. Two other sets of cotton gloves, similar to those described, also were subjected to chamber tests.

22. The procedure used for testing gloves was to subject them to a series of chamber exposures after they had been impregnated. The standard design woolen gloves normally used in chamber tests offer complete protection for hands in repeated chamber tests. When new types of gloves were tested in the chamber their full protective value could not be determined since they were not run until they had "broken". The tests of special gloves were always included in a chamber test series conducted for reasons other than testing protective gloves. If no significant burns resulted on the area covered by the gloves after repeated exposures, the gloves were considered as satisfactory for protection.

23. The development of protective shorts was carried out to provide a satisfactory item of protective clothing for the Navy. In addition, the use of protective shorts in chamber tests was adopted as a standard procedure whenever possible since burns in the genital region are incapacitating whereas much more severe reactions on other body areas are not incapacitating.

24. Data relative to the protective value of one layer, one and one-half layer and one and three-quarter layer clothing has been presented and reviewed in NRL Report No. P-2603 and is not considered a part of this report. Having decided that one and one-half layer clothing was best suited for Navy use, development of a satisfactory protective short was started. Chamber tests were first conducted on standard Navy issue Nainsook shorts.

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Although these shorts were satisfactory from a protective standpoint in one and one-half layer clothing, they were not suitable for hard wear under field conditions. This was brought out in NRL Report No. P-2343, "Tropical Wearing Trials of Protective Clothing", dated 5 August 1944.

25. With the cooperation of the Naval Clothing Depot, Brooklyn, and the Clothing Division of the Bureau of Supplies and Accounts, a satisfactory short was developed. This short was made of medium weight ribbed knit cotton fabric and was of "jockey" type construction. Size adjustment was provided by means of gussets and tie tapes at each side of the waist. The crotch area was reinforced by using two layers of fabric. A gas-proof type fly opening was provided by having a three inch opening in the outer layer of the reinforcement which was cut at an angle of 45 degrees to and six inches below the waistband. The fly opening was completed by having a similar opening in the inner layer of crotch reinforcement two inches below the outer opening. Legs were attached to the shorts extending to midthigh and were held tight to the legs by a wide, heavy, double layer, ribbed knit hem.

26. Chamber tests on protective shorts were all run as one and one-half layer tests, i.e., impregnated protective suits were worn over the impregnated shorts. Other standard equipment was used such as masks, socks, gloves, overshoes and ointment. Successive daily exposures to H vapor at 1200 CT, followed by four hours wear, were continued until subjects had an intense erythema (E) on some part of the body.

(5) Hood Designs.

27. The chamber tests conducted with reference to hood designs may be divided into four series. The first series has been described above in the section "Modified Design of Navy Protective Suit" in which a major design change was made in the attached hood of the Navy protective suit. The second series has also been described above and comprises the special detached hoods worn with the U.S.M.C. Protective Clothing.

28. A third series of tests was run in an effort to determine the causes of burns when no ointment was used in the face and neck in chamber tests of standard Navy suits. In addition to CC-2 suits, suits of carbon-rayon fabric (Type 148) were run inasmuch as some evidence had been obtained that protective ointment poisoned the carbon in such suits. The test was designed to demonstrate the relative importance of wearing time, leakage of gas through fabric and leakage of gas past the hood and mask closure.

29. A total of 32 subjects were used in this series and these were divided into eight groups of 4 men each. Three groups of four men each were dressed in standard 1-1/2 layer CC-2 aqueous impregnated clothing. The first group used no ointment and wore the clothing for the customary four hours after each daily exposure. The second group were no ointment, did not wear the clothing after each exposure (except for 15 minutes aeration) and the hoods on the suits were lined with cellophane. The third group used no ointment, did not wear the clothing after exposure, but had a CC-2 cloth flange between the hood and the mask.

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30. The cellophane hood liners were made of scrim-backed protective cover material. They were stitched to the suit hoods just behind the drawcord channel of the face opening. In addition they had a six-inch shawl which was tacked to the suits front and back and over the shoulders. Since the cellophane material was known to be impermeable to vesicant vapors, it was considered that these hood liners would eliminate leakage through the fabric yet not interfere with any leakage through the hood and mask closure. The cellophane liners were replaced as needed during the trials.

31. The cloth flanges were circular with an outer periphery equal to the full face opening of the protective hoods. A hole in the center of the flanges had a periphery equal to the distance around the gas mask for normal hood fitting. The flanges were permanently fastened to the gas mask with rubber cement. Each day before the chamber tests, masks were put on and the flanges were sewn by hand to the hoods on the protective suits. In this manner a positive seal was obtained between the hood and the mask and the factor of leakage between the mask and hood closure was eliminated.

32. There were five groups of four men each wearing carbon-rayon suits of No. 148 fabric. None of the groups used ointment. The first group was dressed in standard 1-1/2 layer equipment and wore the suits for the 23 hours after each daily exposure. The second group was the same except that they did not wear their suits between exposures. The third group had hoods lined with cellophane but did not wear their clothing after each exposure. The fourth group were equipped with carbon-rayon cloth flanges and did not wear their clothing after each exposure. The fifth group used both cellophane hood liners and cloth flanges and wore the clothing 23 hours after each daily exposure.

33. For convenience, the test groups are shown in Table I with a description of the factors which each group was designed to emphasize. It should be pointed out that the factor of desorption for carbon clothing is very important and in these tests refers mainly to sweep-off of vapors from the contaminated side of the fabric. It was suspected that such a sweep-off might be appreciable during the first hour or so after exposure when the face and neck of unmasked men would be burned by vapors rising from the outer surfaces of the garment. The desorption factor does not exist for CC-2 clothing, since other tests have shown that wearing time following exposure is not important.

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Table I

Groups of Subjects Used in Chamber Tests of Hood Design

Group	Equipment	Factors Excluded	Factors Tested
1. CC-2	None, 4 hrs. wear	None	All*
2. CC-2	Cello liner, no wear	Fabric leakage	Closure leakage
3. CC-2	Cloth flange, no wear	Closure leakage	Fabric leakage
1. Carbon	None, 24 hrs. wear	None	All
2. Carbon	None, no wear	Desorption	Fabric and closure leakage
3. Carbon	Cello liner, no wear	Desorption, fabric leakage	Closure leakage
4. Carbon	Cloth flange, no wear	Desorption, closure leakage	Fabric leakage
5. Carbon	Cello liner and cloth flange, 24 hrs. wear	Fabric and closure leakage	Desorption

* Consists of closure leakage, fabric leakage and desorption (for carbon clothing).

[redacted]

34. The daily chamber tests were run in the standard manner. Groups of 5 to 10 subjects were exposed for one hour to a concentration of 20 γ/l of H vapor at chamber conditions of 90°F - 65% R.H. Successive daily exposures of the same men dressed in the same clothing were continued until each man was withdrawn by the medical officer because of an intense erythema of the neck or because the test was stopped.

35. Following the tests outlined above on hood design, a few CC-2 suits and carbon-rayon suits were made at NCD, Brooklyn, with a zipper closure on the hood. The zipper covered a folded gusset which opened out to provide a sufficiently large face opening on the hood so that it could be thrown back over the head. When the gusset was folded down over the head and the zipper closed the face opening of the hood was reduced so that the drawcord had to pull up only a little slack in effecting a tight seal around the mask. Screening tests were run on two carbon suits and one CC-2 suit with successive daily exposures to H vapor at 1200 CT. No ointment was used in these tests and the clothing was removed after each exposure.

36. The fourth series of tests on protective hoods were conducted to evaluate the principle of providing positive pressure inside the hood by virtue of expired air forced into the space between the mask and the hood. A preliminary test was made on two detached hoods of Oxford cloth designed to be worn with the Navy Mark IV mask and to cover the outlet valve. The subjects were given successive daily exposures of one hour to H vapor at CT 300. No ointment was used, the hoods were not impregnated, and wire guards were fitted over the mask outlet valves to insure satisfactory functioning underneath the hoods.

37. Another test was conducted on four poplin hoods of the same type which had been improved in design to provide greater fullness around the outlet valve. These hoods had channeled drawcords around the neck and around the front opening. The front opening was drawn up tight around the eyepieces and hose tube of the facepiece, so that the speech diaphragm, the outlet valve, and other parts of the mask were covered. In addition to the four hoods of poplin cloth, two other special hoods were tested at the same time. One was made of impermeable fabric and the other was made of one layer Oxford cloth Type IV. Both hoods surrounded an oxygen type mask and hose tube, and contained a flexible plastic window. The hose tube of the mask extended through a hole in the back of the hood to an adapter on which a canister could be screwed. In use, these hoods covered the oxygen mask and hose tube, fastened snugly around the neck by means of a tiecord and provided internal pressure by reason of expired air forced into the space between the mask and hood.

38. A preliminary test was run on the two special hoods described above against tear gas (CNB). No tear gas was detected by subjects who were exposed 15 minutes in a chamber in which tear gas had been dispersed by atomization. Nevertheless, when chamber tests against H vapor were run, the oxygen masks were replaced by full face masks (Army LWS) to prevent possible eye damage to the subjects. This change meant that effects of H vapor penetrating the hood would be observed on the neck instead of both the neck and eyes.

[redacted]

39. Chamber tests on the four poplin hoods and two special hoods were run as successive daily exposures for 30 minutes with an H vapor concentration of 10 γ/1, (300 CT). The six subjects were dressed in standard CC-2 1-1/2 layer clothing in addition to the hoods. After the fifth day all subjects had been withdrawn from the test except the one wearing the special impermeable hood and he continued with daily exposures of 15 min. at 20 γH/1 (300 CT).

40. Following the chamber tests against H vapor, additional tests against tear gas were made on six of the special hoods of Oxford cloth. For these runs oxygen masks were used instead of full face masks. In the first test, the subjects were dressed in 1-1/2 layer CC-2 clothing in addition to the hood. One exposure was made against an average concentration of 6.7 γ CN/1. The CN concentration was set up by aspirating air through an alcholic solution but the temperature and humidity were not controlled in the chamber.

41. A second tear gas test was conducted at a lower concentration (0.4 γ CN/1) with several modifications of the hoods. Two of the Oxford hoods were equipped with full face masks, three Oxford hoods were equipped with an oxygen mask as in the previous tear gas test, one Oxford hood with an oxygen mask was fitted with an air line through which a steady flow of 10 1/min. of pure air was forced in, in an effort to accentuate the internal pressure, and one impermeable hood with an oxygen mask was included. The subjects were clothed in the same CC-2 clothing used for the first tear gas test and the temperature and humidity of the chamber were not controlled.

B. Results and Discussion

(1) Modified Design of Navy Protective Suit.

42. The results of the first two tests of the modified design Navy protective suit are given in Tables IX and X at the end of the text. An attempt was made to obtain a numerical comparison of the old and new design suits by assigning arbitrary numerical values to the physiological readings shown in Table VII. The average values thus obtained for the old and new design suits are shown below in Table II.

Table II

Comparison of Average Numerical Values for Physiological Readings in Tests of Old and New Design Navy Protective Suit

	Old Design		New Design	
	24 Hrs.	48 Hrs.	24 Hrs.	48 Hrs.
First and Second Tests	1.4	1.7	1.5	1.4

[redacted]

43. It was concluded that no improvement in protective value for the modified design suit was apparent from the data. In the third test, which was run with successive daily exposures, the four subjects wearing modified design suits tolerated an average of 6.3+ exposures while the seven subjects wearing standard suits tolerated an average of 5.9+ exposures. The data are shown in Tables XI and XII at the end of the text. Thus there was no marked difference between the new and old design suits when ointment was used and successive daily exposures to H vapor were employed. One other aspect of these tests which should be pointed out is the fact that the modified design suits in the test were made from cloth which had been impregnated in a textile mill with an aqueous CC-2 suspension, while the standard suits were impregnated with an aqueous suspension of CC-2 by the usual garment impregnation process.

(2) U.S.M.C. Protective Suits.

44. The results of chamber tests on Marine Corps protective suits is summarized below in Table III. More detailed results are shown in Tables XIII, XIV and XV at the end of the text. The data show that there was not any appreciable difference between the Type A hoods with the small face opening and the Type B hoods with the large face opening. Since the drawstrings in the hoods with the large face opening must gather up the cloth to fit around the mask, it may be concluded that gathering of the hood above the eyepiece is not a source of H vapor leakage. Moreover, there was no marked difference between the two fabrics, herringbone twill and Arnzen cloth, as far as the hoods were concerned. The superior protective value of the Arnzen suits over the utility suits is not attributed to the difference in fabric but to the difference in impregnation. In many different tests with Navy protective clothing, it has been found that solvent process impregnation results in greater protective value than aqueous impregnation.

Table III

Summarized Results of Tests of Marine Corps Protective Suits

Suit Type	Fabric	Hood Type	Fabric	No. of Men	Av. No. of Exps. Tolerated
Utility	HBT	A	HBT	4	5.5
Utility	HBT	A	Arnzen	4	4.0+
Utility	HBT	B	HBT	4	4.5
Utility	HBT	B	Arnzen	4	5.0+
Protective	Arnzen	-	-	7	8.3+

(3) Gas-Proof Fly

45. The results of the chamber test on suits with a gas-proof fly and control suits without the fly are shown in Tables XVI and XVII at the end of the text. The average number of exposures tolerated by men in suits with the gas-proof fly was 5.6+ compared to 3.9 for men in the control suits. It was concluded that no leakage of H vapor occurred through the special fly opening even under the various conditions of exposure attained by the prescribed exercise during the tests. It is possible that the extra layers of cloth in the crotch region with a consequent lower leakage of H vapor through the fabric was responsible for the greater protection afforded by the suits with the fly.

(4) Socks, Gloves and Protective Shorts

46. The all-cotton socks under test as a substitute for the cotton-wool socks were used in a standard "man-break" chamber test which was conducted in the study of another problem. These all-cotton socks gave complete protection and were comparable in all respects to the cotton-wool socks. In addition, all cotton socks which had been worn in a wearing trial at Camp Lejeune, N. C., (see NRL Report No. P-2406) were tested in conjunction with similarly worn cotton-wool socks. Both types gave complete protection in the trials. Thus it was concluded that no difference in protective value of all-cotton over cotton-wool socks could be detected under the conditions of the tests conducted.

47. When woolen protective gloves made of two-ply yarn were impregnated and tested in the chamber with woolen gloves of three-ply yarn, no difference in protection was apparent. Both types of gloves gave complete protection in the tests and a recommendation was made that gloves made of two-ply yarn were equal in protective value to gloves made of three-ply wool yarn.

48. The results of the tests on all-cotton gloves as replacement for woolen gloves are shown in Tables XXII and XXIII. Of the nineteen subjects in these two tests only one showed a reaction on the hand or wrist that could be considered due to lack of protection by the gloves. This subject had an E° reading 72 hours after his last exposure in the chamber. It was concluded therefore that from the standpoint of protective value in chamber tests, all-cotton gloves are fully as satisfactory as woolen gloves.

49. Observations made on the knit wristlet type compared to the gauntlet type during the chamber trial showed that the former had a greater tendency to slip down the arm and were more likely to result in a faulty closure at the wrist. A complete evaluation of the all-cotton gloves in comparison with the woolen gloves would have to be made under field conditions where extended wear and hard work would show which type of glove provided a better wrist closure. Although the chamber tests indicated that the cotton gloves gave complete protection, it is believed that further work should be done on the design of the cotton gloves in an effort to improve the gauntlet or wristlet construction.

50. The effectiveness of impregnated shorts in reducing the incidence of H vapor burns in the scrotal region may be seen by comparing the readings in Tables XIII and XIV with the readings in Tables XVI and XVII. Since scrotal region burns are more apt to be incapacitating, chamber tests were run whenever possible with subjects wearing impregnated shorts.

51. Chamber tests conducted to compare the effectiveness of the standard issue Nainsook shorts with the special ribbed knit shorts developed by NCD, BuSandA, and this Laboratory, are shown in Tables XXIV and XXV. From the standpoint of protective value there is very little difference in the two types of shorts. A decision to recommend the knit short was based therefore on results of wearing trials which showed that Nainsook shorts were too light and flimsy to be satisfactory in the field, (see NRL Reports No. P-2343 and P-2406).

(5) Hood Design

52. Very early chamber tests had indicated that protective ointment was required to prevent neck burns in chamber tests on Navy protective suits (see Tables X and XI in comparison with Tables XII and XIII). The use of ointment was adopted as standard for all chamber tests but no clear-cut data was obtained showing why the hoods on the Navy suits failed to protect the neck or to what extent ointment was required. Some chamber trials on carbon-rayon suits in which ointment had been used, showed that neck burns occurred earlier than burns on other parts of the body. It was not known whether this could be ascribed to poisoning of the carbon by the ointment, leakage through the fabric, leakage past the hood and mask closure, or desorption of vapors from the suits during wear following chamber exposures when the hoods were worn thrown back around the neck.

53. The results of the series of chamber tests carried out to indicate the various factors causing neck burns are shown in summarized form in Table IV. More detailed data is given in Table XVIII. It was deemed advisable to separate "breaks" occurring at the neck and other parts of the body in order to show the results more clearly. Men who "broke" on the body before the neck were given impregnated clothing for the affected region and continued in the test. Examination of the data for the CC-2 groups shows that leakage of H vapor through the fabric is the most important factor. It is not clearly established that no leakage occurs between the hood and mask closure but this factor is certainly not very significant. Assuming that no closure leakage occurs in group (1) as well as group (2), it is seen that a neck break occurs before a body break in one case and not the other. Although the man breaks are somewhat low in this particular series of tests, breaks at the neck and at other parts of the body are of the same order of magnitude.

[redacted]

Table IV

Summarized Results of Chamber Tests of Hood Design

Group	Region	No. of Daily Exposures Tol. 1	2	3	4	5	6	7	8	Average
1. CC-2, 4 hr. wear	Neck		1	1	1	1				3.5
	Other			1	1	1				4.0+
2. CC-2, cello liner, no wear	Neck		1*				2		1	6.7
	Other			3						3.0
3. CC-2, flange, no wear	Neck			2	1		1*			4.0+
	Other			3	1					3.3
1. Carbon, 24 hr. wear	Neck				1*	1		2		6.3
	Other				1*		1			6.7+
2. Carbon, no wear	Neck				1*					8.0+
	Other				1*					8.0+
3. Carbon, cello liner,	Neck				1	1(1*)			1	5.3+
	Other									8.0+
4. Carbon, flange, no wear	Neck									8.0+
	Other									8.0+
5. Carbon, cello liner and flange, 24 hrs. wear	Neck									8.0+
	Other									8.0+

* These subjects were withdrawn from the test for reasons other than a "break".

[redacted]

54. Examination of the data for the five groups wearing carbon-rayon suits shows first that there is no leakage of vapor through the fabric. This fact was known from earlier laboratory and chamber tests. The relative importance of desorption and leakage through the hood and mask closure is more difficult to assess primarily because of variation in making a gas tight hood and mask closure. A comparison of carbon group (1) with carbon group (2) indicates that desorption is more important than closure leakage. On the other hand, desorption was not evidenced by carbon group (5). A comparison of carbon group (3) with group (2) indicates that closure leakage is accentuated by the impermeable hood liner. This is attributed to the fact that vapors leaking past the hood and mask closure were prevented from being adsorbed on the inside surface of the carbon fabric.

55. In all carbon groups except the first the only "breaks" were those occurring in the region of the neck. This correlates with previous tests in which complete protection was exhibited by #148 carbon-rayon suits for more than 8 exposures. However, comparison of the results of this test with earlier tests show that it is unwise to use ointment for the neck and face when carbon clothing is worn. Patch tests have shown that ointment (M-5) can poison carbon and promote release of adsorbed vesicant vapors.

56. Though the tests do not clearly show that closure leakage is more important than desorption, there is certainly an indication of this view. Another fact which must be considered is that in these tests, hood and mask closures were made under optimum conditions with trained personnel. Under service conditions it is more than likely that poor closures would be effected frequently. It is believed that the present design Navy hood for carbon clothing will give adequate protection for as long or longer than CC-2 clothing. To realize the full protective value of carbon-rayon clothing, an improved hood closure device is required.

57. The results of the screening test on the suits with hoods having a zipper closure is shown in Table XIX. Unfortunately, the subject wearing the CC-2 suit was withdrawn from the test before he broke and the two subjects wearing carbon suits had not broken when the test was stopped after the eighth exposure. The results may be taken as an indication that the zipper closure on the hoods is at least as satisfactory if not superior to the standard drawstring closure from the standpoint of protective value.

58. The results of the screening test on the two detached unimpregnated hoods of Oxford cloth are shown in Table XX. Both men tolerated 5 exposures (1500 CT total) before having readings of E or greater on the neck. From these results it could not be claimed that the hoods were as effective as the standard impregnated attached hoods of the Navy suit but it was believed that the results were indicative of some protective value resulting from the positive pressure inside the hoods.

59. Data on the six special hoods designed to provide positive pressure between the mask and hood are shown in Table XXI and have been summarized in Table V below.

[redacted]

Table V

Summarized Results of Tests on Special Hoods

Hood	No. of Exps. Tolerated	Total CT	Readings (After withdrawal)
Impermeable	12	3600	E° ant. neck & sternum.*
Oxford	5	1500	E lat. & post. neck, sternum.
Poplin	2	600	E ant., post., lat., neck
Poplin	2	600	E post., neck & rt. post. auricular area
Poplin	3	900	E post neck; E° ant. lat. neck & sternum
Poplin	3	900	E post. neck.

* Subject had not broken when test was stopped.

60. It is apparent that the impermeable hood afforded practically complete protection throughout the length of the test. The Oxford hood afforded appreciable protection but was less effective than the impermeable hood. The Poplin hood afforded little protection and cannot be considered effective. The relative air permeabilities of the impermeable cloth, Oxford cloth, and poplin cloth (0, 2.3, and 7.7 cu. ft./min./sq.ft. respectively), may explain the relative protective efficiencies of the three type hoods. Apparently, even the closely woven Oxford cloth permits diffusion of H vapor through the hood against flow of expired air with resulting neck burns. It was further noted in these tests that whereas the Oxford and Poplin hoods were comfortable to wear, the impermeable hood was hot, collected perspiration around the hood, and readily became fogged up.

61. In the first tear gas test against the relatively high concentration of 6.7 γ CN/l. all the men were forced to come out of the chamber within six minutes. In this case sufficient gas entered the hood to cause eye effects despite the internal positive pressure of expired air. The second test against tear gas at an average concentration of 0.4 γ CN/l was more successful and the results are shown in Table VI.

Table VI

Results of Second Tear Gas Test Against Special Hoods

Mask and Hood Combination	Mins. Tolerated in Chamber
LWS full face mask; Oxford hood	16
LWS full face mask; Oxford hood	16
Oxygen mask; Oxford hood	16
Oxygen mask; Oxford hood	16
Oxygen mask; Oxford hood with air line	60*
Oxygen mask; Oxford hood	60
Oxygen mask; impermeable hood	60

* Though this subject stayed in the chamber for a full 60 min., he showed severe eye symptoms and stated that he was forced to close his eyes after the first 15-20 minutes in the chamber.

The results of this test are somewhat conflicting. The failure of the full face mask must be attributed to a faulty canister, faulty hose tube seals, or contaminated hose tubes. The failure of the two hoods with oxygen masks is in line with the results at the higher concentration. It is suspected that the hood fitted with the air line failed after about 15 - 20 minutes. However, the one Oxford hood with oxygen mask which gave complete protection suggests that under the right conditions the combination is effective. The complete protection afforded by the impermeable hood corresponds with earlier results.

62. In conclusion it may be stated that the principle of maintaining positive pressure inside a hood by covering the outlet valve has not been found to afford complete protection against gas vapors when the hood is made of a permeable fabric. When an impermeable fabric hood is used, complete protection is afforded. It is quite possible that a combination of permeable and impermeable fabric might be used to construct an effective hood to work on the principle of positive internal pressure.

[redacted]

SUMMARY AND CONCLUSIONS

63. A modified design of Navy protective suit was tested in the chamber along with standard design suits as controls. In two single exposure tests conducted without protective ointment reactions on the neck were substantially equivalent for subjects wearing the two types of suits. A third test was conducted with successive daily exposures and ointment was used. Again a substantial equivalence in the protection of the two types of suits was revealed. It was concluded that the new modified design of Navy protective suit should be recommended because it was simpler to manufacture and to wear, and had shown a protective value equivalent to the old design suits.

64. Chamber tests were conducted on Marine Corps utility suits equipped with two types of detached hoods, and on Marine Corps protective suits made of Arnzen cloth. The utility suits and detached hoods were impregnated by the aqueous process with Field Sets, M-1, while the protective suits were impregnated by the solvent process with $CaCO_3$ stabilizer at a CWS Z of I plant. Subjects wearing the utility suits tolerated an average of 4 - 5 exposures to H vapor at 1200 CT and no difference was found between the hoods with a small face opening and the hoods with a large face opening made from either Arnzen cloth or herringbone twill. The subjects wearing the plant impregnated protective suits tolerated an average of 8.3 exposures and the superior protective value of the suits over the utility suits is attributed mainly to the method of impregnation.

65. Chamber tests were conducted on suits containing a gas-proof fly developed jointly by this Laboratory and the Naval Clothing Depot. Subjects wearing these suits and control suits without the fly followed prescribed exercises in the chamber designed to test the fly realistically. It was found that a somewhat greater number of exposures to H vapor at 1200 CT was tolerated by men wearing the suits with the gas-proof fly in comparison to the plain suits.

66. All-cotton socks similar in construction and weight to the cotton-wool socks used as a standard item of protective clothing were found satisfactory during repeated exposures in the chamber.

67. Chamber tests on woolen protective gloves made of two-ply wool yarn showed they offered complete protection and were in every way equivalent to gloves made with three-ply yarn.

68. Two different series of chamber tests were carried out on cotton gloves designed to replace woolen protective gloves. Two types of gloves were included in both series; one type with a ribbed knit wristlet and one type with a woven gauntlet. Repeated chamber tests were run with these gloves which showed that they gave almost complete protection. They were not as satisfactory as the standard wool gloves inasmuch as they had a tendency to slip down the arm.

69. Upon the basis of chamber tests illustrating the need for an impregnated protective short to be worn with the Navy protective suit, a ribbed knit short was designed with the help of the Naval Clothing Depot and the Bureau of Supplies and Accounts. Though the protective value of this short was no greater than that of a standard Nainsook short, the former was preferred upon the basis of results of wearing trials.

70. A series of chamber tests was conducted on both CC-2 impregnated and carbon-rayon protective suits to evaluate the various factors contributing to neck burns when a complete outfit of Navy protective clothing is worn in H vapor. It was concluded that the major factor contributing to neck burns for CC-2 suits was leakage of H vapor through the fabric. However, elimination of leakage through the fabric for CC-2 suit hoods would not greatly improve the overall protective efficiency of the CC-2 clothing.

71. There is no leakage of H vapor through the fabric for carbon-rayon Type 148 clothing but both desorption and leakage through the hood and neck closure occur. The present design of Navy protective clothing limits the protective value of carbon-rayon clothing for these reasons.

72. Preliminary tests on Navy protective suits equipped with a zipper closure for the hood indicate that this feature was desirable and should be investigated further.

73. Chamber tests against both H vapor and tear gas have been conducted on special detached hoods designed to operate with a positive internal pressure provided by expired air from a mask. Limited protection against H vapor and CN was exhibited on such hoods made of Oxford cloth. Hoods made of poplin fabric were less effective while a hood made of an impermeable fabric offered complete protection. It was concluded that internal pressure provided by expired air was not sufficient to prevent H or CN vapor from diffusing through a permeable type hood.

[redacted]

RECOMMENDATIONS

74. The modified design Navy protective suit described in this report was recommended in a letter to the Chief of the Bureau of Ships, dated 21 February 1944. This design was adopted by the Navy and has been under procurement for more than 18 months.

75. It is recommended that the utility suits of herringbone twill supplied by the USMC be considered satisfactory for use as protective clothing after field set impregnation. The two types of detached hoods furnished to be run with the utility suits are equally satisfactory and the type adopted should be based on the type of masks with which troops will be equipped.

76. The gas-proof fly developed jointly by this Laboratory and the Naval Clothing Depot was recommended in a letter to the Chief of the Bureau of Ships, dated 7 November 1944. The gas-proof fly was adopted and has been included in all protective suits manufactured recently.

77. A recommendation was made that the all-cotton socks described in this report be considered suitable for impregnation and issue as an item of protective clothing in a letter to the Chief of the Bureau of Ships, dated 21 October 1944. Procurement of all-cotton socks was never effected since the shortage of cotton-wool socks eased up.

78. A recommendation was made that woolen protective gloves made of two-ply yarns be considered satisfactory as an item of protective clothing in a letter to the Chief of the Bureau of Ships, dated 13 April 1944.

79. It is recommended that further work be carried out on the design of an all-cotton protective glove with particular reference to a better method of wrist closure.

80. It is recommended that the cotton ribbed knit protective short described in this report be adopted as a standard item of protective clothing. The specification for these shorts has been prepared by the Bureau of Supplies and Accounts.

81. It is recommended that further work be carried out to improve the design of the hood on Navy protective clothing especially for carbon-rayon fabrics. Preliminary results indicate this work should follow along the lines of the zipper hood closure described in this report.

[redacted]

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The subjects participating in these tests were volunteer personnel from NTC, Bainbridge, Maryland.

[redacted]

Table VII

Physiological Readings - Legend

Symbol	Reaction
E-	Mild Erythema
E°	Moderate Erythema
E	Intense Erythema
E+	Papular Erythema
NPV	Numerous Pin-Point Vesicles
NV	Numerous Vesicles
V	Vesicle
P_1	Mild Pigmentation
P_2	Moderate Pigmentation
P_3	Intense Pigmentation

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

[redacted]

Table VIII

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	ne	neck
al	anterior and lateral	paf	posterior axillary folds
ar	arms	paur	post. auricular
ash	anterior shoulders	par	posterior arms
athi	anterior thighs	pa	palm
ax	axillae	pen	penis
bt	buttocks	ple	posterior legs
C_7	7th cervical	pne	posterior neck
cf	cubital fossae	pop	popliteal spaces
chb	cheekbones	psh	posterior shoulders
cl	clavicles	pthi	posterior thighs
dh	dorsum of hands	sc	scapulae
dth	dorsal thorax	scr	scrotum
el	elbows	uab	upper abdomen
fa	forearms	uar	upper arms
igf	intergluteal folds	ulth	upper lateral thorax
il	iliac crest	umar	upper medial arms
ing	inguinal	umthi	upper medial thighs
kn	knees	ust	upper sternum
lax	lateral axillary	uvth	upper ventral thorax
lar	lateral arms	vth	ventral thorax
lne	lateral neck	wr	wrist

[redacted]

Table IX

Comparison of Standard Design (Old) With Modified Design (New) Protective Suits

(All subjects given one exposure at 1200 CT - no ointment used).

Date Started: 2/15/44

Design	No. Men	Readings (Hours After Last Exposure)		
		24		48
Old	9	5 E 4 E° neck		3 E+ 5 E 1 E° neck
New	10	1 E+ 4 E 5 E° neck	2 E•	1 E+ 5 E 2 E- neck

[redacted]

Table X

Comparison of Standard Design (Old) With Modified Design (New) Protective Suits

(All subjects given one exposure - no ointment used).

Date Started: 3/6/44

Design	Readings (Hours After Last Exposure) 24	48
Old	E- sc	E- dth, sh, sc
Old	E- sc, dth	E- sh, sc, paf, cf, dth
Old	E- pne, lne, sc	E- pne, sh, sc, dth
Old	E° pne	E° vth
	E- sc	E- pne
Old	E° ne	
	E- cf, sc, aaf, dth	E° lne
		E- cf, sh, sc, dth
New	E- lne	E- pne, cf, sc
New	E- ne, ar, sh, dth, cf	No remarks
New	None	No remarks
New	E- sc, dth	E- lne, sc, sh, dth
New	E- lne	E- lne

[redacted]

Table XI

Tests on Modified Design Protective Suits
(Made from fabric impregnated in the piece-goods)

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 ++		

* In this and succeeding tables, an asterisk denotes subject withdrawn from test for reasons other than a "break".

[redacted]

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Table XII

Tests of Standard Design Protective Suits (Standard Aqueous Impregnation 75% CP)

Date Started: 4/25/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure 24	48
8	E sc, dth E° kn, ash, lth, ar, aaf, 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 cf, dth, sc E° ash, lth, bt

Av. 5.9+

[redacted]

Table XIII

Tests of Marine Corps Utility Suits and Type A Hoods (Aqueous Impregnation by Field Set, M-1)

Date Started: 5/10/45

Hood Fabric	No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
HBT	4	E aar, cf, pthi, kn, alc, paf, psh, vth, sc, dth, pop E° lne, ust, C_7, par	E aar, pthi, kne, ple, paf, psh, lth, sc, dth, pop E° vth, par, C_7
HBT	6	E paf, psh, C_7, sc, dth E° ane, lne, pne, ust, ax, lth, kn, el	E lth, pne, psh, C_7, sc, dth E° alne, ust, aar, cf, ax, kn, ple, paf, el, pthi, pop
HBT	6	E paf, psh, sc, dth E° ane, lne, pne, ust, ax, lth, kn, el, pthi, pop, ple	E ust, athi, kn, pne, paf, psh, sc, dth E° alne, ale, C_7, pthi
HBT	6	E ane, lne, pne, ust, paf, psh, C_7, sc, dth E° athi, kn, ale	E ane, lne, pne, ust, le, lar, paf, psh, sc, dth E° aar, cf, pthi, kn, ple, pop, C_7
Arnzen	2	E lax, psh, sc, dth E° ane, lne, pne, ust, par, el, C_7	E lax, ane, lne, pne, ust psh, sc, dth E° kn, par, el, C_7
Arnzen	9	NV umar, psh E° alne, ust, kne, paf	NV umar, psh E ust E° alne, lar, kn, pop
Arnzen	3*	E ane, ust, lth E° lne, pne, vth, psh, C_7, sc, dth	E ane, ust, el, vth E° lne, pne, paf, psh, C_7, sc, dth
Arnzen	2*	Sick E° alne, ust	E pth, dth, lum, lne, cl E° cl, lne, kn

Average HBT = 5.5
Average Arnzen= 4.0+

Grand Average = 4.8+

[redacted]

Table XIV

Tests of Marine Corps Utility Suits and Type B Hoods (Aqueous Impregnation by Field Set, M-1)

Date Started: 5/10/45

Hood Fabric	No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
HBT	5	E ane, cl, lax E° ust, aar, paf, ax, kn, psh, sc, dth	E ust, cl, paf, ax, lth, vth, sc, dth, pop E° cf, kn, ale, psh, C_7
HBT	2	E ane, ust, cf, dth E° lne, pne, kn, paf, psh, par, el, sc	E ane, ust, cl, aar, cf, paf, pne, sc, dth E° lne, pne, ax, lth, vth, kn, par, el, C_7
HBT	4	E ane, lne, pne, ust, paur E° psh, el, C_7, sc, dth	E ane, lne, pne, ust, paur, psh, C_7, sc, dth E° cf, kn, el
HBT	7	E umthi E° ane, lne, pne, ust, psh, C_7, sc, dth, pop	E umthi, pop E° ane, lne, pne, ust, athi, kn, ale, psh, par, el, sc, dth
Arnzen	5	E psh, sc, dth E° ane, lne, pne, ust, cf, ax, lth, vth, athi, kn, ale, paf, pop, ab	E cf, ax, kn, paf, sc, dth E° ane, lne, pne, ust, lth, vth, ab, athi, ale, C_7, pop
Arnzen	3*	no E E° ane, lne, pne, ust	no E E° ane, lne, ust
Arnzen	6	E dth E° ane, lne, pne, kn, psh, sc, pthi, pop, ple	E pne, paur, dth E° ane, pne, pthi, kn, ple, pop, psh, el, sc
Arnzen	6	E kn, sc, dth, pop E° ane, lne, pne, ust, cf, lth, pthi, ple, el, psh	E athi, pthi, kn, ale, pop, sc, dth E° ane, lne, pne, ust, cf, ar, paf, psh, ple

Average HBT = 4.5
Average Arnzen= 5.0+
Grand Average = 4.8+

[redacted]

Table XV

Tests of Marine Corps Arnzen Protective Suits (Solvent Impregnation with $CaCO_3$ Stabilizer)

Date Started: 5/10/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
1*	Sick	-
12	V cf, fa E° ane, lne, pne, ust, psh, aar, kn, paf, el, sc, dth	V fa; NV, dh E ane, ust, cf, paf, psh, el, sc E° ash, ar, aaf, kn, pne, sc, pthi, pop, le
8*	E ane, lne, E° ust, kn, pne	E ane, lne, pne E° ust, cl, pne
6	E paf, psh, sc E° pne, ust, el, dth	E apne, paf, psh, sc, dth E° ust, cl, umar, kn
4*	E ane, lne, ust E° kne, pne, psh, sc, dth	E ane, lne, cl, ust E° ar, cf, kn, pne, psh, el, sc, dth, pop, le
12	NV kn E ane, lne, pne, ust, psh, el, sc, dth	NV kn E° ane, lne, pne, el, psh, sc, dth
7*	E ane, ust E° lne, pne, ash, psh, kn, paf, sc, dth	E ane, lne, ust E° ash, psh, athi, kn, ale, paf, sc, dth, pop
9	NV aar E° ane, pne, ust, scr, kn, psh, el, C_7, sc, dth	NV aar E aar, cf E° ane, pne, ust, kn, psh, sc, dth

Av. 8.3+

[redacted]

Table XVI

Tests on Single Layer Aqueous Impregnated Suits with Gas-proof Fly
(Subjects following prescribed exercises in chamber)
(First exposure 600 CT-subsequent exposures 1200 CT)

Date Started: 10/17/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
6	E lth, ax, ar E° bt, pop, ash, uar, cf, sc, dth	E ash, aaf, uar, sc, dth E° cf
4	E scr E° ust, ne, sc	E scr E° ane, ust, ash, ax, sc
1*	E scr, ab, vth, ash, ne, face Blotched E sc, dth (allergy?)	E chb, vth, pne dth subsiding allergy?
6	E scr, ing E° ash, lth, thi, kn, bt, paf, ple	E nose E° scr, paf
5	E aaf, lax, uar, cf E° sc, paf	E ash, ax, aaf, cf, uar, sc, paf E° ab, bt, el, pop
7**	E° cf, scr, sc	No reading E° or greater

Av. 5.6+

** Denotes test stopped in this and succeeding tables.

[redacted]

Table XVII

Tests on Single Layer Aqueous Impregnated Suits
(Controls for Suits with Gas-Proof Fly)

(Subjects following prescribed exercises in Chamber. First exposure at 600 CT - subsequent exposures at 1200 CT).

Date Started: 10/17/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure)	
	24	48
4	E ing, pen, scr, ash, aaf, kn, cf, sc, dth, bt, el, pthi	E ing, pen, ash, aaf, lth, cf, apthi, kn, sc, dth E° scr, ash, ax, pop
4	E ing, umthi, kn E° chb, upst, ax, lth, cf	E ing, ax, lth, cf, athi, kn E° ash, vth, pne
4	E ing, ax, lth, sc, dth E° ax, uth, dh, wr, scr, bt, el	E ing, ash, vth, ax, lth, cf, kn, sc, dth, paf E° pen, scr, pne, el, bt
4	E ing, ax, lth, sc, dth E° ash, vth, bt	E ing, ash, ax, lth, uar, sc, dth, paf E° ax, lth, scr
3	E sc E° ash, ar, dh, sc, dth, pne, el, bt	E ash, ar, athi, kn, sc, dth, paf, bt E° chb, lth, el, pop
4	E+ scr E ing, umthi E° sc, dth, pop	E ing, upthi E° scr, sc, dth
4	E ash, aaf, sh E° cf, sc, paf	E ing, ash, paf, uar, cf, upthi, sc, dth E° ax, cf, bt, pop

Av. 3.9

[redacted]

Table XVIII

Chamber Tests on Aqueous CC-2 Suits and Carbon-Rayon Type 148 Suits with Various Modified Hoods

Date Started: 12/12/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
	Group (A) Aqueous CC-2 suits, 4 hours wear after last exposure.	
4	E ane, lne, pne, ust, cl, ash, psh, sc E° aar, cf, kn, dth	E+ ane, lne, pne E ust, cl, ash, psh, aar, cf, athi, kn, sc, dth, pop E° ax, par, chb
3	E pne, psh, sc E° alne, ust, cl, rash, aar, psh, dth	E ane, lne, pne, cl, rash, psh, sc, dth, paf E° ash, aar, cf, ax
5	E ane, lne, pne, lth, psh, sc, dth, paf; SK-4 E° ust, ash, aaf, ax, athi, kn, ar	(E+ ane, lne, pne at 72) E ane, lne, pne, ust, psh, aar, cf, ax, lth, paf, athi, pthi, kn, psh, sc, dth, pop E° cl, par
2	E ane, lne, pne, ust, fh E° chb, scr, psh, sc, dth	E+ ane, lne, pne, ust E face, pne E° scr, psh, sc, dth
	Group (B) Carbon-Rayon Type 148 Suits, 24 Hours Wear Daily.	
4*	Sick E° ane, ust	E- ane, lne, pne, face, ust, kn
5	E pne	E pne, ash, dh E° rash, psh
7	E lne, pne E° ane	E+ lne, pne E° ane, ust, lne, fh
7	E lne E° pne	E ane, lne E° lne, pne, face, ust

[redacted]

Table XVIII (Cont'd.)

No. of Exposures Tolerated	Readings (Hours After Last Exposure)	
	24	48
	Group (C) Carbon-Rayon Type 148 suits not worn after each exposure.	
8**	E- ane, lne, pne	E° ane, pop E- lne, pne, psh, sc
8**	E° pne E- lne, ust, C_7	E° fh, pne E- lne, dth, sc
8**	E° lne E- pne, ane	E° fh, lne E- ane, lne, pne
4*	Sick- E-	E-
	Group (D) Aqueous CC-2 suits with cellophane hood liners, no wear after exposure.	
2*	Sick - SK-3	E° ash, thi, kn
6	E ane, lne, cf, lth, paf, ash, psh, athi, kn, sc, par, pop, ple, dth E° face SK-3	E ane, lne, ax, paf, face, lth, athi, pthi, kn, le, pop E° pne, lne
8	E+ pop, psh, sc, dth E ash, aar, cf, lne E° fh, ane, pne, aaf, SK-3	E+ pop E ane, lne, pne, psh, sc, dth, paf, pthi, ple, cf E° pne, face, athi, kn, ale
6	E lne, ax, lth, psh, sc, dth, pop E° ane, pthi	E ane, lne, ax, aar E° pne, athi, pthi, kn, ale, ple

[redacted]

Table XVIII (Cont'd.)

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
	Group (E) Carbon-Rayon Type 148 suits with cellophane hood liner, no wear after exposure.	
5*	Emergency leave	-- 11 days - no remarks.
7	E ane, lne E° lne, pne	E– ane, lne E° lne, pne, face
5	NPV lne SK-4 E+ cl, ust, pne E lum	NV's entire lne. E+ cl, ust, pne E lum
4	E lne E° pne	E lne E° pne
	Group (F) Aqueous CC-2 suits with cloth flange between hood and mask, no wear.	
4	E lne, pne, ash, aaf, psh, paf, lth, sc, dth SK-3 E° ane, ust, aar, cf, athi, kn	E ane, lne, pne, ust, cl. psh, ash, aaf, paf, lth, athi, kn, le, sc, dth, paf, C_7, pop
3	E lne, pne, psh, C_7 E° dth, chb, ane, ust, cl, ash, aaf, paf, ax, sc	E+ lne, pne E ane, ash, psh, ust, cl, aaf, lth, C_7, sc, dth E° ar, cf, ax, athi, kn, pop
6*	Sick SK-4 E psh, sc, dth, ax E° lne, pne, ust, cl, paf, thi, pop	No reading
3	E pne, pop E° alne, ust, ash, psh ar, cf, ax, lth, kn, dth, sc, chb	E pne, psh, ust, cf, ax, paf E° lne, ash, lth, sc, dth, el, par

[redacted]

Table XVIII (Cont'd.)

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
	Group (G) Carbon-Rayon Type 148 suits with cloth flange between hood and mask, no wear.	
8**	E-?	E- C_7
8**	E° lne, pne E- ane, ust, sh, thi	E° pne E- lne
8**	E° sh E- sc	E° kn E- psh, sc
8**	E- sh, sc, dth	E° ane, lne E- pne, lne, kn, psh
	Group (H) Carbon-Rayon Type 148 suit cellophane head liner and cloth flange between hood and mask, 24 hours wear each day.	
8**	E° fh, sc, sh, par	E° ane, fh, face, ust, kn, psh, sc
8**	E- sc	E-?
8**	E° fh E- kn	E° kn, athi E- ane
8**	E- face SK-5	E° kn E- ust

Note: Subjects who had a reading of E or greater on the body before the neck were given a CC-2 impregnated shirt and continued in the test. SK-3, SK-4, etc., indicates the subject was given the shirt on the 3rd, 4th, etc., day of the test.

[redacted]

Table XIX

Screening Tests on CC-2 and Carbon-Rayon Suits with Zipper Closures on the Hoods

Date Started: 6/13/45

Suit Type	No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
CC-2	7*	E° P_1, ane, pne, kn E- P_1, lne, ust, el	E ane E° P_1, ust, lne, pne, kn
Carbon	8**	E- P_1, ane, lne, pne, ust, el	F° P_1, ane, lne, pne, ust
Carbon-Rayon 193	8**	E° P_1, pne, pthi, pop, kn E- P_1, ane, lne, ust	NV E° pthi, pop, P_1, pne E°- P_1, ane, lne, ust

[redacted]

Table XX

Screening Test of Oxford Cloth Hoods Designed
to Cover Outlet Valve of Navy Mask
(Daily Exposures to 300 CT H Vapor)

Date Started: 4/19/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure)	
	24	48
5	E ane, lne, pne, ust, paur E° pop	E ale, pne, lne, ust, paur E° athi, pthi, kn, ale, ple, psh, sc, dth
5	E P_2, pne E° ane, lne, paur, pop	E P_3, pne E− P_2, ane, lne E° P_2, athi, pthi, kn, ale, ple, pop

[redacted]L

Table XXI

Tests of Special Hoods Designed to Provide Positive Pressure Between Mask and Hood

(First 5 exposures for 30 min. at 300 CT, subsequent exposures 15 min. at 300 CT.)

Date Started: 10/15/45

Type Hood	No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
Oxford	5	E lne, pne E° ane, ust, psh, el, sc, dth	(72) E pne E° ane, lne, psh, sc, dth
Impermeable	12**	No 24 hour readings	(72) E– ane, lne, pne, ust P_1 pne
Poplin	2	E pne, raur, paur, C_7 E° laur, paur	E pne, C_7 E° paur
Poplin	3	E pne E° ane, lne, ust, paur	E pne E° ane, lne, ust
Poplin	3	E pne E° paur	E– lne, pne
Poplin	2	E pne, raur, paur, kn E° ust, athi, pthi, ale, ple, psh, sc, pop	E pne E° athi, pthi, kn, ale, ple, paur, pop

[redacted]

Table XXII

Tests of Cotton Gloves Worn in Chamber

Date Started: 3/27/45

No. of Exposures Tolerated	Readings (24 Hours After Last Exposure)
6	E athi, pthi, kn, ale, psh, sc, dth, pop No reaction dh, wr.
8	NV ane, lne E athi, kn, psh, sa, dth No reaction dh, wr.
4	E athi, kn, alc, pne, pop No reaction dh, wr.
3	E psh, sc, dth No reaction dh, wr.
5	E ax No reaction dh, wr.
4	E ax, psh, sc, dth E° reaction dh, wr, 72 hrs. after last exposure.
5*	Sick; E° psh, sc, dth, pthi, pop, ple (All E at 48 hrs.) No reaction dh, wr.

Av. 5.0+

[redacted]

Table XXIII

Test of Special Cotton Gloves Worn in Chamber

Date Started: 9/27/45

No. of Exposures Tolerated	Readings (24 Hours After Last Exposure)
7	E cf; No reading gloves.
5	E- psh; No reading gloves.
9	E- kn, le, pop: No reading gloves.
5	E- thi, le; No reading gloves.
7	E thi, kn, le, pop; No reading gloves.
5	E- ash, psh, athi, kn, ale, paf; No reading gloves.
2	E thi, le, sh, sc, dth; No reading gloves.
2	E psh - No reading gloves.
1	E pthi, pop, ple; No reading gloves.
3	E generalized; No reading gloves.
2	E generalized; No reading gloves.
2	E- kn, ale, ple, pop, pthi; No reading gloves.

[redacted]

Table XXIV

Chamber Tests on Navy Protective Suits Worn with Impregnated Nainsook Shorts

Date Started: 3/21/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
3	E sc, ing E° cf, aaf, ash, dth, thi, pop	E sc, dth, P_2, ash, ar, thi, pop E° ing
5**	E-sh, ar	E° ar, cf, sh, vth, sc
3	E ing E° ar, ash, lth, sc, dth, thi, le V hand	V hand E° ar, sh, sc, dth, bt, pthi, ing
4	E sc, dth	E° pen, scr, cf, ax, vth, ne, sc, dth
3	E sc, dth E° ax	E sc E° sh, ar, dth
2	E lower pne (suit); E° vth, sc	E sc E° vth, sc, dth
3*	V pa E° cf, sc, dth, thi, le	V pa E° cf, sc, dth, thi, pop, scr
2	E sc E° dth	E ash, psh, aaf, cf, sh, sc, dth E° pthi, le
2	E sc, dth E° scr, med, thi, lne	E sc, dth E° sh, lth, pthi

Av. 3.0+

[redacted]

Table XXV

Chamber Tests on Navy Protective Suits with Impregnated Special Knit Shorts

Date Started: 3/21/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
1*	Sick; E-	E-
2	E sc, dth E° scr, vth, sh, ar, lth, chb	E ash, ar, cf, sc, dth E° lth, pthi, ple, thi
3	E ash aaf, ar, sc, dth E° pthi	E sc, lth, dth, ash, ax E° pop, thi
3	E° scr, sc, dth	E° scr, thi, sc, dth, pop, thi
4	E sc E° ash, cf, sc, dth, pop, thi	E° thi, le, dth, sh, sc,dth
3	E sc, dth E° scr, ne, sh, ar	V styloid process; E cf, ar, sh, sc, dth E° lth, pop, thi
1*	Sick - no reading	No reading
2	E sc E° aaf, ash, ar, sc, dth	E lthi E° cf, ar, sc, dth, pop
2	E sc, dth E° sh, ne, cf	E vth, sh, ar, ax, aaf E° sc, dth, pen, pthi, le

Av. 2.7

[redacted]

Distribution

Bu Ships	7
Bu Med	2
ORI	2
CO, Naval Unit, EA	1
CWS, Tech. Div.	4
CWS, Med. Div.	1
CWS, Med. Div. EA	1

[redacted]