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A Study of Perclene (Tetrachloroethylene)

as a Solvent for Use in the
Decontamination of Airplanes.

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NAVY DEPARTMENT

Report on

A Study of Perclene (Tetrachloroethylene)
as a Solvent for Use in the Decontamination of
Airplanes

NAVAL RESEARCH LABORATORY
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ABSTRACT

This is a progress report on the study of the decontamination of persistent chemical warfare agents. A number of solvents were studied to determine their suitability as solvents to be used with RH-195 in the decontamination of naval airplanes and Navy deck paint. Tetrachloroethylene (Perclene) was found to be the best of these solvents for use in the decontamination of airplanes. Perclene/RH-195 is better than TCE/RH-195 for this purpose for reasons which are outlined in this report.

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AUTHORIZATION

1. This work was authorized under Project No. 547-41, "Maintenance, Bureau of Ships," dated 16 November 1940. Problems proposed for study were given in Bureau of Ships letter S-S77-2 (Dz), Serial 811 of 17 December 1940.

STATEMENT OF THE PROBLEM

2. This study was undertaken to find a solvent which is superior to tetrachloroethane (TCE) for use in decontamination systems against HS and other agents.

KNOWN FACTS BEARING ON THE PROBLEM

3. In NRL Report No. P-1944, entitled "The Use of RH-195 for the Decontamination of HS and M-1," it was pointed out that:

(a) A 10% solution of RH-195 in TCE (tetrachloroethane) is a very efficient decontaminant for HS and M-1 in painted metal surfaces.

(b) TCE is quite toxic when compared to other common solvents.

(c) TCE is nonflammable which is a requisite for a solvent which is to be used on shipboard.

(d) TCE quickly softens the plastics, Lucite, Plexiglas and cellulose acetate, which are used for transparent closures on airplanes.

(e) TCE/RH-195 is moderately corrosive to metals, but not nearly as corrosive as HTH slurry.

(f) TCE is harmful to most paints, frequently causing a separation of the paint film from the metal within a short time.

(g) TCE is readily available at low cost.

(h) o-Dichlorobenzene was shown to be useful as a substitute for TCE as a solvent. It is less toxic than TCE but has most of the other disadvantages of TCE; e.g., removing paint and softening clear plastic.

THEORETICAL CONSIDERATIONS

4. Studies up to the present time have shown no agent which is superior to chloroamides for the decontamination of vesicant agents in painted metal surfaces. In order to quickly

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decontaminate paint films it is essential that the chloroamide be contained in a solvent which will penetrate the paint. A solvent is required which will not react with the chloroamide. The solubility of the chloroamide in the solvent may also be significant.

5. There are a number of other factors of importance in the choice of a solvent for the chloroamide:

(a) The chloroamide solution must be effective for decontaminating painted metal surfaces.

(b) It is desirable that the solvent and the decontaminating solution be nonflammable. For shipboard use this is imperative.

(c) The solvent vapors should not be toxic.

(d) The solvent should not injure the surface to which it is applied, such as paint, metal, clear plastics, doped airplane fabrics and rubber tires.

(e) The solvent must be easily available at a reasonable cost.

(f) The physical characteristics of the solvent must be satisfactory. It should not freeze at temperatures likely to be encountered in use or in storage. The vapor pressure of the solvent should be sufficiently low to avoid special storage problems and should not evaporate too rapidly to be effective.

6. In paragraph 3 it was stated that a solution of RH-195 is an effective decontaminant. Several disadvantages in the use of TCE were also given. Since TCE/RH-195 is the present decontaminating system for use on naval vessels, any solvent recommended for decontamination must be sufficiently superior to TCE to warrant such a change,

EXPERIMENTAL. PART I. DECONTAMINATION OF AIRPLANE LACQUER PANELS BY SPRAYING WITH SOLUTIONS AND SLURRIES OF RH-195

7. Painted steel panels were prepared by using two spray coats of Army-Navy Specification Primer ANTTP656 (formerly Naval Aero. Spec. P27) followed by two spray coats of Naval Aero. Spec. M485A blue grey lacquer. Unless otherwise stated, the panels used for decontamination experiments were two inches square. Two drops of vesicant (approximately 0.05 g.) was spread over each panel to simulate gross contamination and left for one hour before decontamination was begun.

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The panels were then suspended vertically and sprayed with the decontaminating solution. In most cases they were sprayed thoroughly two times at 10-minute intervals. After one hour the panels were washed off with water and dried at room temperature. The panels were tested for completeness of decontamination in a constant temperature box at 35°C. Congo Red-S-328 paper in conjunction with a sodium carbonate filter paper was used for the HS tests. The time in minutes for the first appearance of a positive test was recorded as the test time. All tests which were still negative after four hours were discontinued. Physiological data obtained subsequent to this data indicate that a painted surface giving a paper test time of more than 45 minutes at 35°C may be considered safe.

8. A number of solvents studied for use with RH-195 for the decontamination of vesicants were discussed in NRL Report No. P-1944, entitled "The Use of RH-195 for Decontamination of HS and M-1." Some other solvents studied since the above report was written are included in Table I. Most of the solvents in Table I have high flash points or are nonflammable.

9. The decontamination tests in Table I were carried out by spraying the panels with a 5% solution or suspension of RH-195 in the solvents listed. In each case the data given is representative of at least two trials. If decontamination was not complete the first day, the panels were tested the second and third day if necessary.

10. Perclene did not soften the airplane lacquer. It was the best of all the solvents tested in this respect. Dichloroethyl ether softened the paint so that it was removed by brushing. Dichloroisopropyl ether did not harm the paint as much. However dichloroethyl ether is irritating to the eyes, nose and lungs. According to Jacobs, "Analytical Chemistry of Industrial Poisons, Hazards and Solvents" this ether is very toxic. It is probable that dichloroisopropyl ether is of the same order of toxicity as dichloroethyl ether.

11. Both monobutylamine and diethylamine removed all the paint so that no test for completeness of decontamination was made. Diethylhexylamine/RH-195 decontaminated the airplane paint with no apparent change. However some heat was evolved on mixing the RH-195 and diethylhexylamine. Tricresyl phosphate/RH-195, tri-o-chlorophenyl phosphate/RH-195 and trichloroethyl phosphate/RH-195 did not decontaminate the paint. Since these solvents are quite viscous the

mixtures with RH-195 were applied by pouring them over the panels. Even after one hour the panels treated with these phosphate solvents were quite sticky. Triethyl phosphate softens and tends to remove the paint. RH-195 in the chlorinated kerosenes did not satisfactorily decontaminate the airplane lacquer panels. After the chlorinated kerosenes themselves had stood for a month or two a sharp odor developed which was probably due to the formation of HCl.

Table I

Solvents for Use in Decontamination

Two-inch square steel panels painted with M485 airplane lacquer were treated with HS. Each was decontaminated by spraying twice thoroughly with 5% RH-195 dissolved or suspended in the solvents listed below.

<u>Solvent</u>	<u>Test Time, Minutes</u>		
	<u>1st day</u>	<u>24 hrs.</u>	<u>48 hrs.</u>
Perclene	>240		
Dichloroethyl ether	>240		
Dichloroisopropyl ether	>240		
Monobutylamine	No test, paint removed		
Diethylamine	"	"	"
Diethylhexylamine	>240		
*Tricresyl phosphate	2	35	>240
Tricresyl phosphate (10%) in Perclene	>240		
*Tri(o-chlorophenyl) phosphate	2	45	>240
*Trichloroethyl phosphate	1	>240	
Triethyl phosphate	>240		
Chlorinated kerosene (10.5% Cl)	1	12	>240
" " (21.1% ")	1	21	>240
" " (39.6% ")	2	>240	
" " (39.6% ") 10%			
in Perclene	>240		
Carbitol acetate	>240		
Butyl carbitol acetate	>240		
Ethylene glycol diacetate	>240		
Dichloroethyl formal	>240		
Cellosolve	>240		
Diethyl carbitol	>240		
Dimethoxy tetraglycol	>240		

*Too viscous to spray, applied three times by pouring over the panel.

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12. The rest of the solvents in Table I were obtained from Carbide and Carbon Chemicals Corporation. The flash point of each is high and the ester and ether linkages might be expected to be stable with chloroamides. However, all of these solvents softened and tended to remove M485 airplane lacquer. Dichloroethyl formal was perhaps the least harmful to the paint of these solvents.

13. The tests showed that Perclene/RH-195 will decontaminate M485 lacquer without softening the paint. Many of the other solvents when mixed with RH-195 decontaminated the paint but are unsatisfactory because they damage the paint, are quite irritating or toxic or are not sufficiently stable when mixed with RH-195.

EXPERIMENTAL PART II. PERCLENE/RH-195 AS A DECONTAMINANT FOR NAVAL AIRPLANES.

14. In Experimental Part I it was found that Perclene/RH-195 decontaminated steel panels painted with M485 grey airplane lacquer without softening the paint. This made it desirable to determine whether this mixture had other advantages over TCE/RH-195 for decontaminating airplanes.

A. Perclene/RH-195 as a Decontaminant for Airplane Lacquer.

15. Besides M485 blue-grey lacquer, Perclene/RH-195 was found to decontaminate M485 dark blue and DuPont 71 Line-British Camouflage Yellow painted panels.

(1) Decontamination under various conditions.

16. The Perclene/RH-195 mixture decontaminated M485 paint at room temperature in the laboratory. The following tests were made to determine the effectiveness of this decontaminant under conditions likely to be encountered in the field:

(a) Six panels were treated with HS and allowed to stand outdoors for one hour before decontamination was begun. The temperature was 3°C (37°F), the sky was clear with a slight wind. Five out of six panels were decontaminated under these conditions. The sixth panel was found to be decontaminated when tested the next day.

(b) Two M485 panels were treated with HS and allowed to stand outdoors for one hour. The temperature was 5°C (41°F) with a rather strong wind. Both panels were completely decontaminated by spraying with Perclene/RH-195 in the usual manner.

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(c) Two M485 panels were completely decontaminated outdoors at 25°C (77°F). The sky was clear and there was a slight breeze.

(d) Two M485 panels were completely decontaminated outdoors with temperature at 30°C (86°F) in the shade. The panels were left in the sun. A moderate breeze.

(e) M485 blue-grey painted panels and DuPont 71 Line painted panels which had been exposed to accelerated weathering in a weatherometer for 102 hours were completely decontaminated in the laboratory and outdoors under summer conditions.

(2) Perclene with other chloroamides.

17. The following chloroamides in Perclene were tested to see if they would decontaminate airplane lacquer panels: RH-851, RH-852, RH-855, S-461 and S-330. 5% slurries or solutions were used. In all cases HS on M485 test panels was decontaminated in the laboratory.

(3) Perclene/RH-195 against other vesicant agents.

18. The tests were conducted in a manner similar to that used for HS on M485 airplane lacquer panels. To test for completeness of decontamination of M-1, DT (dithizone) paper was used. It gives a pink or red color if M-1 is present. For 1130 the DB3 paper with a sodium carbonate filter was used. Blue spots appeared on the white paper if 1130 was present. All tests for decontamination were made at 35°C.

19. 1130 and M-1 in M485 paint were each completely decontaminated by Perclene/RH-195. A spray of Perclene alone gave good results also, which was not true for HS.

20. HS thickened by the addition of 8% chlorinated rubber was completely decontaminated by Perclene/RH-195. The tests for completeness of decontamination were made with the C.R.-S-328 paper.

B. Perclene/RH-195 on Clear Plastics.

21. The plastics used in these tests were Lucite obtained from the Naval Aircraft Factory, Philadelphia, Pennsylvania., Plexiglas from Rohm & Haas Company, Philadelphia, Pennsylvania, and cellulose acetate from the Naval Air Station, Anacostia, D. C.

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(1) Effect of Perclene on the Plastics.

22. It was shown in NRL Report No. P-1944, "The Use of RH-195 for the Decontamination of HS and M-1," that TCE greatly injures these clear plastics, but Perclene does not injure any of these plastics within 24 hours. To confirm these data in regard to Perclene, strips of Plexiglas, cellulose acetate and Lucite 3 in. long, 1/2 in. wide and 3/32 in. thick were two-thirds immersed in Perclene, and 5% RH-195 in Perclene in separate beakers. The materials were left at room temperature with occasional addition of Perclene to replace evaporated solvent. The results of these tests are given in Table II. After 120 hours no change could be detected in any of the plastics partially immersed in Perclene alone. No change was observed within 24 hours in any of the plastics partially immersed in Perclene/RH-195. After 72 hours, of the plastics in Perclene/RH-195, Lucite was slightly cloudy with no crazing; the Plexiglas was clear with slight crazing at the edges; and the cellulose acetate was faintly cloudy with no crazing. These deleterious effects gradually increased up to 120 hours when the test was discontinued. At that time a strongly adhering deposit was observed on each plastic at the air-liquid interface.

23. The effect of solvents on these plastics under strong stress was studied by bending a strip of the plastic 7 inches long and 2 inches wide to form an arc with the longest chord of 5-3/4 inches. The plastic strips were sprayed with solvents while bent in this manner. TCE was not used in these tests because of its known injurious effect on these plastics. Kerosene and gasoline were used for comparison because they are sometimes used for cleaning these plastics and are regarded as harmless. Under these conditions Perclene, Perclene/RH-195, gasoline and kerosene all caused immediate and extensive crazing in Lucite and Plexiglas. Cellulose acetate under the same conditions showed a slight crazing effect. The extent of crazing was the same for each of the above solvents as nearly as could be observed.

24. Pieces of Lucite and Plexiglas were heated at 100°C until plastic and then moulded into arcs. Some stress lines in these plastic pieces were seen when examined under polarized light. These moulded strips showed no crazing or other injury when repeatedly sprayed with Perclene, Perclene/RH-195, gasoline or kerosene.

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Table II

Effect of Perclene and Perclene/RH-195
on Clear Plastics

Strips of each plastic were partially immersed in Perclene and Perclene/RH-195 and observed at intervals.

<u>In Perclene</u>	<u>Appearance of Plastic after</u>			
	<u>24 hours</u>	<u>72 hours</u>	<u>120 hours</u>	
Lucite	no change	no change	no change	
Plexiglas	" "	" "	" "	
Cell. Acetate	" "	" "	" "	
<u>In Perclene/RH-195</u>				
Lucite	no change	slightly cloudy	increased cloudiness*	
Plexiglas	" "	clear, slight crazing at edges	checking at edges*	
Cell. Acetate	" "	faint cloudiness	slightly cloudy*	

*After 120 hours there was a strongly adhering deposit at the air-liquid interface.

(2) Decontamination of Plastics with Perclene/RH-195.

25. Pieces of plastic 2 inches square were used for decontamination tests. Two 25 mg. drops of vesicant were applied without spreading and left to stand for one hour before decontamination was begun. After the decontamination procedure the pieces were tested for completeness of decontamination at 35°C in the usual manner.

26. The data obtained for Perclene solutions are given in Tables III, IV and V. In no instance was any harmful effect to the plastics observed except at spots where a vesicant had been applied. Lucite and Plexiglas dissolve in vesicants readily; consequently, the vesicants cause these plastics to become soft and tacky at points of application. In this respect M-1 was more injurious than HS, which in turn was more injurious than 1130. These vesicants had also a slight harmful effect on cellulose acetate but the characteristics of this plastic seemed little affected.

27. As can be seen in Tables III and IV, Perclene and Perclene/RH-195 were not effective decontaminants for Lucite,

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Plexiglas or cellulose acetate contaminated with HS or M-1 under the conditions given. Their use was somewhat beneficial, especially with Lucite. Where plastics were contaminated with 1130, Perclene solutions gave a complete decontamination in the case of Lucite and fairly good results with Plexiglas and cellulose acetate.

Table III

Decontamination of HS in Plastics

HS was left on for one hour before decontamination spray followed by washing with water an hour later.

<u>Plastic</u>	<u>Treatment</u>	<u>Paper Test Times (Min.), 35°C</u>		
		<u>1st day</u>	<u>2nd day</u>	<u>3rd day</u>
Lucite	None		< 1	2
"	Spray twice, Perclene	5	> 240	
"	" " " /RH-195	15*	> 240	
Plexiglas	None		< 1	< 1
"	Spray twice, Perclene		1	3
"	" " " /RH-195	< 1	1	3
Cell. Acetate	None		< 1	3
" "	Spray twice, Perclene	< 1	5	11
" "	" " " /RH-195	< 1	5	15

*Only one spot showed on the test paper.

Table IV

Decontamination of M-1 in Plastics

M-1 was left on for one hour before decontamination spray which was followed by washing with water one hour later.

<u>Plastic</u>	<u>Treatment</u>	<u>Paper Test Times (Min.), 35°C</u>		
		<u>1st day</u>	<u>2nd day</u>	<u>3rd day</u>
Lucite	None	< 1	< 1	1
"	Spray twice, Perclene	1	9	36
"	" " " /RH-195	< 1	22	53
Plexiglas	None	< 1	< 1	< 1
"	Spray twice, Perclene	< 1	< 1	< 1
"	" " " /RH-195	< 1	1	2
Cell. Acetate	None	< 1	< 1	< 1
" "	Spray twice, Perclene	< 1	< 1	2
" "	" " " /RH-195	< 1	< 1	2

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Note: More than one month later positive tests for M-1 were obtained in less than one hour using samples of each plastic which had not been decontaminated.

Table V

Decontamination of 1130 in Plastics

1130 was left on for one hour before decontamination spray which was followed by washing with water one hour later.

Plastic	Treatment	Paper Test Times (Min.), 35°C		
		1st day	2nd day	3rd day
Lucite	None	< 1	12	29
"	Spray twice, Perclene	> 240		
"	" " " /RH-195	> 240		
Plexiglas	None	< 1	5	12
"	Spray twice, Perclene	40	> 240	
"	" " " /RH-195	25	> 240	
Cell. Acetate	None	< 1	11	26
" "	Spray twice, Perclene	35	> 240	
" "	" " " /RH-195	11	170	> 240

28. When vesicants have been on these plastics for an hour, Perclene/RH-195 is not very effective for decontamination in some cases. Probably any good penetrating solvent for plastics, such as TCE, would harm the plastics. RH-195 causes the vesicant spots to become whitened and opaque. The vesicants injure the plastics considerably with cellulose acetate being the least harmed. Paper test times of less than one hour were obtained for M-1 on plastic panels which had been left to stand one month in the laboratory after contamination. HS and 1130 were not as persistent as M-1. It was concluded that swabbing these plastics with Perclene is beneficial in removing surface contamination and in some cases helps decontaminate dissolved vesicant. However, the plastic windows should be swabbed and not sprayed with this solvent because the rubber used in mounting the plastics is attacked by Perclene.

C. Perclene/RH-195 on Doped Airplane Fabrics.

(1) Preparation of Doped Fabric Panels.

29. The doped fabric panels were prepared by stretching airplane fabric over wooden frames, 7x9 inches and stapling

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along the edges. Both the cellulose acetate butyrate and the cellulose nitrate dopes were applied in the same manner, except that a different thinner was used in each case. Two coats of reduced clear dope were brushed on, followed by two coats of unreduced clear dope. After drying overnight the panels were sanded with 4/0 sandpaper. Then three coats of pigmented dope were applied, the panels sanded again, followed by a final spray coat of pigmented dope.

(2) Decontamination of Doped Fabric Panels.

30. In the following decontamination tests of doped fabrics, 20 drops of HS was applied to each 7x9 inch panel and spread immediately over the entire panel as uniformly as possible and left for one hour before decontamination was attempted. The decontamination procedure consisted of thoroughly spraying the contaminated panels twice at ten minute intervals with 5% RH-195 in TCE or Perclene. After standing for one hour the panels were washed with water, dried and tested for residual HS at 35°C in the usual manner. Panels requiring tests on more than one day were kept outdoors between the tests. The results of these tests are given in Table VI.

Table VI

Decontamination of Doped Fabric Panels

Type of Panel	Treatment	Paper Test Times (Min.), 35°C			
		1st day	2nd day	3rd day	4th day
Cell. acetate-butyrate	Spray twice, TCE/RH-195	>200			
Cell. acetate-butyrate	Spray twice, Perclene/RH-195	<1	4	9	
Cell. acetate-butyrate	None	-	-	>1	
*Cell. nitrate	Spray twice, TCE/RH-195	>240			
" "	Spray twice, Perclene/RH-195	>240			
Cell. acetate-butyrate	Spray twice, Perclene/RH-195	>1			5
Cell. nitrate	Spray twice, Perclene/RH-195	>1			12
" "	None				2
Cell. acetate-butyrate	"				1

*Note: Panels marked * were aged in the laboratory more than one year before use in this work.

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31. HS dissolved rapidly in cellulose butyrate doped fabric causing the dope to swell somewhat. HS did not seem to dissolve readily in cellulose nitrate doped fabric and did not seem to damage the dope. TCE/RH-195 decontaminated the cellulose acetate butyrate doped fabric but most of the dope was removed by the treatment. It has previously been shown in NRL Report No. P-1944 that TCE/RH-195 will decontaminate cellulose nitrate doped fabrics without any change in appearance. Perclene/RH-195 did not completely decontaminate cellulose acetate butyrate doped fabric, but it did not harm the coating as did TCE. Perclene/RH-195 decontaminated cellulose nitrate doped fabric which had been aged more than a year, but did not completely decontaminate cellulose nitrate panels which had been standing about two weeks. In each instance where Perclene/RH-195 was used, both on cellulose acetate butyrate and cellulose nitrate fabrics, there was some indication that this treatment was beneficial. It is certain the surface contamination was removed by Perclene/RH-195.

(3) Effect on Tensile Strength of Doped Fabric.

32. Tests were made to determine the effect of HS and decontaminating solutions, separately and in combination, on the tensile strength of both types of doped fabric. Tensile strength loss gives a measure of the deteriorating effect of these various treatments on the doped airplane cloth. For the tensile measurements four strips, 2x6 inches, were cut from each 7x9-inch fabric panel. Each strip was tested by the one-inch grab method on the Scott tester.

33. Table VII contains the experimental data for cellulose acetate butyrate doped fabric panels treated once with HS and decontaminating solutions as indicated. One treatment of the decontaminating solutions consisted of thoroughly spraying twice at 10-minute intervals. The panels were left outdoors for two weeks after this treatment, then 24 hours at 75°F and 50% relative humidity before tensile strength measurements were made. It was found that, within the limits of experimental error one treatment of HS alone, Perclene/RH-195, or HS and Perclene/RH-195 did not decrease the tensile strength of cellulose acetate butyrate fabrics. One application of TCE alone caused a decrease in tensile strength of 10-15%. TCE/RH-195 and HS followed by TCE/RH-195 decreased the tensile strength about 40%.

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Table VII

Tensile Strength of Cellulose Acetate
Butyrate Doped Fabrics

Where used, 20 drops of HS was spread on these panels and left for one hour before spraying treatment. Only one treatment of HS or decontaminating solution was used on these panels. Tensile strength measurements were made two weeks after the treatment.

<u>Treatment</u>	<u>Tensile Strength (Lbs.)</u>				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>Average</u>
None	128	128	128	137	130
HS only	127	137	134	132	133
Perclene/RH-195	131	134	125	146	134
HS followed by Perclene/RH-195	132	141	131	129	133
TCE/RH-195	78	74	82	90	81
HS followed by TCE/RH-195	75	73	75	92	79
TCE only	113	111	113	110	112

34. In the experiments tabulated in Table VIII, both cellulose acetate butyrate and cellulose nitrate doped fabrics were given three treatments of Perclene/RH-195, HS or HS followed by Perclene/RH-195 at three-day intervals. Each treatment with Perclene/RH-195 consisted of thoroughly spraying twice at ten-minute intervals. After the last treatment the panels were kept outdoors for two weeks, then at 75°F and 50% relative humidity for 24 hours before tensile strength measurements were made. HS alone did not affect the tensile strength of either type of fabric. Perclene/RH-195, after three treatments, decreased the tensile strength of both types of fabric by less than 10%. HS followed by Perclene/RH-195 caused a decrease of 30-40% in tensile strength of both types of fabric. TCE and TCE/RH-195 were not used in this experiment because one application removed the cellulose acetate butyrate dope, and it had previously been reported (NRL Report No. P-1944) that TCE/RH-195 decreases the tensile strength of cellulose nitrate doped fabric considerably even after one treatment.

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Table VIII

Tensile Strength of Doped Fabrics

Cellulose acetate butyrate and cellulose nitrate doped fabric panels were used. Where used, 20 drops of HS was spread on these panels and left for one hour before spraying treatment. (The treatment indicated was carried out three successive times at three-day intervals.) Tensile strength measurements were made two weeks after the last treatment.

Type of Panel	Treatment	Tensile Strength (Lbs.)				
		<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>Average</u>
Cell. acetate-butyrate	None	123	111	121	119	119
Cell. acetate-butyrate	HS only	109	120	122	124	119
Cell. acetate-butyrate	HS followed by Perclene/RH-195	59	74	67	82	71
Cell. acetate-butyrate	Perclene/RH-195	102	120	109	103	109
Cell. nitrate	None	130	110	119	130	122
" "	HS only	116	122	127	122	122
" "	HS followed by Perclene/RH-195	60	96	96	105	89
" "	Perclene/RH-195	108	117	127	99	113

D. Corrosion of Metals by Perclene/RH-195.

(1) Test Procedure.

35. Samples of Aluminum 2S, Dural 52S, copper, brass, monel, cold-rolled steel and stainless steel were used in these tests. The metal strips, 1-1/2" x 3/4" x 1/32", were cleaned with steel wool, washed successively in benzene and alcohol, dried at 50°C for about 10 minutes, and weighed. Then the metal samples were two-thirds immersed in the solutions contained in cork-stoppered test tubes. After a given storage time the strips were removed, cleaned in the same manner as above and weighed to determine the percent loss in weight. The loss in weight due to the cleaning procedure was found to be negligible.

(2) Experimental Results.

36. The corrosion of the above metals by Perclene, Perclene/RH-195, TCE and TCE/RH-195 was determined both

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at 30°C (86°F) and 50°C (122°F). The samples stored at 30°C were removed after one month; those at 50°C were removed after two weeks. These data are given in Tables IX and X.

Table IX

Corrosion of Metals

Specimens stored at 30°C for one month.

<u>Metal</u>	<u>Percent Loss in Weight</u>			
	<u>Perclene</u>	<u>Perclene/5% RH-195</u>	<u>TCE</u>	<u>TCE/5% RH-195</u>
Al 2S	0.00	0.07	0.00	0.08
Al 52S	0.00	0.12	0.00	0.38
Copper	0.04	0.59	0.01	0.94
Brass	0.00	2.66	0.00	3.36
Monel	0.00	0.17	0.00	0.08
Cold R. Steel	0.00	0.62	0.00	1.01
St. Steel	0.00	0.44	0.00	1.06

<u>Metal</u>	<u>Appearance after Cleaning</u>			
	<u>Perclene</u>	<u>Perclene/5% RH-195</u>	<u>TCE</u>	<u>TCE/5% RH-195</u>
Al 2S	No change	No change	No change	Dull where not immersed
Al 52S	" "	Dull where not immersed	No change	Dull where not immersed
Copper	Dull where immersed	Very dull	More dull	All dull
Brass	No change	Copper covered where not immersed	No change	Copper entirely covered
Monel	" "	Dull	No change	All dull
Cold R. Steel	" "	Rusted, very slightly pitted	No change	" "
St steel	" "	Very slightly pitted	No change	Dull where not immersed

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Table X

Corrosion of Metals

Specimens stored at 50°C for one month.

<u>Metal</u>	<u>Percent Loss in Weight</u>			
	<u>Perclene</u>	<u>Perclene/5% RH-195</u>	<u>TCE</u>	<u>TCE/5% RH-195</u>
Al 2S	0.04	0.20	0.05	0.28
Al 52S	0.00	0.91	0.04	0.24
Copper	0.04	0.89	0.08	5.09
Brass	0.04	0.79	0.04	1.15
Monel	0.00	0.07	0.00	0.35
Cold R. Steel	0.00	0.24	0.00	1.91
St Steel	0.00	0.21	0.00	1.33

<u>Metal</u>	<u>Appearance after Cleaning</u>			
	<u>Perclene</u>	<u>Perclene/5% RH-195</u>	<u>TCE</u>	<u>TCE/5% RH-195</u>
Al 2S	No apparent change	No apparent change	No change	Considerably pitted and corroded
Al 52S	No change	Pitted where immersed	No change	No apparent change
Copper	No apparent change	No apparent change	Slightly more dull	Considerably pitted
Brass	More dull	Heavily spotted with copper	No change	Copper covered
Monel	No change	Slightly dull where not immersed	No change	No apparent change
Cold R. Steel	" "	Dull where not immersed	No change	Pitted where immersed
St Steel	" "	No apparent change	No change	Dull where immersed

37. Neither Perclene nor TCE was found to be very corrosive on any of the metals tested. The loss in weight was negligible. The copper samples showed some signs of corrosion. Of the two RH-195 solutions, TCE/RH-195 was almost uniformly more corrosive than Perclene/RH-195. At 30°C, the brass samples were attacked more than any other metals. In general, monel seemed to be the least affected by the RH-195 solutions. The aluminum alloys were not seriously corroded.

E. Other Considerations.

38. Other considerations which are factors in the study of Perclene are given as follows:

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(a) Perclene is non-flammable.

(b) Perclene is relatively non-toxic when compared with TCE. Comparative data on the toxicities of the solvent vapors were obtained from a table in Industrial Medicine, 8, 426 (1939). The upper limit of the concentration of TCE in the air which will not cause any injury to a person exposed to this concentration for an indefinite period of time is 10 parts per million. For Perclene this value is 200 parts per million.

(c) The freezing point of Perclene is -22.3°C and its boiling point is 121°C . The freezing point of TCE is -46.3°C and its boiling point is 146.5°C . The vapor pressure of Perclene is higher than the vapor pressure of TCE at room temperature. However, no difficulty has been encountered in handling Perclene at temperatures ranging from 25°F to 95°F .

(d) Perclene is readily available at low cost (about \$0.08 per lb.) which is practically the same as the cost of TCE.

(e) A solution of RH-195 in Perclene is not quite as stable as a solution of RH-195 in TCE but the stability is satisfactory for the use of Perclene/RH-195 for decontamination. It is not recommended that this solution be prepared and stored for long periods before use.

(f) Perclene softens and swells rubber just as does TCE. Gas mask rubber partially immersed in these solvents at 35°C showed noticeable swelling within 20 minutes and the solvents were discolored. For this reason Perclene as well as TCE should be kept away from all rubber articles including rubber tires and gas masks.

EXPERIMENTAL PART III. PERCLENE/RH-195 AS A DECONTAMINANT FOR DECK PAINT.

39. The blue deck paint panels were prepared by brushing one coat of Bureau of Ships Spec. 84-D-1 primer on steel strips, followed by two brush coats of Bureau of Ships Spec. 20B blue deck paint. Two-inch square panels were used for the decontamination tests. The decontamination procedure and the tests for completeness of decontamination were the same as described in Part I.

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A. Comparison of Solvents for Use with RH-195 in Decontamination of Deck Paint.

40. Many of the same solvents used with RH-195 on M485 airplane lacquer were also used against HS on blue deck paint. Table XI gives representative data of the decontaminating efficiency of some of these solvents with RH-195. The thickness of the film of paint is an important factor, and because it is difficult to obtain a uniform coat by brushing, the paper test times should be regarded as only approximate.

41. o-Dichlorobenzene and TCE are good decontaminating solvents, but both of them blister and remove deck paint readily. These data indicate that dichloroethyl ether and dimethoxy tetraglycol are fairly efficient, but other trials gave poorer results. Dimethoxy tetraglycol blisters deck paint. None of the other solvents seemed to harm the deck paint. Carbitol acetate and butyl carbitol acetate show some promise as decontaminating solvents.

Table XI

Two-inch square steel panels painted with blue deck paint were treated with HS. Each was sprayed thoroughly with 5% RH-195 dissolved or suspended in the solvents listed below.

Solvent	Test Time, Minutes		
	1st day	2nd day	3rd day
Perclene	1	8	30
Dichloroethyl ether	1	3	7
ODB	200		
TCE	>240		
Diethylhexylamine	1		11
Carbitol acetate	1		200
*Dichloroisopropyl ether	2	>240	
Butyl carbitol acetate	1	14	>240
Dichloroethyl formal	1	9	19
Ethylene glycol diacetate	1	4	8
Cellosolve	1	3	11
*Dimethoxy tetraglycol	20	>240	
Diethyl carbitol	1	9	35
Triethyl phosphate	1	30	>240

*Other panels took three days for decontamination.

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42. In Table XI Perclene is shown to be a poor decontaminating solvent for deck paint. However, the other solvents have lower vapor pressure at ordinary temperatures than does Perclene, and consequently solutions and slurries of RH-195 in these solvents wet the painted surface much longer than does Perclene. Therefore it was felt that Perclene, which evaporates in a short time, could be made more effective by adding some material which would reduce the rate of evaporation of Perclene. This seemed particularly worth trying because Perclene has been shown to be the best solvent for use with RH-195 for the decontamination of airplanes. Work in this direction is described in Part B.

B. Effect of Addition Agents in Perclene/RH-195 for
Use as a Decontamination Spray on Deck Paint.

43. In an attempt to decrease the rate of evaporation of Perclene a number of additives were used as shown in Table XII. Several high-boiling solvents were used in concentrations up to 20%. In some cases there was indication of beneficial results as shown by third day paper test times. Tricresyl phosphate and dimethoxy tetraglycol looked better than the others. However, reference to Table XI shows that the mixture with Perclene is no better than the added solvent alone. The results indicated that the addition of solvents to Perclene probably would not sufficiently retard the rate of evaporation of Perclene to give substantially better results. Therefore, it was felt that an additive which would form a protective film or skin over the Perclene/RH-195 would be more promising. Ethyl cellulose (Dow) was found to be quite effective when 2% was added to the Perclene solution and sprayed. However, it was found impossible to remove the ethyl cellulose film from the paint without using Perclene or other solvent. Addition of sorbitan monolaurate to the ethyl cellulose spray solution helped in the removal of the ethyl cellulose with water, but the removal was still difficult. Because ethyl cellulose is a critical material and because of the difficulty of removing it from the paint, attention was then turned to the use of pastes of Perclene with a chloroamide plus an additive to give better adhesion.

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Table XII

Deck paint panels were treated with HS and sprayed with 5% RH-195 in Perclene to which the substance listed below were added.

<u>Additive</u>	<u>% Added</u>	<u>Test Times (Minutes)</u>		
		<u>1st day</u>	<u>2nd day</u>	<u>3rd day</u>
None	-	1	8	30
Tricresyl phosphate	10	1	15	>240
Chlorinated kerosene (39.6% Cl)	10	1	8	36
Aerosol O.T.	2	1	8	30
Dichloroisopropyl ether	10	1	2	11
Mineral oil	20	1	6	65
Diethylhexylamine	20	1	5	21
Dimethoxy tetraglycol	10	1	10	>240
*Ethocel	2	>240		
Sorbitan laurate	2	1	8	24
G.I. Soap (brown)	1	1	1	2
*Ethocel + 4% sorbitan laurate	2	>240		
Paraffin	5	1	6	40
" , filtered	5	1	4	8

*Some trials gave poorer results.

C. Pastes of Perclene/RH-195.

44. It was found that a paste of RH-195 or S-461 in Perclene was fairly effective for decontaminating HS in deck paint. However, these pastes did not adhere to vertical surfaces. Pastes have since been made containing various materials which it was hoped would produce a better adhering paste and increase the decontaminating efficiency. Of the materials used, some seemed more beneficial than others. A paste consisting of a mixture of potassium oleate, S-461 and Perclene, is described in NDRC Informal Report #8, entitled "A New System for the Decontamination of Painted Surfaces and Metallic Surfaces which have been Exposed to C. W. Agents." This paste looks promising but RH-195 cannot be substituted for S-461 because the mixture of potassium oleate with RH-195 reacts readily. Other promising additives are potassium stearate, diglycol stearate and diglycol laurate. These pastes are efficient decontaminants and are under investigation at the present time. A full report of this work will be forthcoming.

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SUMMARY OF RESULTS

45. In Experimental Part I a number of solvents were tested for suitability as solvents for RH-195 for the decontamination of naval airplane paint. It appeared that Perclene (tetrachloroethylene) was the most satisfactory solvent for this purpose for several reasons. Consequently this solvent was thoroughly investigated as a possible decontamination solvent, especially for use on airplanes.

46. It was found that Perclene/RH-195 satisfactorily decontaminates M485 airplane lacquer and 71 Line enamel under a variety of conditions. M-1, 1130 and thickened HS (containing chlorinated rubber) were likewise decontaminated by this mixture. Other chloroamides when used in Perclene decontaminated HS in M485 airplane lacquer also.

47. Perclene caused no injury to Plexiglas, Lucite or cellulose acetate except under conditions under which gasoline and kerosene were also damaging. It was concluded that Perclene and Perclene/RH-195 can be used on these plastics during decontamination of vesicants without any harmful effects. In this respect it is much better than TCE (tetrachloroethane) which softens these clear plastics immediately. In some cases Perclene and Perclene/RH-195 were found to be beneficial in the decontamination of vesicants in these plastics.

48. HS, HS followed by Perclene/RH-195 and Perclene/RH-195 were found not to be harmful to acetate butyrate doped fabric during one treatment. By contrast TCE, TCE/RH-195 and HS followed by TCE/RH-195 caused serious loss of tensile strength after one treatment. Also, TCE removes the cellulose acetate butyrate dope from the fabric very quickly. Even after treatment with Perclene/RH-195 three times at three-day intervals there was no serious loss of tensile strength for either cellulose acetate butyrate or cellulose nitrate doped fabrics. However, both types of panels which were grossly contaminated with HS and decontaminated with Perclene/RH-195 three times lost 25 to 40% of their tensile strength. It was concluded that TCE must never come in contact with cellulose acetate butyrate doped fabric. The use of TCE on cellulose nitrate doped fabric should be avoided. It is safe to use Perclene/RH-195 on either type of doped fabric for one decontamination but repeated use of this treatment cannot be recommended.

49. TCE and Perclene were both found to be non-corrosive to metals when compared to their RH-195 solutions. In most

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cases Perclene/RH-195 was found to be less corrosive than TCE/RH-195.

50. In addition to the above facts regarding Perclene/RH-195 as a decontaminant for naval airplanes there are other points to be considered. Perclene is non-flammable and is relatively non-toxic when compared to TCE. The physical characteristics of Perclene are satisfactory. It is readily available at low cost. Its solution of RH-195 is sufficiently stable for decontamination use but not stable enough for storage as a solution. Perclene attacks rubber just as does TCE and therefore should not be used for decontamination of rubber tires or stored near rubber materials such as gas masks which would be damaged by the solvent.

51. The use of Perclene in a decontamination system for deck paint was studied. It was found necessary to resort to additives to increase the efficiency of the Perclene for this purpose. Promising results have been obtained and this work is being pursued further.

CONCLUSIONS AND RECOMMENDATIONS

52. A 5% mixture of RH-195 in Perclene (tetrachloroethylene) was found to be an excellent decontamination system for use on naval airplanes. This mixture was shown to be superior to a solution of RH-195 in TCE (tetrachloroethane) in several respects. Perclene is much less toxic than TCE, is far less damaging to paint, plastics and doped fabrics.

53. Laboratory experiments have shown Perclene to be sufficiently superior for use as a decontamination solvent for naval airplanes so that it should replace tetrachloroethane for this purpose. It is recommended that field trials be made to verify this conclusion.

54. Decontamination systems using Perclene as a solvent have been found promising for use on deck paint. It is recommended that work on these systems for the decontamination of ships be continued.

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