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on
The Use of Chemical Materials as Shark Repellents

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ABSTRACT

This is a final report on the development and testing of a material designed for the protection of personnel from attack by insects. Earlier laboratory development is summarized and the results of the field testing are presented in their entirety. The effectiveness of several substances in protecting baits has been demonstrated by field tests under conditions varying from that of the slowest line firing tests to conditions represented by large numbers of insects feeding voracously on the surface. The properties of a repellent material consisting of 80 percent dark water-soluble dye and 20 percent copper arsenate, a mixture proved by field tests, are described. Two types of a unit for the employment of the repellent material designed for individual protection are described.

Reference is made to a motion picture film portraying the development and the testing of the repellent material and the use of the individual unit.

INTRODUCTION

1. **Authorization.** The research on this problem at the Laboratory was authorized by a directive originating with the Chief of the Bureau of Ships to the Director of the Naval Research Laboratory, C-19/P(c)(347) dated 9 April 1943. Further authorization was contained in letters from the Chief of the Bureau of Ships to the Director of the Naval Research Laboratory, 19/P-(4)(336) dated 9 December 1943, and 19/P-(4)(336)(63350) dated 22 March 1944.

2. **Statement of Problem.** Studies on the development and testing of a shark repellent material had been under way for almost a year by other investigators at the time the Laboratory was authorized to begin work on the problem. A substance, copper acetate, had been selected by these investigators, and its effectiveness as a shark repellent evaluated. The main problem at that time appeared to be the development of a suitable container or device that would permit the repellent material to be used efficiently and economically and that could be worn on life jackets or clothing without inconvenience.

3. The problem changed in character as work progressed. Further testing of the repellent qualities of copper acetate was indicated, and when it became evident that under certain conditions the material lost much of its effectiveness the search for other materials as shark repellents was actively pursued. The search for new shark repellent materials was coordinated with an extensive program of field testing and development of a practical unit for survival use.

4. **Previous Work Bearing on the Problem.** A Naval Research Laboratory Report No. P-2230 dated 25 February 1944 and entitled "First Partial Report on the Use of Chemical Materials as Shark Repellents" summarized the work of other investigators on the problem and described the work of the Laboratory on the subject up to that time.

5. Work on the project by previous investigators was initiated by a directive issued June 1942 by the Chief of the Bureau of Aeronautics, in compliance with which a contract was made with Marine Studios, Inc. by the Committee on Medical Research of the Office of Scientific Research and Development. The results of the work by these investigators indicated that certain chemical materials possessed shark repellent properties and that copper acetate in particular showed strong repellent properties both in tank tests at the Woods Hole Oceanographic Institute and in field tests in the Gulf of Guayaquil on the coast of Ecuador.

6. The work of this Laboratory was begun in April 1943 as a cooperative effort with the Committee on Medical Research and was later carried out independently when that group terminated work on the project in August 1943. The work of the Laboratory as described in Report No. P-2230 comprised both laboratory experimentation and field testing.

7. The laboratory experimentation as previously reported may be summarized briefly as the formulation of copper acetate into a convenient cake form, a search for other chemical materials with shark repellent properties, and the combination of the several materials into a practical shark repellent unit. The cylindrical cake form of copper acetate was designed as a convenient practical form of the material to be used for individual protection. The uniform and consistent rate of solution of the material in this form also made possible more accurately controlled field tests.

8. Then it was found that under certain conditions copper acetate was less effective as a repellent than the original tests had indicated, a search was begun for other chemical materials which might be added to it to enhance its effectiveness under varied conditions. The field of dark dyestuffs was investigated, since it appeared that the visual sense of the shark was important in the circumstances where copper acetate suffered its loss of effectiveness. None of the existing dyestuffs fulfilled all of the requirements of high tinctorial strength, solubility in sea water and compatability with copper acetate. Through the cooperation of the Calco Chemical Division of the American Cyanamid Company, a modified nigrosine type dye was developed with all of the requisite properties. It possessed a very high tinctorial strength, was readily soluble in sea water and when combined with copper acetate in sufficient proportions, maintained a pH which enabled the copper salt to dissolve uniformly in sea water.

9. While the shark repellent properties of the dye, Calco VBSA, were being proved by field tests, the Laboratory experimentation was concentrated on the improvement of a unit to be used for individual protection. The flat compressed cake as originally developed for copper acetate possessed the desirable characteristics of a nearly uniform rate of solution throughout most of its life, but some of the binding agents was completely satisfactory in giving the desired strength. When the difficulty of the precipitation of the copper by sea water was eliminated by the inclusion of Calco VBSA in the formula, it was possible to enclose the cake in a porous bag. The porous bag gave protection to the cake of repellent yet it permitted the dissolved material to pass through readily. By forming the cake within the porous bag, air spaces were eliminated and the resulting density of the unit was sufficient to cause it to sink in sea water. A water soluble wax, Carbowax 4000, was used as a binding agent. This wax has a melting point of about 55°C so that the repellent mixture could be pressed while the wax was molten, thereby forming a uniform dense cake when the wax solidified.

10. The porous bag containing the repellent cake was enclosed in a waterproof envelope made of a vinyl-copolymer coated fabric. The envelope was closed by heat sealing and provided with an easy-opening flap permitting quick release of the inner bag when need for the repellent arose. The inner bag was made fast to the outer envelope by a length of cotton tape so that it would hang suspended below the wearer in the water.

11. The field tests that were reported included line tests by which the effectiveness of copper acetate and of dark dyes was evaluated. Also included in the field tests were studies of the diffusion pattern formed by the repellent material as it dissolved in sea water, both from a unit as used in bait tests and also from a unit as would be used by a floating survivor. Studies of the rates of solution of the repellent unit were made as the design was improved in order to insure an adequate rate for protection and maximum life of the unit.

12. <u>Theoretical and Practical Considerations.</u> Although the system of line fishing tests described in the earlier report gives actual numerical data on the effectiveness of a repellent substance in protecting baits, the results of such tests are more an evaluation of the relative merits of the various substances tested than a measure of their usefulness in actual human survival. Field tests of this nature are none the less important. A program of field testing based on bait tests makes possible the comparison of various repellent substances, and by varying the conditions under which the tests are carried out the over-all effectiveness of a substance can be determined. Other advantages of bait tests over

observations of the results in actual survival use are the speed with which the desired data can be obtained, the ability to get sufficient data to be statistically significant, and the practicability of having qualified observers at the scene of the test to properly interpret the results. The objective adopted was to obtain the most effective repellent substance that could be developed within a reasonable period and to produce the most practical unit that could be designed on the basis of existing knowledge. If substantiated reports of actual use of the repellent in human survival indicate some modification of the formulation or the design, such modifications should be carefully considered.

13. The portion of the work on the problem dealing with laboratory experimentation has been largely covered in an earlier report, and only that part not previously reported will be given in detail here. A part of the field testing was presented in the earlier report, but the methods used and the results of all field testing done by this Laboratory are included in this report in order to give to each phase of the tests its proper significance.

METHODS USED.

14. Laboratory Experimentation. This work was made up largely of the development of the repellent materials, studies of solubility and tinctorial strength of the materials, the production of a satisfactory unit for individual protection, and further studies of the unit for rates of diffusion, length of life and general serviceability.

15. The use of copper acetate as a shark repellent material was proposed and first tested by the committee on Medical Research before the Laboratory began work on the problem. The development of the dyestuff, Calco WBSR, was done by Calco Chemical Company in response to a request by the Laboratory for a dark dye with a high tinctorial value, readily soluble in sea water, and compatible with copper acetate. Studies of tinctorial strength were made with a Cenco-Sanford-Sheard Photalometer calibrated against neutral density filters. Transmission data were obtained for solutions in distilled water and sea water with and without copper acetate added. Transmission measurements were also used later to follow the rate of diffusion of the repellent material from the individual units. The sea water was prepared synthetically, from C.P. chemicals according to the following formula:

Magnesium Chloride ($MgCl_2 \cdot 6H_2O$)	11.0 Gm/liter
Calcium Chloride ($CaCl_2 \cdot 2H_2O$)	1.6 " "
Anhydrous Sodium Sulfate (Na_2SO_4)	4.0 " "
Sodium Chloride (NaCl)	25.0 " "

16. The compatability of the dye with copper acetate was studied by means of pH measurements as well as by transmission data. The pH of sea water is sufficiently high to precipitate copper from dilute solutions of copper acetate so that one of the requisites of the dye was that it maintain the pH of sea water solutions of the mixture at a point where the copper would not be precipitated. Measurements were made with a Coleman pH meter at various concentrations of the dye alone and of the dye-copper acetate mixture.

17. Individual units of the repellent materials for use in bait tests were made up by mixing the repellent with suitable binding and solubilizing agents and then forming into a dense cake by pressing in a steel die with a laboratory

model hydraulic press. The design and development of the units for actual survival use was somewhat different and will be treated at a later point in this report.

18. Field Tests. The repellent value of a substance was determined by its ability to protect a suitable bait under a variety of conditions. The use of live animals or freshly killed animals was considered by the original investigators for the Committee on Medical Research but was judged impractical. These investigators used a method of determining the ability of a substance to protect bait fish to evaluate its effectiveness as a shark repellent. This method with some modifications was used for the first part of the Naval Research Laboratory field tests. Two shark lines were used simultaneously, identical except for the presence of a repellent on one line; the other line acted as a control. The baits on the hooks were suspended at the desired depths by means of floats. The lines were fished from the stern of an anchored boat and were kept separated a distance of 25 to 50 feet by means of outriggers and small paravanes.

19. Plate 1, Figures 1 and 2, are underwater photographs showing the relationship of the paravane, float, repellent and bait. Figure 1 is a picture of the line with a repellent unit attached while the line in Figure 2 has a dummy repellent cake of bakelite attached and acts as a control. The repellent was attached at the lead sinker so that its depth did not change. The depth of the bait depended somewhat on the rate of the current, consequently, it did not at all times remain in the repellent as it diffused concurrent from the repellent cake.

20. The edges of the flat cylindrical repellent cake were protected to enable the repellent to dissolve from the unprotected face at a uniform rate. A rate of solution of 30 grams per hour was chosen as a standard for the line fishing tests. This rate would vary with the temperature of the water, rate of current flow and roughness of the surface water, but under average conditions a 100 gram cake would last slightly more than 3 hours.

21. In another type of test, instead of fishing a control and a repellent line simultaneously, two control lines were fished for a definite period, then two repellent lines, and finally two control lines again. In this way the rate at which the shark could be expected to be caught was established by the control periods and the effectiveness of the repellent was determined by comparing that rate with the rate at which they were caught when the repellent was used.

22. The repellent was also tested against large groups of sharks feeding on the surface. This mass feeding condition exists where a large amount of food such as fish or garbage is thrown repeatedly into an area inhabited by sharks. The sharks become accustomed to taking the discarded material and feed voraciously on the surface whenever the food is thrown over. Field tests were conducted in the vicinity of Mayport, Florida, where, during the months of May and June, large numbers of sharks follow the shrimp boats to feed on the trash fish that is taken in the shrimp trawl and discarded. The purpose of the tests was to determine the effectiveness of the repellent material in stopping the sharks from feeding on the trash fish which they ordinarily took so voraciously. The first tests of this nature were conducted from a boat other than a shrimper. A quantity of bait fish was taken aboard and the boat brought alongside a shrimp boat that was discarding trash fish. By throwing over bait from the experimental boat just as the discarding of trash fish from the shrimper was discontinued the

sharks could be induced to follow the experimental boat, and take the bait as it was thrown over. A sea water solution of the repellent material was then sprayed on the surface of the water and bait fish thrown into the treated area. The effectiveness of the repellent was judged by the extent to which it was able to stop the feeding on the surface.

23. This method of testing was only partly successful. It was difficult to keep the sharks in the vicinity of the experimental boat because the sharks had evidently become so highly conditioned that they could readily differentiate between the experimental boat and the shrimp boats from which they ordinarily received their food. For this reason it was difficult to determine whether the repellent material drove the sharks from the vicinity of the experimental boat or whether they left of their own volition. Another difficulty met with in this type of test was that the action took place in such a short space of time that it was difficult to obtain any quantitative numerical data to substantiate the observed results.

24. The first difficulty was overcome by carrying out tests from boats actually engaged in shrimping operations. In this case the presence of the shrimp trawl, the sound of the motors and other factors were exactly those to which the sharks were conditioned and as long as bait fish was thrown over, there was no difficulty in keeping the sharks in the vicinity of the boat. The difficulty of obtaining numerical data was overcome by the use of motion picture photography. By this means the activity of the sharks on the surface at the stern of the shrimper, the manner in which the repellent material was used and the effect of the repellent on the shark activity could be shown. The Photographic Science Laboratory of the Bureau of Aeronautics collaborated with this Laboratory in the production of a 16 mm. Kodachrome film which is not only a photographic record of the field tests but also tells briefly the entire story of the development of a shark repellent for survival use.

25. Plate 2, Figures 1 and 2, are photographs showing the activity of the sharks at the stern of a shrimp boat as trash fish is being thrown over. The lines to the trawl are visible. Plate 3, Figs. 1 and 2, are additional shots of sharks feeding on the surface.

26. The sharks dealt with in the mass feeding tests were mostly of the common black tip variety, Carcharinus Limbatus, a species not generally considered dangerous to man. These sharks were of an average size of five to seven feet. It may be considered pertinent, however, that at the same time that the tests were being conducted in the vicinity of Mayport, Florida, a young girl was bitten, apparently by a shark, while bathing on the beach in 3 to 4 feet of water. Plates 4, Figs. 1 and 2, are photographs of the wound, a typical shark-bite, which were taken at the dispensary of the Mayport Naval Frontier Base where the girl was brought for emergency treatment.

DATA AND RESULTS OBTAINED.

27. Laboratory Data. The tinctorial strength of many dyes was measured photometrically but only those data on the dyestuff, Calco WBSR, and its combination with copper acetate are included here. Transmission vs. concentration curves are given in Plate 5. The curves are for the pure dyestuff, Calco WBSR, in synthetic sea water and for an 80/20 mixture of the dye and copper acetate. The curves were obtained with a Cenco-Stanford-Sheard Photelometer with tungster

light. For further identification of the repellent mixture the transmission characteristic were measured using a Wratten #89 filter. At a concentration of 40 p.p.m. the repellent mixture showed a transmission for white light of 36% while at the wave length given by the Wratten #89 filter the transmission for the same solution was 50%.

28. A spectral transmission curve for the mixture containing 76% dye, 19% copper acetate and 5% Carbowax 4000 was prepared by the Calco Chemical Division of American Cyanamid Company. This curve is reproduced in Plate 6. The concentration used was 40 p.p.m. in distilled water.

29. Hydrogen ion concentration measurements were made by means of a Coleman glass electrode pH meter. The results of measurements on synthetic sea water solutions of the dye, WESR, and of the 80/20 mixture of the dye and copper acetate are given in the following table.

Conc. P.P.M.	pH Soln. of Calco WESR	pH Soln. of 80% WESR - 20% $Cu(Ac)_2$
50	6.2	6.6
100	- -	6.5
250	- -	6.0
500	5.4	5.6
1000	5.3	5.2
5000	5.2	5.0
10000	5.1	5.0
25000	5.0	4.9
50000	4.9	4.8
100000	- -	4.8

30. Results of Line Fishing Tests. Line tests were conducted in the vicinity of St. Augustine, Florida; Biloxi, Mississippi; and the Florida Keys. Series I, II, and III are tests of the repellent value of copper acetate. Series IV and V are tests of the dye, WESR. In all cases, the rate of solution was approximately 20 grams of repellent per hour.

Series I

Tests conducted at:	North River, St. Augustine, Florida, July 1943 between hours of 1930 and 0500.
Rigs:	Two similar rigs used, one of which was protected with repellent cake. Floats used so that baits hung from 5 to 15 feet below the surface and repellent cake was attached 30 to 48 inches from bait.
Bait:	Fresh shrimp.
Repellent:	Copper acetate.
Type of Sharks:	Small hammerhead and shovelnose.

Results: Number of sharks caught on control line - 25
Number of sharks caught on repellent line- 7
Percent effectiveness - - - - - - - - - - 72

Series II*

Tests conducted at: Chandeleur Island, Louisiana, off Biloxi, Mississippi, 30 July 1943 to 8 August 1943 between hours of 0730 and 2000.

Rigs: Two similar rigs used, one with repellent cake. Floats used to suspend baits about 3 feet below surface. Repellent cake attached 30 inches from bait.

Bait: Fresh white trout and ground mullet.

Repellent: Copper acetate.

Type of sharks: Black tip and one sharp nose, other types including hammerhead, lemon shark and tiger shark, known to be in vicinity.

Condition of sharks: The sharks were stirred up and brought to the surface by dragging a shrimp trawl and by chumming. The tests have been divided into two parts arbitrarily on the basis of rate of fishing. During the period of great shark activity the sharks often struck the bait a few seconds after it struck the water and it is possible that some of the sharks attacked the bait without encountering any of the repellent.

Results:

	Control**	Repellent	Percent Effectiveness
Period of great shark activity	67	37	45
Period of lesser activity	46	11	76
Combined periods	113	48	58

Series III

Tests conducted at: Florida Keys off Bahia Honda Channel, 12 October and 11 December 1943 during hours of 1000 and 2000.

Rigs: Two similar rigs used, one with repellent cake attached 36 inches from bait. Floats used to keep baits about 12 feet below surface.

**Numbers include both catches and strikes.

*The test represented by Series II was conducted by the Committee on Medical Research with the cooperation of a representative of the Naval Research Laboratory.

Bait: Fresh mullet.

Repellent: Copper acetate.

Type of Sharks: Black tip, sharp nose and black nose. One large nurse shark caught on non-experimental rig.

Condition of Sharks: Efforts made to attract sharks to vicinity by occasional chumming with chopped mullet and bottom fishing for other fish. Exploratory catches made to show presence of sharks in vicinity.

Results:

	Catches	Strikes	Totals
Exploratory catches	8	0	8
Control line	12	4	16
Repellent line	1	0	1
Percent effectiveness	92	-	94

Series IV

Tests conducted at: Florida Keys within a radius of 25 miles of Marathon, Florida during all hours including hours with bright moon and no moonlight conditions.

Rigs: Two similar rigs used, one with repellent cake and the other with dummy bakelite cake. Repellent cake attached 36 inches from bait. Floats used to keep baits 3 to 15 feet below surface.

Bait: Fresh mullet.

Repellent: Dyestuff Calcomon.

Type of Sharks: Black tip, shovelnose, black nose and sharp nose.

Condition of Sharks: Occasional chumming with chopped mullet. Simultaneous fishing for bottom fish. Exploratory catches made to show presence of sharks in vicinity.

Results:

	Catches	Strikes	Combined
Exploratory catches	114	4	118
Control line	50	23	73
Repellent line	2	0	2
Percent effectiveness	96	-	97

Series V

Tests Conducted at: Florida Keys near Marathon, Florida 12 January 1944.

Rigs: Two similar rigs without repellent during first period, two with repellents during second period and two without repellent again during 3rd period. Baits 5 feet below surface.

Bait: Fresh mullet.

Repellent: Dyestuff Calco WBSR.

Type of Sharks: Black tip, black nose and sharp nose.

Condition of Sharks: Chumming with chopped mullet at a relatively constant rate throughout test.

Results:

1st Fishing period - 100 minutes, no repellent

Sharks caught - - - - - - - - - -	12
Strikes - - - - - - - - - - - - -	9
Greatest interval between actions - - - - - - - - - - - - -	13 minutes

2nd fishing period - 100 minutes, repellent used.

Sharks caught - - - - - - - - - -	0
Strikes - - - - - - - - - - - - -	0
Greatest interval between actions - - - - - - - - - - - - -	100 minutes.

3rd fishing period - 58 minutes, no repellent.

Sharks caught - - - - - - - - - -	4
Strikes - - - - - - - - - - - - -	2
Greatest interval between actions - - - - - - - - - - - - -	21 minutes.

31. Results of Mass Feeding Tests. The first tests of a repellent material against large numbers of sharks on the surface were conducted by the investigators for the Committee on Medical Research in the vicinity of St. Augustine during May 1943. In these tests it was demonstrated that copper acetate lost most of its effectiveness as a repellent under the conditions of mass feeding. Tests with dark water-soluble dye were conducted near Mayport, Florida in June, 1943, near Biloxi, Mississippi in August 1943 and again at Mayport and Fernandina, Florida in September 1943. In none of these instances, however, was the activity of the sharks sufficiently great to make the results of the tests conclusive. They did indicate in a qualitative way that the dark dyes possessed repellent qualities against the mob action displayed by surface feeding sharks.

32. A more extensive series of tests was planned in order to evaluate the effectiveness of the Calco WBSR, copper acetate mixture under mass feeding conditions after the repellent qualities of the dye had been established by line tests. These mass feeding tests were carried out in the vicinity of Mayport, Florida between 27 May and 3 June 1944.

Series I

This series of tests was conducted from an experimental fishing boat that had been engaged in work for the United States Bureau of Fisheries. The boat was equipped for menhaden fishing and had a crow's nest 40 feet above the waterline from which the cameraman was able to work.

The difficulties met with in attempting to get successful tests from the experimental fisheries boat have already been mentioned. Sharks were induced to feed on bait fish thrown on the surface from the experimental boat, and a sea water solution of repellent was sprayed among them. A definite lessening of activity of the sharks could be noted when the repellent was used, but in control runs when no repellent was used there was also a gradual lessening of activity, making an exact evaluation of the effectiveness of the repellent difficult. When it became obvious that it would be impossible to maintain any semblance of uniform activity of sharks in the vicinity of the experimental fisheries boat, operations were transferred to a shrimp boat actually engaged in trawling for shrimp.

Series II

These tests were conducted from a shrimp boat where there was little difficulty in obtaining the desired shark activity on the surface and as long as trash fish was thrown overboard there appeared to be no lessening of activity of the sharks. When a shovelful of trash fish was thrown over, the sharks would strike it almost immediately within a few feet of the boat and churn the water as large numbers of the sharks competed for the food. (See Plate 2). The shrimp trawl was being dragged during these operations with the boat making two to three miles per hour. For this reason the shrimp boat would gradually pull away from the activity centered about any one shovelful of fish that had been thrown over, but the sharks were sufficiently plentiful that each succeeding shovelful would also be taken almost immediately. The trash fish was thrown over by shovelsful near the stern with the boat slowly under way. Then a 5% sea water solution of the WBSR-copper acetate mixture was sprayed overboard near the bow forming a ribbon-like pattern 10 to 12 feet wide as the boat moved through the water. The trash fish was discarded at a uniform rate, and was thrown into the repellent treated area when that area reached the stern. In this test all immediate activity was stopped by the repellent in the treated area with the trash fish floating untouched on the surface until the repellent became so diluted that it no longer offered protection. When the spraying of the repellent was discontinued the sharks could again be gradually brought back to feed at the stern of the boat. The action during this test was recorded on 16 mm. Kodachrome motion picture film.

Series III

This was another type of mass feeding test conducted from the shrimp boat. The surface shark activity was obtained in the same manner as in Series II, but the dry repellent mixture was used instead of a sea water solution. The dry repellent mixture comprising 80% Calco WBSR and 20% copper acetate was mixed with a quantity of trash fish from the shrimp trawl. The approximate proportion of the repellent mixture used was 5% by weight. Successive shovelsful of clean trash fish were thrown over and taken almost immediately by the sharks. With no time interval interposed several portions of the repellent-treated fish were thrown over. Activity was observed in the vicinity of the repellent-treated fish almost immediately but it was primarily a churning of the water and it was not possible to observe whether any of the fish was actually taken. The action started at almost the instant the treated trash fish hit the water before the repellent had time to dissolve appreciably. The activity stopped as the repellent diffused throughout the area. In the second and third tests of this series the only activity that was observed in the vicinity of the treated trash fish were sharks moving away after they had evidently been attracted by the splash in the water, and then driven away by contact with the repellent. A motion picture

record was also made of a typical test of this series.

DISCUSSION OF RESULTS

33. Results of Field Tests. In any discussion of the means by which a chemical substance acts to prevent bait or food being attacked by sharks it is necessary to consider the sensory stimuli involved in shark feeding. It is difficult to make any factual statement regarding the relative importance of the visual stimulus and the olfactory stimulus, or any other stimulus that may be involved in the feeding habits. Also the part played by each is probably not constant but changes with conditions and degree of excitation of the sharks.

34. The field tests cover a wide range of levels of excitement or activity of the sharks. They vary from the slowest line fishing tests where only one or two sharks would be caught in an hour to the tests where dozens of sharks could be observed fighting for food on the surface at one time. In the case of slow fishing tests, regardless of what senses are used by the sharks in locating their food some stimulus other than the visual must have been sufficiently strong to make them take cognizance of the copper acetate used as a repellent.

35. It was not expected that the dark dye, Calco TBSR would produce any more than a visual stimulus in the dilutions met with under field conditions, but the success of line fishing tests made on moonless nights indicated that even under these conditions, the visual stimulus remained sufficiently strong to be effective, or that some other response was being produced by the dye.

36. A substance that depends for its repellent ability on its effect on one sense alone, must necessarily suffer a decrease in effectiveness when the importance of that sense is shifted into the background by some environmental change. A substance or combination of substances whose effectiveness depends on the stimulation of several senses would be certainly less likely to suffer a large decrease in efficiency as the relative importance of the various senses is changed by external conditions during the search for food. It was for this reason that a combination of the dyestuff, Calco TBSR, and copper acetate was prepared and used for the final field tests. It was possible to include 20% of copper acetate in the final formula without sacrificing any of the desirable solubility characteristics of the repellent.

37. The results of the final field tests with the dye-copper acetate mixture were very encouraging. The repellent was effective in protecting trash fish on which the sharks were accustomed to feed so voraciously. These tests differed from the line tests in that the repellent was not constantly being replenished from a cake of the solid material but the repellent was only supplied once to an area. It was to be expected, then, that as the repellent diffused over a large area in the water its concentration would decrease and finally reach a point where it would lose its effectiveness. In the tests where the repellent was sprayed on the surface it was estimated that the original concentration was no more than 0.1 gm per square foot of surface or about 3 parts per million if it were considered to be distributed over a depth of one foot.

38. The reaction of the sharks to the repellent at the very beginning of the mass feeding tests of Series III where the repellent was used in the dry form mixed with the bait fish was not unexpected. The highly conditioned sharks following the shrimp boat on sensing a shovelful of trash fish hitting the water would immediately plunge into it and churn the water as they competed for the fish. When the trash fish mixed with dry repellent was thrown over in the same way immediately afterward it was not surprising that the sharks would plunge into the mass before the repellent had an opportunity to diffuse to any apprecia-

ble extent. When the sharks detected the repellent, however, they hastily moved away from it. With each succeeding addition of treated trash fish the sharks rapidly became more wary and in a short time would avoid the trash fish that was mixed with the repellent. This cumulative effect was noted to carry over to tests that were repeated in the same area several hours later in which case the treated fish was entirely undisturbed.

39. Package Design. The majority of the individuals having need for a shark repellent substance are survivors of air or marine disasters who find themselves in shark infested waters as a result of accident rather than by intent. A unit of shark repellent material may be carried for a long period of time before it is ever needed. For this reason the unit has to be compact and durable yet the repellent should be easily accessible and effective whenever it is needed.

40. The unit developed for general use consists of a flat cake of the repellent material in a bag of cotton sheeting which is protected by a water-proof outer envelope made from a vinyl-copolymer-coated fabric. Plate 7 is an outside view of the assembled unit. Plate 8 shows the front flap pulled down releasing the inner bag of active material. The unit is similar to one described in the earlier report, the main points of difference being the use of cotton sheeting instead of paper as the porous material for the inner bag and the addition of a lanyard at the bottom of the unit to help secure it to the life vests or belts. The use of cotton sheeting for the fabrication of the inner bag was adopted because it permitted higher pressures to be used in the formation of the repellent cake within the bag, and it also proved to be more serviceable in simulated use tests. The inner pocket is to give protection to the bag of repellent material when the user wishes to save it for future use after the front flap has been originally opened.

41. Specifications for the unit are given in Bureau of Ships ad interim Specification R 51S48(INT), Shark-Chasers (Life Jacket) dated 15 June 1944. This specification is classified as Restricted. The Army Air Forces Specification, Packet; Shark Deterrent, No. 40828 dated 25 July 1944 is for a similar type of unit.

42. A multipocket unit was designed for use by individuals who find it necessary to be in shark infested water by intent rather than by accident. This unit is a belt type to be worn around the waist since the user would not ordinarily be wearing a life vest or belt. Instead of having a reclosure feature this unit has four individual inner bags of repellent material, each of which is sealed in a separate compartment of the water-proof outer envelope. The compartments can be opened independently, thereby releasing the individual inner bags as needed. The details of the design and heat sealing of the outer envelope are given in Plate 9. Plate 10 shows how the inner bags containing the repellent are assembled in the outer envelope and also the method of opening.

43. The inner bags are made of cotton nainsook of weight 8.5 yards 40" material per pound. Each bag contains 45 grams of the repellent mixture, pressed without heating into a cake within the bag to prevent sifting through the light weight cotton during the assembly as a final unit. The inner bags are attached to the outer envelope by means of a short strip of vinyl copolymer coated fabric. The strip is heat sealed to the back of the outer envelope and can be readily pulled off when the repellent is exhausted or no longer needed.

44. The front of the water proof envelope is provided with pull tabs and

cut in such a manner that a single compartment can be opened without destroying the water-proofness of the other compartments. A web belt with a corrosion resistant buckle serves to fasten the unit around the waist.

CONCLUSIONS AND RECOMMENDATIONS

45. Evidence ~~has been~~ is presented to show that a mixture of 80% dark dyestuff, Calco TBSR, and 20% copper acetate exhibited strong shark repellent properties in tests where it is used to protect potential food of the sharks.

46. No conditions were found under which the Calco TBSR-copper acetate mixture lost its effectiveness or suffered any serious reduction in effectiveness.

47. It is believed that the field tests by which the effectiveness of the repellent was evaluated simulate actual survival conditions sufficiently close to make the results valid, at least in a qualitative sense, in consideration of human survival.

48. Two types of a shark repellent unit for individual protection have been developed and tested for general serviceability and practicability. The decision as to who needs a shark repellent unit is dependent on the liklihood of exposure of the individual to shark attack and how critical are considerations of weight and space.

49. Substantiated reports of actual survival use should be given careful consideration if any change in composition or design is contemplated. It is believed that the shark repellent units as developed and described here are as effective as can be developed on the basis of existing knowledge.

50. A 16 mm. Kodachrome motion picture film with sound narration showing the development, testing and use of the shark repellent has been prepared by the Photographic Science Laboratory of the Bureau of Aeronautics for this Laboratory and is available through the Bureau of Ships for viewing by interested parties.

The assistance of other members of the Laboratory staff not mentioned in the body of this report is respectfully acknowledged. Stewart Springer formerly of this Laboratory and at present associated with the Reed-Martin Laboratories, Fort Myers, Florida, and Lieut.(jg) C.R. Wallace USNR, were actively connected with the field testing program. Mr. F. E. Brinnick, associate chemist, was instrumental in carrying out much of the laboratory development of the repellent unit.

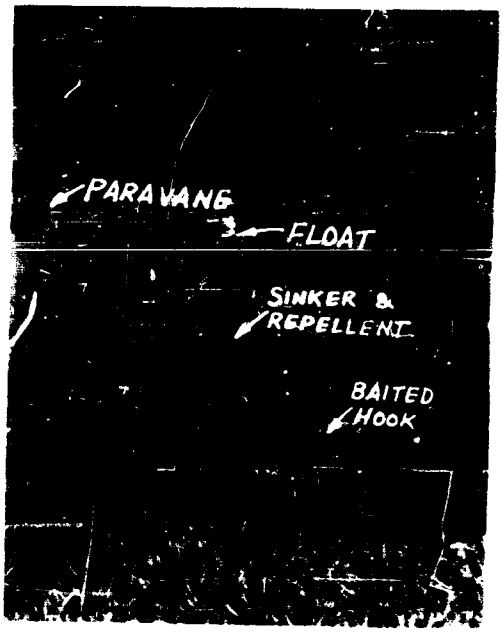

FIG. 1

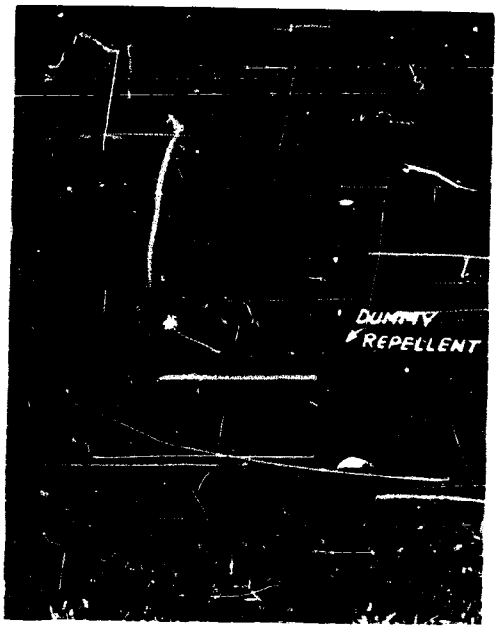

FIG. 2

PLATE I

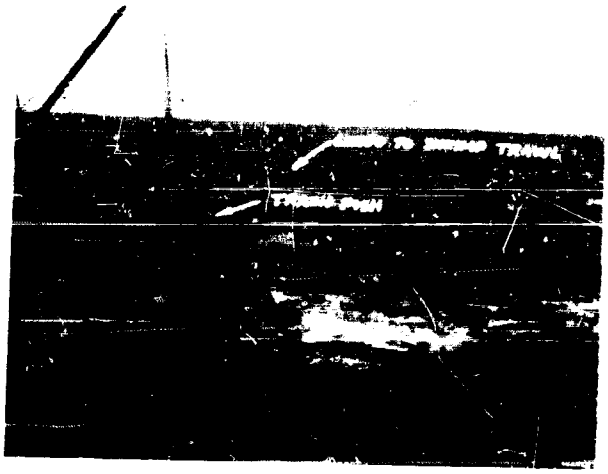

FIG. 1

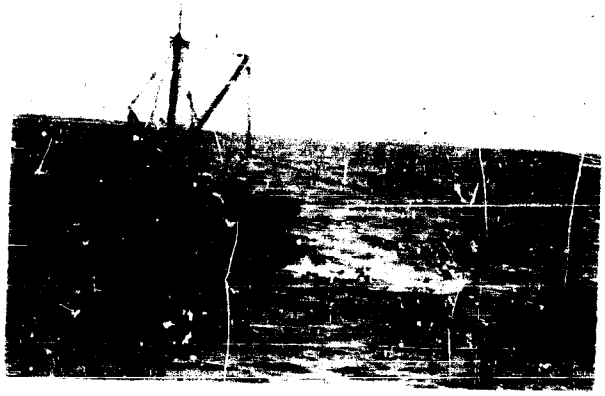

FIG. 2

FIG. 1

FIG. 2

FIG. 1

FIG. 2

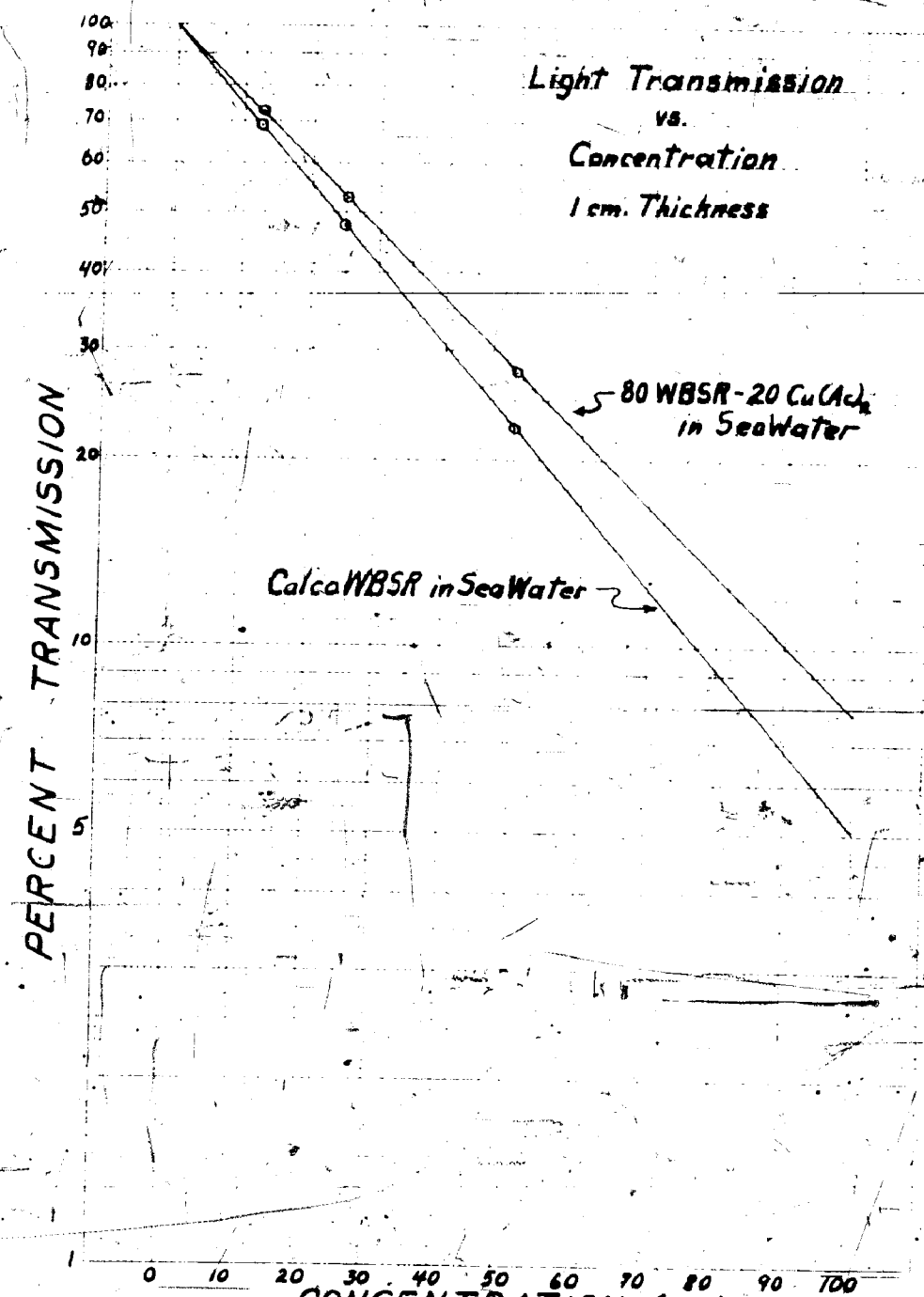
Light Transmission
vs.
Concentration
1 cm. Thickness
80 WBSR - 20 Cu(Ac)2
in SeaWater
CalcoWBSR in SeaWater
PERCENT TRANSMISSION
100
90
80
70
60
50
40
30
20
10
5
1
0
10
20
30
40
50
60
70
80
90
100
CONCENTRATION (ppm)

PLATE 5

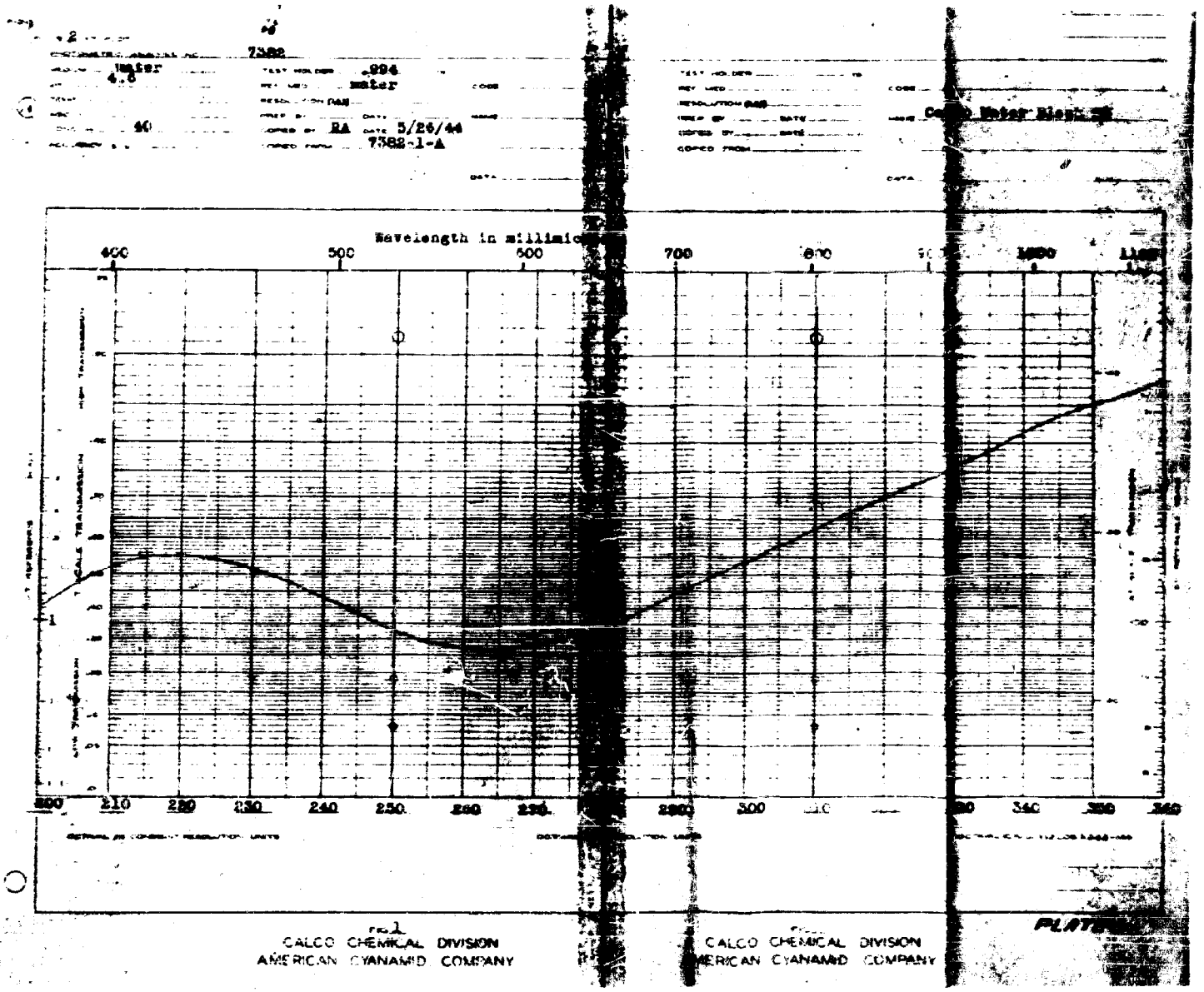

FIG. 1
CALCO CHEMICAL DIVISION
AMERICAN CYANAMID COMPANY

CALCO CHEMICAL DIVISION
AMERICAN CYANAMID COMPANY

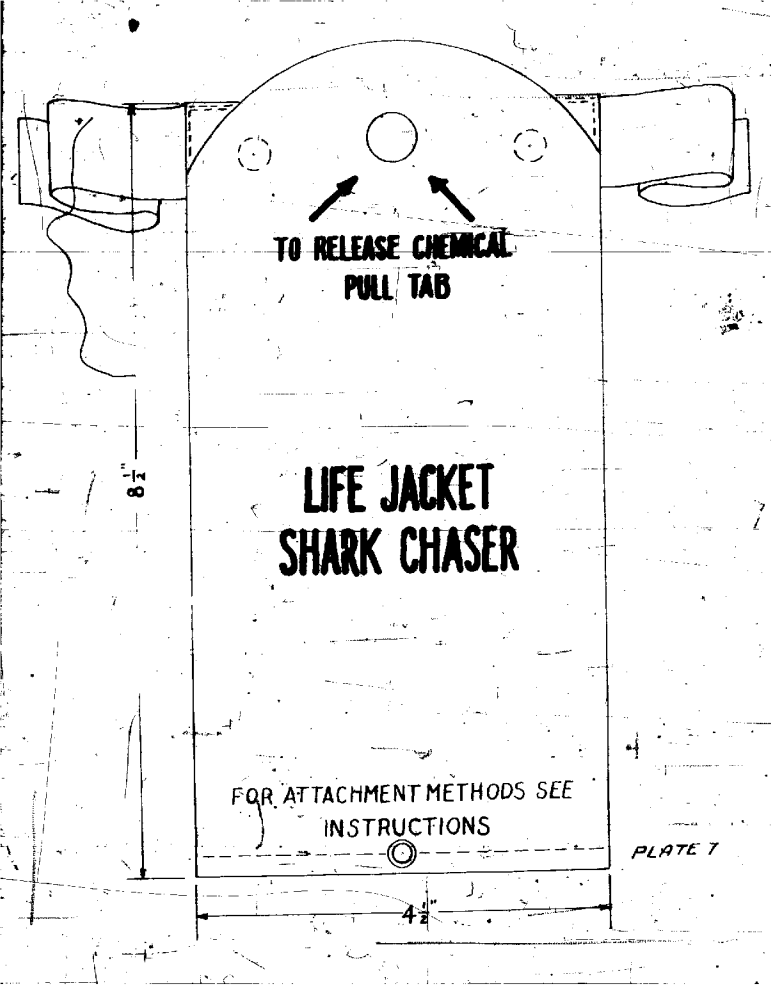

PLATE 7

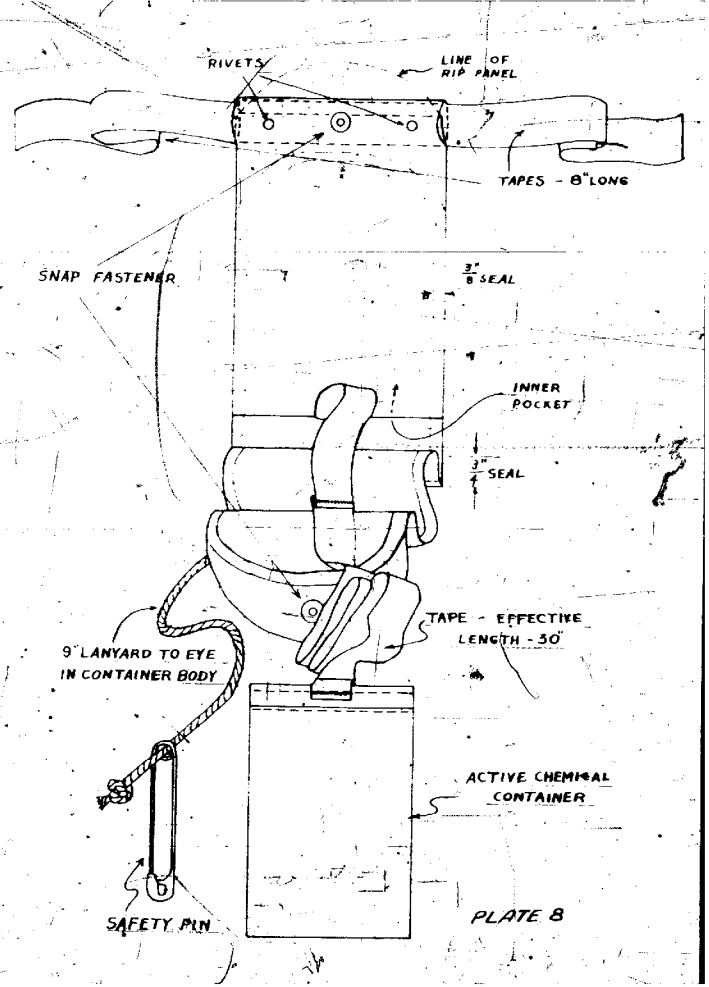

PLATE 8

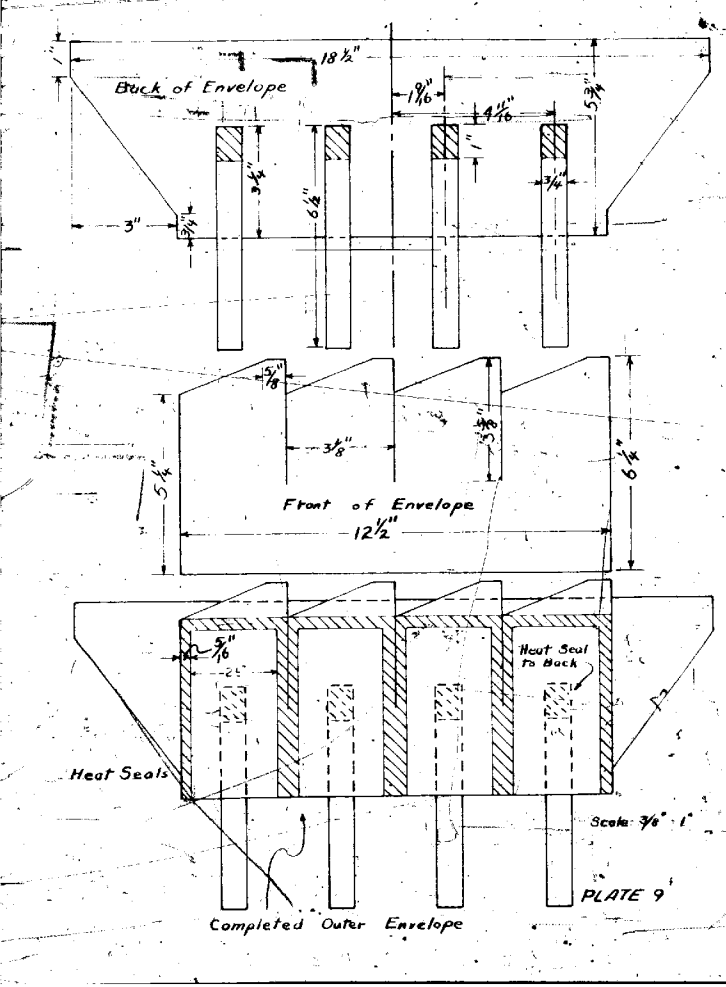

PLATE 9

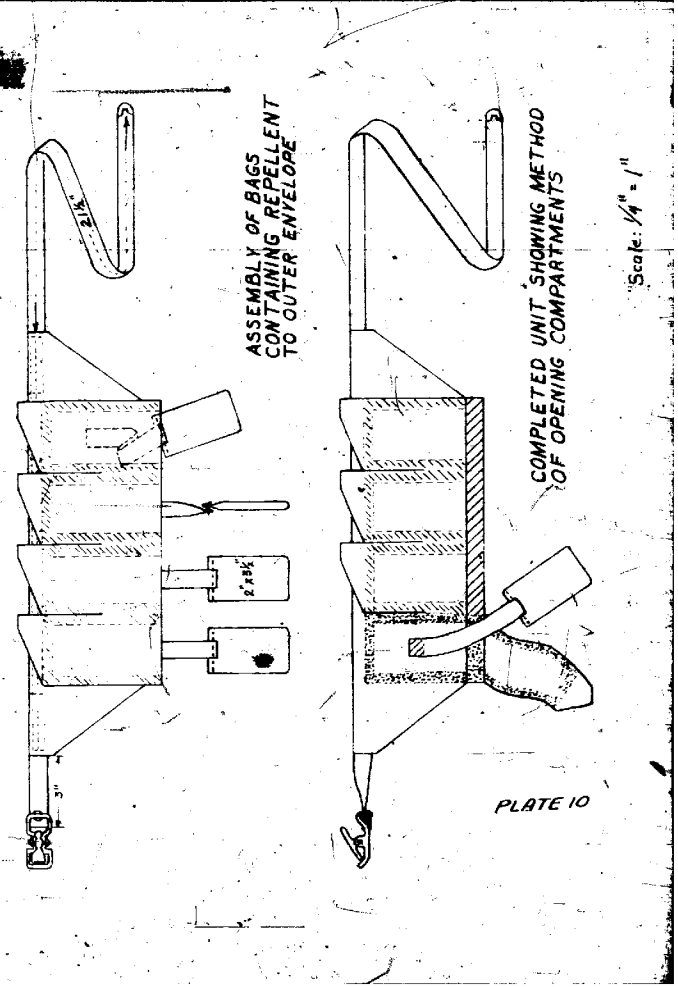

PLATE 10

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