NRL Report 6191

Field Decontamination Studies with Chemical Warfare Decontaminating Solution DS2

G. H. FIELDING

Protective Chemistry Branch
Chemistry Division

December 1964

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH

U.S. NAVAL RESEARCH LABORATORY
Washington, D.C.

CONTENTS

ABSTRACT

The standard U.S. Army chemical warfare decontaminant DS2 has been studied for shipboard applicability. Experimentation was conducted by staff personnel of the ABC School, Treasure Island, California. Single and multiple treatments of DS2 and DANC were compared with water-washdown plus aeration in effectiveness against mustard gas absorbed in Navy paint. Residual mustard gas in paint was evaluated via the vapor source strength, as determined by the NRL Vaporator and the M15 CW Agent Detector kit. When all treatments were preceded by thorough washdown, single treatments with DS2 or DANC were two to four times as effective as simple aeration. Multiple applications of DS2 were of very limited value.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem C08-22
Project No. SF 011-08-09-1726

Manuscript submitted October 1, 1964.

FIELD DECONTAMINATION STUDIES WITH CHEMICAL WARFARE DECONTAMINATING SOLUTION DS2

BACKGROUND

As a result of the favorable properties reported for the U.S. Army Chemical Corps' chemical warfare decontaminant DS2, tests of this material under shipboard conditions appeared desirable. Accordingly, the Bureau of Ships requested the ABC Defense School, Treasure Island, to submit plans for conduct of the tests by its own staff. It was expected that this group would be capable of performing the evaluation both efficiently and from a shipboard point of view.

Test plans were developed by the Treasure Island group and forwarded to the Bureau of Ships. The plans were studied by the Bureau and this Laboratory and approved with minor changes. A target of January 1959, was set for the test period, at which time a supply of DS2 could be supplied through the cooperation of the U.S. Army Chemical Corps.

The chemical warfare agent chosen for the DS2 evaluation tests was mustard gas (HD). Laboratory tests by the Chemical Corps had shown that mustard is the most difficult of the common persistent CW agents to decontaminate with DS2 (1). In addition, mustard was readily available at the ABC school, is safe to handle with reasonable precautions, and is capable of punishing the careless or unprotected worker by burns of varying severity.

INTRODUCTION

It is believed that limited quantities of a chemical decontaminant for persistent chemical warfare agents should be carried aboard ships of the U.S. Navy. Such a material need not be completely effective; it is in fact unlikely that any practical decontaminant will be found which can rapidly and completely neutralize mustard gas, for example, which has been absorbed in a ship's external paintwork, without also removing or weakening the paint. This is not a serious difficulty, however, for it has become clear in recent years that, unless paint is saturated with a chemical warfare agent (a situation which is improbable over any considerable area of a ship), the removal of the surface film of the agent will solve adequately most of the operational problems of CW contamination.

It is at present believed that the major part of a ship's topside area can be sufficiently cleansed of surface films of CW contaminants by the combined use of the washdown system and firehoses, possibly augmented by surface-active materials, emulsion cleaners, or solvents. More complete removal or neutralization of surface films of CW agents on small but especially important areas may require a chemical decontaminant. This more complete treatment is believed to be required only for surfaces or materials which must be frequently handled or traversed, which are in close proximity with certain critical duty stations, or which appear to have a high probability of being touched inadvertently by the unprotected skin.

A candidate for a limited-service shipboard CW decontaminant is the U.S. Army's DS2 (Decontaminating Solution No. 2) (Ref. 1). This liquid material is a mixture of 70-percent diethylenetriamine (DETA), 28-percent methyl Cellosolve and 2-percent sodium hydroxide by weight. Certain engineering tests of DS2 and a related spray applicator, the

E17R1 Decontaminating Apparatus, are covered by a Dugway Proving Ground Report (2). No data exist on the effectiveness of DS2 in shipboard environments, and the application techniques best adapted to shipboard use. Some factors which sharply distinguish the shipboard decontamination problem from that ashore are: (a) the general use on navy ships of paints which are more sensitive to solvents than the paints common to shore or aircraft applications, and (b) the availability of essentially unlimited amounts of water, via the shipboard washdown systems and firehoses, for use in decontamination.

The preliminary trials in the evaluation of DS2 at Treasure Island were designed in part to compare the decontamination effectiveness of DS2 with an obsolete but effective decontaminant DANC, whose performance in a navy environment is well known (3). In addition, the preliminary trials were intended to explore some variations in the methods by which DS2 might be used at sea.

DANC (Decontaminating Agent, NonCorrosive) is a 1 to 15 solution (by weight) of an active-chlorine compound dichlorodimethylhydantoin (RH 195) in the solvent tetrachlorothane (TCE). While effective against mustard gas and the V agents, DANC fails to neutralize G agents; corrodes metals in contact with moisture; and swells and damages paints, rubbers, and plastics. Inhalation of the vapor of TCE or absorption of the liquid through the skin has the characteristic toxic effects of chlorinated solvents. Recognition of these undesirable properties after World War II caused the Navy to discard DANC for shipboard use.

Many of the physico-chemical properties of DS2 are in contrast with those of DANC. DS2 has about four times the viscosity of DANC, so that it drains more slowly from vertical surfaces, and leaves a thicker film. DS2 is also essentially nonevaporating. These two properties would appear to extend the active lifetime of DS2, on a contaminated vertical surface, well beyond that of DANC. However, the chemical reaction between DS2 and mustard gas is inherently slower than the DANC and mustard gas reaction. Moreover, three side reactions between components of DS2 and the atmosphere act gradually to reduce decontamination effectiveness. These are (a) the reaction of atmospheric carbon dioxide with DS2's sodium hydroxide to form sodium carbonate; (b) the reaction of carbon dioxide with the amine DETA, which comprises 70 percent of DS2, to form a solid amine carbonate; and (c) the absorption of water.

The net effect of these complexities could not be predicted and operational tests were required for useful evaluation.

TECHNIQUE FOR MEASURING RESIDUAL CW CONTAMINATION

It was agreed by the Bureau of Ships, the ABC School, and this Laboratory that a convenient and realistic means of evaluating DS2 and competitive decontaminants would be the measurement of the rate of vaporization of the residual mustard remaining after a decontamination procedure. The use of this criterion appeared to be a practical one in the test operations, and also was believed to have the following advantages if extended in the future to fleet use:

1. The evaporation rate of a CW agent uniformly adsorbed in paint, wood, or other substrate is simply related to the nature of the substrate and the concentration of agent in it, assuming a wind speed substantially greater than zero.

2. The evaporation rate of a CW agent from shipboard surfaces is a controlling factor in the CW vapor hazard to the ship's crew.

3. The evaporation rate of a CW agent from shipboard surfaces is in fact the rate at which decontamination by aeration is taking place.

With the recognition of the usefulness of a vaporization meter, there was also the realization that the only conventional field devices and methods which could provide evaporation data are inadequate under the conditions of use. These give results highly dependent on wind speed and direction, in most cases require laboratory services, and are subject to other major errors. Accordingly, this Laboratory produced a new vaporization device, the Vaporator, which is small, light, cheap, adequately accurate, and intended to be operated by anyone capable of using the M15 CW Agent Detector Kit (4).

Readings of vaporization rates with the Vaporator can be obtained either in absolute units, such as micrograms per square centimeter per minute, or in units relative to some convenient standard, such as a free liquid surface of the pure CW agent.

A modification of the first method was chosen for the Treasure Island DS2 studies. In these, the volume of air sampled was standardized at about 400 ml which was obtained with twelve compressions of the rubber sampling bulb of the M15 kit. This automatically set the sampling period at about twenty-four seconds, since the normal operating cycle of the bulb occupies two seconds. After the standard air sample was aspirated through a blue-band tube of the M15 Chemical Warfare Agent Detector Kit, the tube was heated for two minutes at about 100°C, a condition which had been found to result in maximum development in the blue-band tube test for mustard gas. After development of the tubes, they were compared with a photographic standard scale prepared in this Laboratory; hereafter referred to as the Mustard Quantity Scale. This scale is illustrated in Fig. 1. The color numbers are converted to micrograms of mustard in Table 1.

Table 1
Mustard Quantity Scale
(Color Numbers vs
Micrograms Mustard)

Color Number*	Micrograms Mustard
1	0
2	0.05
3	0.1
4	0.25
5	0.5
6	1
7	2.5
8	5
9	10
10	20
11	40

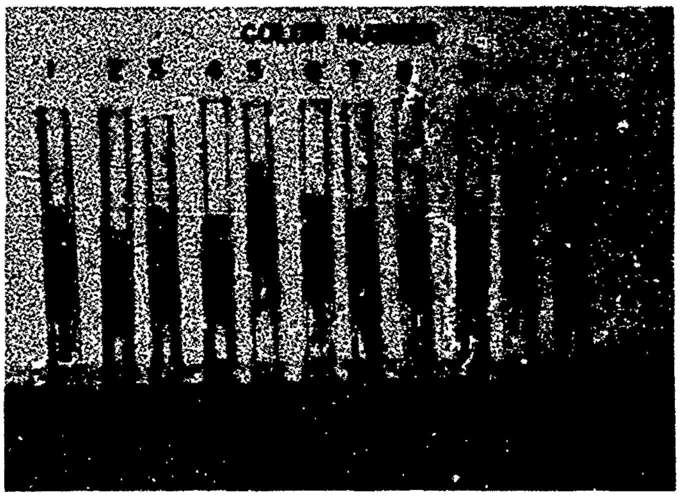

Fig. 1 - Mustard Quantity Scale - Blue-band tubes of M15 CW Agent Detector Kit

---

*It is perhaps well to emphasize that successive color numbers differ by a factor of two in quantity of mustard. Where the difference factor is not exactly two, it is because round numbers were chosen for greater convenience in any future operational service of the Vaporator. In comparing color numbers not adjacent on the scale, it can be seen that the corresponding quantities of mustard differ (exactly or nearly so) by two raised to the power given by subtracting the smaller number from the larger.

A new technique for heating the blue-band tubes in a well-controlled manner under field conditions appeared necessary also. Since the technique should be adaptable to possible general shipboard use, it should use a device or devices which would be small, rugged, inexpensive, and foolproof. Of several methods considered, the best consisted of a 5000-ohm 10-watt Brown Devil resistor connected directly to a 120-volt AC male plug. The 5-mm bore and 1-3/4-inch length of these "furnaces" contain the 5-mm × 1-5/8-inch blue-band tubes with precision, as shown in Figs. 2 and 3. The desired temperature is maintained automatically, while dissipating only 3 watts, as long as the furnace is not exposed to strong currents of air. This condition was met at the Treasure Island outdoor test site by using standard switch boxes to enclose the furnaces. In this way, vapor source strength tests were completed outdoors at the test site immediately after Vaporator samples were taken. The assembled furnace weighs less than 1-1/2 ounces and costs about a dollar.

Fig. 2 - "Brown Devil" resistor (5000-ohm 10-watt) used for heating blue-band tubes

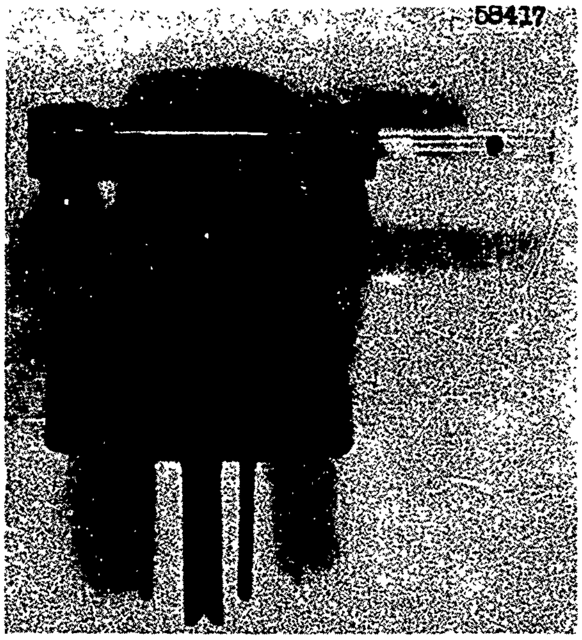

Fig. 3 - Resistor with blue-band tube partly inserted

PRELIMINARY TRIALS

General

To explore the effect of a number of decontamination variables, ten preliminary trials were made (Table 2). In all cases the test surfaces were 1/8-inch painted or unpainted steel plates 18 × 18 inches (Fig. 4). The painted plates had received 2 coats of red lead primer and 3 coats of navy haze gray paint (formula 5H) and had weathered outdoors for 3 weeks before the decontamination trials.

Contamination of the panels was in all cases at a contamination density of approximately 1 ounce per square yard. This is a very heavy contamination and, if applied to smooth vertical surfaces, represents essentially complete coverage plus some runoff. In some cases the mustard was sprayed onto the plate from a hypodermic syringe; in others it was applied uniformly with a paint brush.

Table 2
Decontamination of Steel Panels with DS2 and DANC
Summary of Preliminary Trials

Trial Number	1	2	3	4	5	6	7	8	9	10
Decontaminant	DS2 and DANC	DS2 and DANC	DS2 and DANC	DS2 and DANC	DS2	DS2	DS2	DS2	DS2	DS2
No. of test plates	2	2	2	2	1	1	1	1	1	1
Plate orientation	Vertical	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal
Plate surface	Paint	Bare steel	Bare steel	Bare steel	Bare steel	Bare steel	Bare steel	Bare steel	Paint	Paint
Mustard application	Spray	Spray	Spray	Spray	Brush	Brush	Brush	Brush	Brush	Brush
Prehosing	No	No	No	No	No	No	Yes	Yes	No	Yes
Decontamination treatments	2	3	1	2	3	3	2	2*	1	2
Scrubbing with decontamination	No	No	No	No	Yes	No	Yes	Yes	Yes	Yes
Posthosing	Yes	Yes	No	Yes	No	No	Yes, after second decontamination only	Yes	No	No
Plate temperature during decontamination (°F)	85	61	75	75	57	57	68-73	68-73	75	75
Plate temperature at Vaporator reading (°F)	85	61	75	75	62	62	73	73	75 (40 next morning)	75 (40 next morning)
Final Vaporator reading (color number)	DS2-4 DANC-1	DS2-1 DANC-8	DS2-1 DANC-8	DS2-4 DANC-2	DS2-3	DS2-5	DS2-4	DS2-4	DS2 10 (7 next morning)	DS2:10 (2 next morning)

*Additional water flush between first and second decontamination treatment.

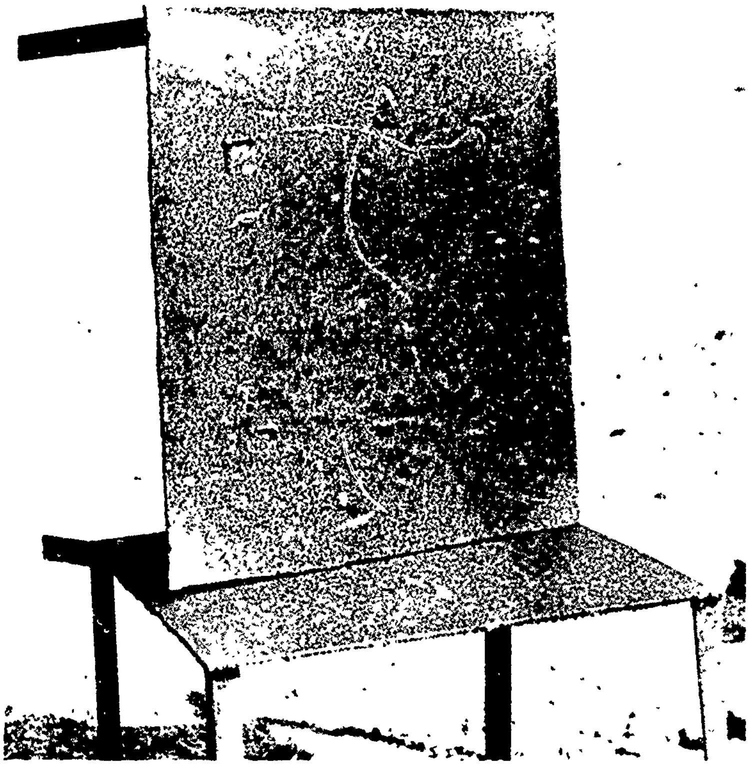

Fig. 4 - Typical steel plate used in these trials

Repeated Vaporator readings on each panel were always made at the same selected spot near the center of the panel with a heavy deposit of mustard. The several Vaporators themselves were found to have zero or negligible contamination after use. The standard air sample aspirated over the panels was 400 ml which was obtained by 12 bulb compressions of the M15 detector kit bulb.

In general, decontamination was started 10 minutes after mustard application and further decontamination treatments were approximately 30 and 60 minutes after the first one. There were some variations to this schedule. The quantities of decontaminants used were not measured, but in all cases they were considered just sufficient to insure formation of a continuous film of the solution used. This probably resulted in a larger volume of DS2 than DANC per application when they were used competitively; the former solution is more viscous and consequently forms a thicker film. All hosing of the plates was done with a standard firehose and nozzle with a pressure of 110 psi. Scrubbing or brushing the plates was done in a uniform manner.

Trial I

This trial was undertaken to assay the decontamination effectiveness of the developmental chemical warfare decontaminant DS2 compared with the older decontaminant DANC. The test surfaces were chosen to simulate vertical painted bulkheads. It was thought that the vertical orientation would bring out differences in the effectiveness of the two decontaminants based on differences in viscosity,* evaporation rate, and speed of the chemical

---

*The room-temperature viscosity of DS2 is about 8 cp; of DANC, about 2 cp. In addition the viscosity of DS2 increases as it absorbs carbon dioxide from the air.

reactions involved in the decontaminating action. DANC has a low viscosity and rapidly drains to a very thin film on a vertical surface. The solvent component also evaporates rapidly (about as fast as water) and the dry deposit of RH195 crystals remaining after the evaporation of the solvent has little or no decontaminating effect. As a result, DANC applied to a vertical surface has a relatively short period in which to act. As a compensating factor, the chemical reactions between DANC and mustard gas are known to be fast.

Two painted steel plates, vertically supported, were used in this trial. The total paint thickness is unknown but can be assumed to be between 0.005 and 0.010 inch on the basis of the number of coats applied (5). The plates were sprayed with mustard gas from a hypodermic syringe to give a coverage of about 1 ounce per square yard. The distribution was unavoidably streaked and uneven.

Ten minutes after contamination, one plate was sprayed with DANC and the other with DS2. Both solutions were applied with M1 decontamination sprayers. These are hand-operated compressed-air devices similar to 3-gallon garden sprayers. The quantities of decontaminants were not measured but were considered just sufficient to cover the surfaces adequately. Vaporator readings were taken on each plate 15 minutes after application of the decontaminants. Thirty minutes after the initial contamination, the decontaminants were reapplied, and Vaporator readings taken 15 minutes later. At 70 minutes after contamination, each plate was flushed with a firehose stream; Vaporator readings were taken 5 minutes later. Vaporator readings (Table 3) on the DANC plate were 12/5, 12/4, and 12/1, respectively, and those on the DS2 plate were 12/10, 12/10, and 12/4. A Vaporator reading of 12/5, for example, signifies 12 compressions of the rubber sampling bulb of the M15 chemical warfare agent detector kit, plus a color intensity in the blue-band tube test corresponding to tube five, i.e., a mustard color number of five. More specifically, in view of the 24-second sampling period dictated by the 12 bulb compressions, and the 20-square-centimeters sampling area of the Vaporator, 12/5 also signifies a mustard evaporation rate of 0.5 microgram per 30 square centimeters per 24 seconds, or 0.04 microgram per square centimeter per minute.

Table 3
Experimental Results of Trial I

Operation	Date/Time	Vaporator Readings	
		Plate A (DANC)	Plate B (DS2)
HD Applied	031400		
Decontaminants Applied	031410		
Vaporator Tests	031425	12/5	12/10
Decontaminants Applied	031430		
Vaporator Tests	031445	12/4	12/10
Firehosing	031510		
Vaporator Tests	031515	12/1	12/4

Both decontaminants damaged the navy 5H paint severely. DANC removed spots of haze gray paint but left all of the red lead primer intact; the remaining paint rehardened in less than an hour. DS2 removed most of the haze gray paint and spots of red lead down to the base metal; in this case the paint surfaces remained soft and pliable for about two hours. Part of the solvent sensitivity of the painted surfaces used in the preliminary trials is attributed to the fact that the coatings were relatively fresh. An additional factor is that DANC and DS2 are both designed for decontamination of Army vehicles and equipment. The baked enamels and lacquers used on such material would be expected to surpass the air-drying Navy shipboard paints and enamels in resistance to the decontamination agents investigated in the Treasure Island studies.

Figures 5 and 6 show the DANC plate and the DS2 plate, respectively, after five months of outdoor weathering following decontamination.

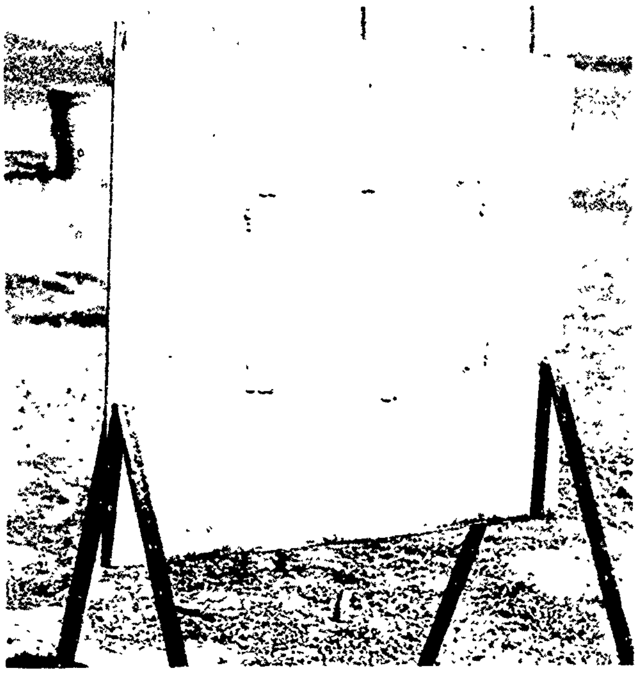

Fig. 5 - Steel plate used for DANC decontamination in Trial I after five months of outdoor weathering following decontamination

Fig. 6 - Steel plate used for DS2 decontamination in Trial I after five months of outdoor weathering following decontamination

The surface temperatures of the two plates remained constant at 85°F throughout the trial. These were measured with bimetallic surface thermometers placed on plates identical with those under test. The air temperature was 66°F.

It is evident that DANC is superior to DS2 on Navy haze gray paint when used to decontaminate mustard gas under the conditions of these trials. The vapor source strengths of heavily contaminated painted surfaces given two applications of decontaminants plus a firehosing differed by three color numbers (a factor of 2^3 or 8); the DANC-treated panel showing the lowest vapor source strength.

Trials II-IV

The decontamination procedures used in these trials (Table 4) were similar to those of Trial I. However, in contrast with Trial I, the steel plates were unpainted and positioned horizontally. Bare steel plates were chosen to avoid the complicating effects of agent absorption in paint. The horizontal arrangement represented a deck situation. One of these plates is shown in Fig. 4; the vertical position was to aid photography. The plate temperatures remained at 61°F during Trials II to IV.

In Trial II, the two unpainted steel plates were sprayed with mustard gas from a hypodermic syringe to give a coverage of about 1 ounce per square yard. As before, the distribution was streaked and uneven. The two decontaminants were used in three applications at 10, 40, and 70 minutes after contamination, and water hosing done at 100 minutes after contamination. Vaporator readings were taken 15 minutes after each decontaminant spray, but 5 minutes after hosing. The readings for the DANC plate were 12/5, 12/5, 12/3, and 12/8; for the DS2 plate they were 12/10, 12/2, 12/1, and 12/1.

Because of the seemingly anomalous results of Trial II, Trial III was undertaken. In Trial III, the same plates were contaminated, decontaminated once in the same manner as before, and Vaporator readings taken before hosing. The readings were 12/8 for the DANC plate and 12/1 for the DS2 plate.

Trial IV used the same plates and decontamination procedures as the previous trials, but included two decontaminant applications and a final hosing, corresponding to Trial I. The schedule specified the first decontamination 10 minutes after mustard was sprayed on the plates, and Vaporator readings 15 minutes after decontamination. This 15-minute interval allowed substantially for complete evaporation of the DANC solvent but left a continuous film of DS2 on the other plate. This cycle was repeated beginning 40 minutes after contamination, and the hosing was carried out 70 minutes after contamination. The readings for the DANC plate were 12/8, 12/3, and 12/2; and for the DS2 plate were 12/10, 12/9, and 12/4. These data correspond reasonably well with those of Trial I.

Trials II and III might be dismissed as anomalous in the light of Trial I, and Trial IV accepted as normal. However, the data were rechecked and it is believed that they are correct. The apparent inconsistencies in the data are believed to be related to the following effects:

1. Insufficient decontaminant may have been added to react completely with the CW agent present. In this case, no matter how thorough the mixing of decontaminant and agent, a residue of the latter will remain. This situation is more likely to occur where there is gross, visible contamination of the surface which has not been removed by hosing or washdown.

2. Enough, or more than enough, decontaminant was added to neutralize the agent present, but incomplete mixing may have resulted in "hot spots" of unneutralized agent.

Table 4
Experimental Results of Trials II-IV

Operation	Date/Time	Vaporator Readings	
		Plate A (DANC)	Plate B (DS2)
Trial II			
HD Applied	041000		
Decontaminants Applied	041010		
Vaporator Tests	041025	12/5	12/10
Decontaminants Applied	041040		
Vaporator Tests	041055	12/5	12/2
Decontaminants Applied	041110		
Vaporator Tests	041125	12/3	12/1
Firehosing	041140		
Vaporator Tests	041145	12/8*	12/1*
Trial III			
HD Applied	041300		
Decontaminants Applied	041310		
Vaporator Tests	041325	12/8	12/1
Trial IV			
HD Applied	041400		
Decontaminants Applied	041410		
Vaporator Tests	041425	12/8	12/10
Decontaminants Applied	041440		
Vaporator Tests	041455	12/3	12/9
Firehosing	041510		
Vaporator Tests	041515	12/2	12/4

*These figures were originally 50/10 and 50/3, equivalent to those given.

This situation, too, is more likely to occur where the pretreatment by washdown or hosing is lacking or ineffective, or where a horizontal surface restricts spread of the agent and its mixing with the decontaminant by gravity flow. The hot spots may be exposed and continue to evolve agent vapor, or they may be covered with a nonvolatile liquid decontaminant, such as DS2, so that they are temporarily masked. Briefly, it is believed that the contamination and decontamination conditions of these trials can, in fact, result in the extremely wide variation in decontamination effectiveness shown in Table 4.

In this particular experiment we can easily calculate the quantity of DS2 which must be added to neutralize completely the HD present. Jackson states that DS2 will destroy 2.5% of its weight of HD in 10 minutes at room temperature, provided that thorough and complete mixing is done (1). Since HD was applied to 1 ounce per square yard, the DS2 should be applied at not less than 1/0.025, or 40 ounces per square yard. This is about 72 cu in. or 4 pints, and when spread over a square yard uniformly, would form a liquid layer over 50-mils thick. Such a liquid layer of DS2 could not be maintained on a surface with appreciable slope. It is doubtful, then, that enough DS2 was applied in the single applications of Trial III to be capable of fully neutralizing the HD present, even if a mixing operation had been added. The low Vaporator reading can then be attributed to a masking effect.

Following these trials, it was noted that the DS2 plate was in a shinier, cleaner looking condition than the DANC plate. By the following morning, however, the DS2 plate showed a heavier coat of rust than did the DANC plate.

Trials V-VIII

Two unpainted steel panels were mounted in a horizontal position for these trials (Table 5) as for Trials II to IV. The other test conditions were modified in an attempt to identify and correct the factors believed responsible for the apparently anomalous results of Trials II and III. In particular, the trials were to study the agent-masking characteristics of DS2 films, and the desirability of scurbbing to improve the thoroughness of decontamination. DANC was not used. Instead of the distinctly uneven syringe application of mustard gas used in the prior trials, the agent was brushed on in a thin even coat over the unpainted plates. The coverage approximated 1 ounce per square yard contamination density with Trials V and VI conducted simultaneously. Throughout Trial V the plate was scrubbed gently but firmly for 30 seconds after each DS2 application to insure complete mixing of agent and decontaminant, but in Trial VI, the decontaminant was applied by spray only.

In Trials V and VI, three applications of DS2 were made to each plate at 15, 45, and 60 minutes after contamination. Vaporator readings for Trial V were 12/9, 12/4, and 12/3; those for Trial VI were 12/10, 12/7, and 12/5.

Trials VII and VIII were conducted simultaneously. The plates were hosed as the first step after the usual contamination with mustard gas. The hosing represented a logical first step, i.e., washdown or firehosing, in decontamination operations aboard ship. DS2 was then applied to both plates by spray, and scrubbed as in Trial V. With the Trial VII plate left undisturbed, the Trial VIII plate was hosed, resulting in an increased Vaporator reading. Each plate was now sprayed again. The Trial VIII plate Vaporator reading decreased. Finally, both plates were hosed. Again, the Vaporator reading for the Trial VIII plate increased. The final Vaporator reading on each plate was 12/4.

A comparison of Trials V and VI suggests that when DS2 is well mixed by scrubbing with HD on a metal plate, a fourfold reduction in vapor source strength of the residual agent (2 scale numbers) occurs. However, this result may occur only when the contaminated metal is not hosed before DS2 application. That is, scrubbing the DS2 into intimate contact with HD may have the same net result as hosing before decontamination, and the combination of hosing and scrubbing may be no more effective than either one separately. There are strong indications that DS2, by reducing evaporation, can mask contamination without completely decontaminating it. This is shown by comparing the Trial VIII Vaporator readings (Table 5) at 1132 with 1137, and at 1155 with 1157.

The final Vaporator readings of 12/4 are consistent with the final reading of 12/3 in Trial V if it is noted that the surface temperature in Trial V was 11 degrees lower than that of Trials VII and VIII. This is approximately the temperature difference required to double the mustard vapor pressure in Trials VII and VIII as compared with Trial V. This vapor pressure, or volatility, difference is the amount required to increase the Vaporator reading by one unit, as was observed.

Table 5
Experimental Results of Trials V-VIII

Operation	Date/Time	Temperatures (°F)		Vaporator Readings	
		Air	Surface	Trial V	Trial VI
HD Applied	050915				
DS2 Applied	050928				*
Vaporator Tests	050943	58	57	12/9	12/10
DS2 Applied	050959				*
Vaporator Tests	051014	58	59	12/4	12/7
DS2 Applied	051016				*
Vaporator Tests	051031	61	62	12/3	12/5
				Trial VII	Trial VIII
HD Applied	051103				
Vaporator Tests	051115	65	68	12/11	12/10
Hosing	051116			Yes	Yes
DS2 Applied	051120			Yes	Yes
Vaporator Tests	051132	65	71	12/3	12/1
Hosing	051136			No	Yes
Vaporator Tests	051137	65	68	-	12/4
DS2 Applied	051140			Yes	Yes
Vaporator Tests	051155	66	73	12/3	12/1
Hosing	051157			Yes	Yes
Vaporator Tests	051157	66	73	12/4	12/4

*Plate not scrubbed after these applications of DS2.

Trials IX and X

The decontamination procedures of these trials (Table 6) were similar to the preceding trials, but were conducted on painted metal plates which were essentially identical with those used in Trial I. The plates were arranged horizontally. The Trial IX plate received a DS2 spray application 10 minutes after contamination with mustard gas, and was hosed off 6 and 33 minutes later. No further treatment was given. The Trial X plate received 2 applications of DS2 18 and 45 minutes after contamination, and was hosed off at 12, 35, and 67 minutes after contamination. In all cases, DS2 was applied with scrubbing. The Trial X plate is shown in Fig. 7 after five months of outdoor weathering following decontamination. This plate underwent essentially the same treatment with DS2 as that shown in Fig. 6, but with the addition of scrubbing after each of the two DS2 applications. The somewhat more severe deterioration of the plate in Fig. 7 is attributed to the scrubbing action on the paint while it was in a softened condition due to the solvent effect of the decontaminant.

Table 6
Experimental Results of Trials IX and X

Operation	Date/Time	Temperatures (°F)		Vaporator Readings	
		Air	Surface	Trial IX	Trial X
HD Applied	051345			-	-
DS2 Applied	051357			Yes	No
Hosing	051357			No	Yes
Vaporator Tests	051359	71	75	12/11	12/10
Hosing	051403			Yes	No
DS2 Applied	051403			No	Yes
Vaporator Tests	051418	71	75	12/11	12/11
Hosing	051420			No	Yes
Vaporator Tests	051422			-	12/11
Hosing	051430			Yes	No
DS2 Applied	051430			No	Yes
Vaporator Tests	051446	71	75	12/10	12/11
Hosing	051452			No	Yes
Vaporator Tests	051455	69	75	-	12/10
Vaporator Tests	060745	48	40	12/7	12/2

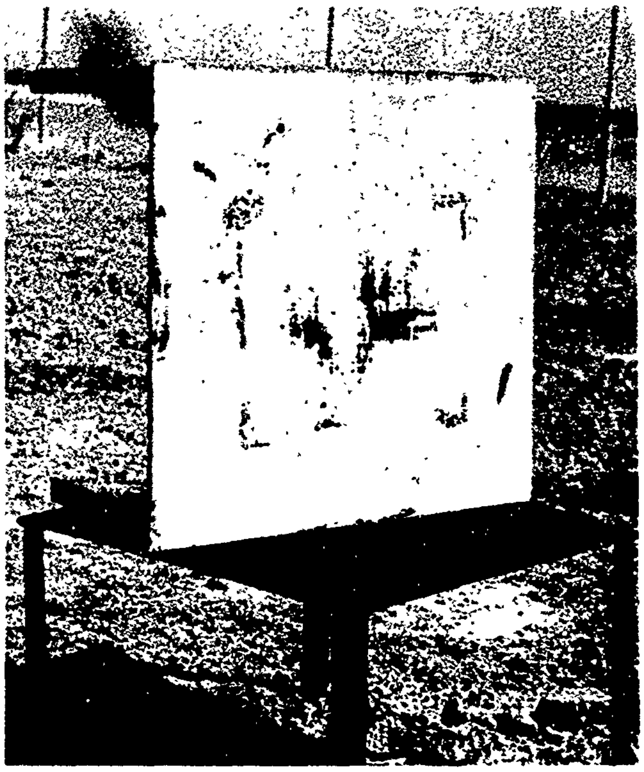

Fig. 7 - Steel plate used in Trial X after five months of outdoor weathering following decontamination

At 70 minutes after contamination, both plates were vaporizing mustard at the same rate. This indicates that both plates had the same surface concentration of mustard gas, which incidentally was essentially at the saturation value of 12/10 or 12/11 at the prevailing temperature. At this time, however, the total quantity of mustard gas in the paint of the Trial X plate must have been less than in the paint of the Trial IX plate. This is demonstrated by the much lower vaporization rate of the Trial X plate next morning. It is believed that the smaller total quantity of mustard gas in the Trial X plate must be attributed to the early prehosing treatment which physically removed a substantial amount of HD before it could be absorbed by the paint. That this noteworthy effect is not related to the additional DS2 treatment received by the Trial X plate is shown by a Vaporator reading of 12/11, indicative of a mustard-saturated surface, which persisted on this plate after the second DS2 treatment. Thus, the early and thorough firehosing of the plate in Trial X was a major factor in producing a low vapor source strength 12 hours after the decontamination operations.

FINAL TRIALS

General

On the basis of the preliminary trials, additional experiments were designed by representatives of the ABC school, the Bureau of Ships, and this Laboratory. These were carried out entirely by personnel of the ABC school after the Bureau of Ships and NRL personnel had returned to Washington.

The improvements desired to be introduced into the experimental conditions of the final trials were: (a) conduct of all trials simultaneously to obtain uniformity of wind and temperature, (b) use of representatively well-aged paint surfaces, (c) addition of an aeration-only trial, (d) use of a paint removed as a decontaminant, (e) prehosing* of all test surfaces after application of mustard, (f) duplication of Vaporator tests, and (g) measurement of the vapor source strengths of decontaminated surfaces for extended periods following decontamination treatments.

The surface chosen for the final trials was the forward shield of a 5-inch gun located on the grounds of the ABC school (Fig. 8). The shield was inclined 45 degrees from the vertical, and faced approximately west and toward the prevailing winds. The navy 5H paint on the gun shield was well-aged and heavy (28 to 34 mils). An extremely useful feature of the shield was a series of reinforcing ribs, about 2-inches high, welded perpendicularly to the surface of the shield. In this way, a series of eight separate but identical test surfaces was provided, each about 14-inches square. These panels were assigned numbers which read from left to right, facing the panels. The gun mount is shown in Fig. 8.

Procedures and Results

Each panel was brushed evenly with 1/9 ounce mustard per square foot. Conditions were a wind speed of 0 to 3 knots, air temperature of 70°F, relative humidity of 63%, and a panel surface temperature of 60°F. The mustard was allowed to stand for 15 minutes, then all panels were hosed from a distance of 25 feet with a solid stream of fresh water

---

*Prehosing signifies hosing to remove surface deposits of mustard prior to use of a chemical decontaminant.

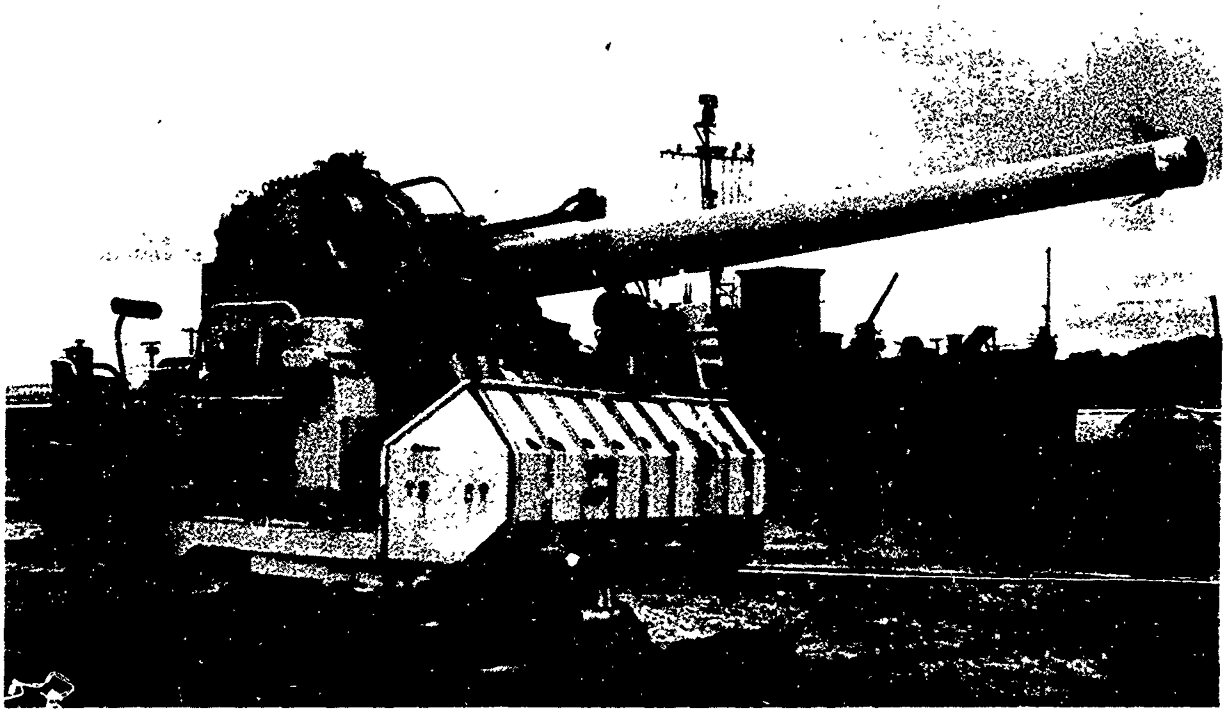

Fig. 8 - Five-inch gun mount used for final trials of DS2

from a 1-1/2-inch firehose under pressure of 110 psi. Panel 7 was given no further treatment and served as a reference panel by indicating the extent of decontamination by aeration.

Hand scrub brushes were used through the tests whenever scrubbing of the panels was required. Twelve back-and-forth and six circular strokes were used in all cases. Separate brushes were used in all applications of DS2, DANC, and paint remover, to avoid cross-contamination of the test surfaces.

Tests for residual mustard contamination were made with M15 Chemical Agent Detector Kits and Vaporators. The quantity of mustard vapor collected in each Vaporator test was read from the photographic Mustard Quantity Scale (Fig. 1). All Vaporator tests were in duplicate, but both readings are given only in the cases of disagreement. Prior to making Vaporator tests, decontaminants, if present, were hosed off following the standard hosing procedure cited above. In this way, the vapor-masking effect of a decontaminant film was eliminated. Panels not to be hosed were protected temporarily by canvas covers. At the end of each group of readings, the Vaporator was placed on an uncontaminated surface and a 150-bulb air sample taken. All such blank tests were negative.

The individual panel treatments follow:

Panel 1 - Sprayed with DANC, scrubbed, and allowed to stand for 15 minutes before hosing and testing. This cycle was repeated 3 times and the panel was then aerated for the balance of the trial.

Panel 2 - Sprayed with DS2, scrubbed, and allowed to stand for 15 minutes before hosing and testing. This cycle was repeated 3 times and the panel was then aerated for the balance of the trial.

Panel 3 - Sprayed with DANC, scrubbed, and allowed to stand for 15 minutes before hosing and testing. The panel was then aerated for the balance of the trial.

Panel 4 - Sprayed with DS2, scrubbed, and allowed to stand for 15 minutes before hosing and testing. The panel was then aerated for the balance of the trial.

Panel 5 - Sprayed with DS2, scrubbed, and allowed to stand for one hour before hosing and testing. The panel was then aerated for the balance of the trial.

Panel 6 - Sprayed with DS2, scrubbed, and allowed to stand for 35 minutes before hosing and testing. Two additional 1-hour cycles and the panel was then aerated for the balance of the trial.

Panel 7 - Reference panel. Aeration only.

Panel 8 - Sprayed with high-viscosity nonflammable paint remover (Specification TT-R-251), scrubbed, and allowed to stand for 15 minutes before hosing and testing, then aerated for balance of trial.

The unprocessed data are given in Table 7. In Table 8 the unprocessed data are converted to vapor source strengths in mmg per sq cm per minute, then normalized to a temperature of 26°C.

The arithmetical manipulations involved in the above conversion are as follows. The Bulb Compressions/Color Number data are converted to Sampling Time in Seconds/Micrograms of mustard by noting that each bulb compression requires two seconds, and by consulting the Mustard Quantity Scale to obtain the quantity of mustard corresponding to any color number. Owing to the fact that the Vaporator sampling area is 30 sq cm, the fraction, Sampling Time in Seconds/Micrograms of mustard can be inverted and multiplied by two to yield mmg/sq cm/minute. In the last column of each section of Table 8, the uncorrected vapor source strengths are normalized to an arbitrary temperature of 26°C. This was done by calculating, from the data of Pecorella and Macy (6), the volatility of mustard at the various gun shield surface temperatures measured. A volatility factor, or ratio, relative to the mustard volatility at 26°C (1 mg/liter) was then computed for each temperature. Division of the uncorrected vapor source strengths by the respective volatility factors resulted in normalization of all vapor source strengths to 26°C, a convenient intermediate value. Normalization was considered necessary to obtain maximum reliability of the data in view of the large range of surface temperatures: from 9° to 49°C. Over this temperature range, the uncorrected vapor source strengths would vary by a factor of 22, or over 4 Vaporator color numbers, due to temperature alone.

It should be pointed out that the normalization produced by the above procedure is not complete, i.e., it does not in all cases yield the same vapor source strengths which would have prevailed had the evaporation occurred at a constant temperature of 26°C. For example, a panel temperature of 15.5°C, as in the first set of Vaporator readings in Table 8, not only depresses the rate of evaporation at that time but also reduces the total amount evaporated during the low temperature period. Accordingly, a low temperature episode conserves agent for subsequent evaporation, and all subsequent normalized evaporation rates will be somewhat higher rate than if evaporation had taken place at a constant 26°C. The opposite effect is produced by panel temperatures above 26°C. The overall result is that the normalization is only partial, and that the normalized evaporation curve is not a smooth one. Complete normalization would be difficult to achieve, however, and the quasinormalization achieved is considered adequate.

Table 9 summarizes the temperature-normalized vapor source strengths, read from smoothed plots, for times of 3, 12, 24, and 48 hours after contamination. The table also includes relative decontamination factors for each of the 7 decontaminated panels relative to aeration panel 7.

Table 7
Decontamination of 5-inch Gun Mount Shield with Various Decontaminants
(Unprocessed Data and Schedule of Experimental Conditions)

Date/Time	Operation	Panel 1	Panel 2	Panel 3	Panel 4	Panel 5	Panel 6	Panel 7	Panel 8
		DANC	DS2	DANC	DS2	DS2	DS2	Aerate	Paint Remover
3-2-59/1000	All panels brushed evenly with 1 oz. HD/sq yd								
1015	All panels firehosed 60 sec at 100 psi								
1020	Vaporator readings	12/10	12/10	12/10	12/10	12/10	12/10	12/10	12/11
1025	Decontaminant sprayed on and scrubbed	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
1040	Firehosing	Yes	Yes	Yes	Yes	No	No	No	Yes
1040+	Vaporator readings	12/8	12/10	12/10	12/10	12/10	12/10	12/10	12/7
1045	Decontaminant sprayed on and scrubbed	Yes	Yes	No	No	No	No	No	No
1100	Firehosing	Yes	Yes	No	No	No	Yes	No	No
1100+	Vaporator readings	12/4	12/9	12/8	12/9	12/10	12/10	12/11	12/7
1107	Decontaminant sprayed on and scrubbed	Yes	Yes	No	No	No	Yes	No	No
1125	Firehosing	Yes	Yes	No	No	Yes	No	No	No
1125+	Vaporator readings	12/2	12/9	12/9	12/8	12/8	12/9	12/10	12/6
1207	Firehosing	No	No	No	No	No	Yes	No	No
1207+	Vaporator readings	12/2	12/7	12/7	12/8	12/7	12/8	12/8	12/3
1307	Firehosing	No	No	No	No	No	Yes	No	No
1307+	Vaporator readings	12/1	12/6	12/6	12/6	12/7,8	12/3	12/6,7	12/1
1500	Vaporator readings	12/1	12/4,5	12/4	12/4	12/4,5	12/1	12/5	12/1
3-3-59/0900	Vaporator readings	150/1	12/4	12/4,3	12/6,4	12/2,4	150/2	12/5,6	100/2
1210	Vaporator readings	150/2	12/4,3	12/3	12/4	12/4,3	150/3	12/7,6	75/4
1500	Vaporator readings	150/3	12/3	12/1	12/2	12/2	150/2	12/4	100/3
3-4-59/0830	Vaporator readings	150/1	150/4	150/2	150/1	150/3	150/1	150/4	150/2
1315	Vaporator readings	150/1	150/6	12/4	12/5	12/4	150/1	12/6	150/6

Table 8
Decontamination of 5-inch Gun Mount Shield with Various Decontaminants
(Conversion of Unprocessed Data to Vapor Source Strengths at 26°C)

Elapsed Time (hrs)	Panel Temp. (°C)	Volatility Factor (to 26°C)	Bulb Comps/Color No.	Sampling Time/HD (sec/mmg)	Vapor Source Strength (mmg sq cm min)	Vapor Source Strength (26°C) (mmg sq cm min)	Bulb Comps/Color No.	Sampling Time/HD (sec mmg)	Vapor Source Strength (mmg sq cm min)	Vapor Source Strength (26°C) (mmg sq cm min)
			Panel 1 (DANC)				Panel 5 (DS2)			
0	15.5	0.42	12/10	24/20	1.7	4.1	12/10	24/20	1.7	4.1
0.4	15.5	0.42	12/8	24/5	0.4	1.0	12/10	24/20	1.7	4.1
0.8	31	1.4	12/4	24/.25	0.02	0.01	12/10	24/20	1.7	4.1
1.2	31	1.4	12/2	24/.05	0.004	0.003	12/8	24/5	0.4	0.3
1.9	30.5	1.4	12/2	24/.05	0.004	0.003	12/7	24/2.5	0.2	0.1
2.9	26	1.0	12/1	50/0	0.002	0.002	12/7.5	24/3.7	0.3	0.3
4.8	20.5	0.61	12/1	24/0	0	0	12/4.5	24/.37	0.03	0.05
23	13	0.34	150/1	300/0	0	0	12/3	24/.1	0.008	0.02
26	31.5	1.5	150/2	300/.05	0.0003	0.0002	12/3.5	24/.17	0.015	0.01
29	33	1.7	150/3	300/.1	0.0007	0.0004	12/2	24/.05	0.004	0.002
46	9	0.24	150/1	300/0	0	0	150/3	300/.1	0.0007	0.003
53	49	5.3	150/1	300/0	0	0	12/4	24/.5	0.02	0.004
			Panel 2 (DS2)				Panel 6 (DS2)			
0	15.5	0.42	12/10	24/20	1.7	4.1	12/10	24/20	1.7	4.1
0.4	15.5	0.42	12/10	24/20	1.7	4.1	12/10	24/20	1.7	4.1
0.8	31	1.4	12/9	24/10	0.8	0.6	12/10	24/20	1.7	1
1.2	31	1.4	12/9	24/10	0.8	0.5	12/9	24/10	0.8	0.6
1.9	30.5	1.4	12/7	24/2.5	0.2	0.1	12/8	24/5	0.4	0.3
2.9	26	1.0	12/6	24/1	0.08	0.08	12/3	24/.1	0.008	0.008
4.8	20.5	0.61	12/4.5	24/.37	0.03	0.05	12/1	24/0	0	0
23	13	0.34	12/4	24/.25	0.02	0.06	150/2	300/.05	0.0003	0.001
26	31.5	1.5	12/3.5	24/.17	0.015	0.01	150/3	300/.1	0.0007	0.0005
29	33	1.7	12/3	24/.1	0.008	0.005	150/2	300/.05	0.0003	0.0002
46	9	0.24	150/4	300/.25	0.0017	0.006	150/1	300/0	0	0
53	49	5.3	150/6	300/1	0.007	0.001	150/1	300/0	0	0
			Panel 3 (DANC)				Panel 7 (Aeration)			
0	15.5	0.42	12/10	24/20	1.7	4.1	12/10	24/20	1.7	4.1
0.4	15.5	0.42	12/10	24/20	1.7	4.1	12/10	24/20	1.7	4.1
0.8	31	1.4	12/8	24/5	0.4	0.3	12/11	24/40	3	2
1.2	31	1.4	12/9	24/10	0.8	0.6	12/10	24/20	1.7	1
1.9	30.5	1.4	12/7	24/2.5	0.2	0.1	12/8	24/5	0.4	0.3
2.9	26	1.0	12/6	24/1	0.08	0.08	12/6.5	24/1.7	0.15	0.15
4.8	20.5	0.61	12/4	24/.25	0.02	0.03	12/5	24/.5	0.04	0.07
23	13	0.34	12/3.5	24/.17	0.015	0.04	12/5.5	24/.75	0.06	0.2
26	31.5	1.5	12/3	24/.1	0.008	0.005	12/6.5	24/1.7	0.15	0.1
29	33	1.7	12/1	24/0	0	0	12/4	24/.25	0.02	0.01
46	9	0.24	150/2	300/.05	0.0003	0.001	150/3	300/.1	0.0007	0.003
53	49	5.3	12/4	24/.25	0.02	0.004	12/6	24/1	0.08	0.02
			Panel 4 (DS2)				Panel 8 (Paint Remover)			
0	15.5	0.42	12/10	24/20	1.7	4.1	12/10	24/20	1.7	4.1
0.4	15.5	0.42	12/10	24/20	1.7	4.1	12/7	24/2.5	0.2	0.5
0.8	31	1.4	12/9	24/10	0.8	0.6	12/7	24/2.5	0.2	0.1
1.2	31	1.4	12/8	24/5	0.4	0.3	12/6	24/1	0.08	0.06
1.9	30.5	1.4	12/8	24/5	0.4	0.3	12/3	24/.1	0.008	0.006
2.9	26	1.0	12/6	24/1	0.08	0.08	25/2	50/.05	0.002	0.002
4.8	20.5	0.61	12/4	24/.25	0.02	0.03	12/1	24/0	0	0
23	13	0.34	12/5	24/.5	0.04	0.1	100/2	200/.05	0.0005	0.002
26	31.5	1.5	12/4	24/.25	0.02	0.01	100/5.5	200/.75	0.007	0.005
29	33	1.7	12/2	24/.05	0.004	0.002	100/3	200/.1	0.001	0.0005
46	9	0.24	150/1	300/0	0	0	150/2	300/.05	0.0003	0.001
53	49	5.3	12/5	24/.5	0.04	0.01	150/6	300/1	0.001	0.001

Table 9
Summary of Normalized Data for Decontamination of Gun Mount

Decontaminant (All preceded by initial prehosing)	No. of Decontamination Cycles	Length of Decontamination Cycle (min)	Panel No.	Vapor Source Strength, Normalized to Constant Temperature, at Indicated Hours after Contamination (mmg/sq cm/min) Taken from Smoothed Curves			
				3 hr	12 hr	24 hr	48 hr
DANC	3	15	1	0.002 (75)*	0.0005 (80)	0.0003 (100)	0 (100+)
DS2	3	15	2	0.08 (2)	0.02 (2)	0.008 (4)	0.0015 (13)
DANC	1	15	3	0.08 (2)	0.02 (2)	0.008 (4)	0.0015 (13)
DS2	1	15	4	0.08 (2)	0.02 (2)	0.008 (4)	0.0015 (13)
DS2	1	60	5	0.08 (2)	0.02 (2)	0.008 (4)	0.004 (5)
DS2	3	60	6	0.08 (2)	0.001 (40)	0.0005 (60)	0 (60+)
Aeration	-	-	7	0.15 (1)	0.04 (1)	0.03 (1)	0.02 (1)
Paint Remover	1	15	8	0.004 (40)	0.002 (20)	0.002 (15)	0.0015 (13)

*Figures in parentheses are relative decontamination factors by which the various decontaminants are compared to simple aeration.

A promising degree of self-consistence is seen in the summarized data of Table 9. That this feature is not an artifact is strongly indicated by the relative decontamination factors. The systematic progress, with time, in the factors adds weight to their individual values.

Although the decontamination trials here reported were not intended to be a test of the Vaporator principle and system, the simple and straightforward conduct of the trials, as well as their consistent results, afford reason for optimism regarding the ultimate operational utility of the Vaporator system. The simplicity and negligible cost of the Vaporator are mentioned in Ref. (4), and its very high sensitivity is better seen in Tables 8 and 9. It need only be said that these data are in terms of fractions of a millimicrogram evaporating per square centimeter per minute, and that the data were obtained by nontechnical personnel to whom the Vaporator system was entirely new.

It is understood that DS2 suffers a progressive loss in decontaminating efficiency if mixed with more than 10 percent water. This may place a considerable handicap on DS2 as a shipboard decontaminant because of the likely presence of water, due to use of the washdown system or firehoses, preceding periods when a chemical decontaminant would be required. However, it is believed that this difficulty would not necessarily be a sufficient basis to reject DS2 for shipboard use if it were otherwise the best choice. This problem is now under study.

It is significant that most of the decontamination procedures used showed little advantage (i.e., relative decontamination factors of only 2 to 4) over simple aeration. It is not known, however, whether comparable data would be obtained for thinner paint films. In any case, future use of relative decontamination factors of the type introduced in Table 9 may be advisable in evaluating CW decontaminants for shipboard use.

On July 6, 1959, paint was chipped from panels 1 to 7 of the gun mount in order to observe the condition of the underlying metal. In all cases the steel was free of rust. The paint on panel 8 was badly deteriorated due to the prior use of paint remover.

The photograph of the entire mount (Fig. 8), made on October 26, 1959, show the chipped sections of each panel as dark areas. This coloration is due to extensive accumulation of rust during the 3-1/2 months prior to photographing.

CONCLUSIONS

1. DS2 can screen or mask a mustard-contaminated surface without completely decontaminating it. In this situation, the contaminated surface is a stronger vapor source after hosing off the DS2 film than with the film in place.

2. Prehosing is advantageous in reducing the vapor source strength to a much lower value a number of hours after decontamination. This advantage was not evident immediately after the completion of DS2 treatments.

3. Scrubbing immediately after DS2 application is advantageous when mustard contamination is heavy and no prehosing has been done; in this situation the vapor source strength is reduced by 2 Vaporator Color numbers, or a factor of 4. When mustard contamination is reduced by prehosing. scrubbing seems to have no value.

4. DANC appears to be distinctly superior to DS2 in actual decontamination efficiency, as determined by vapor source strength after posthosing has removed all decontaminant residues.

5. Provided that mustard-contaminated painted surfaces are first thoroughly flushed with a firehose stream, the following decontamination treatments are all about equally effective (2 to 4 times as effective as simple aeration) when post-decontamination vapor source strengths are used as the measure of decontamination effectiveness:

(a) A single treatment with DS2.

(b) A single treatment with DANC.

(c) Three treatments wtih DS2 at fifteen minute intervals.

(d) Three treatments with DS2 at 60-minute intervals, for vapor source strength measurements made up to 3 hours.

6. With the same proviso as above, the following decontamination treatments are about equally effective (40 to 100 times as effective as aeration) and yield vapor source strengths between 1 and 2 orders of magnitude lower than the treatments listed above:

(a) Three treatments with DS2 at 60-minute intervals, for vapor source strength measurements made 12 hours or more after beginning decontamination.

(b) Three treatments with DANC at 15-minute intervals.

7. Insufficient data exist at the present time for recommending adoption of a chemical decontaminant for use aboard ship. It would be desirable to have a decontaminant less damaging to paint than DS2 and less expensive, and possibly also less prone to deactivation by water.

8. A thorough firehosing of a ship within 15 minutes of contamination by CW agents is a very useful cleansing process. This process is half as effective in reducing the mustard vapor hazard, at 3 and 12 hours postcontamination, as several plausible processes utilizing DS2 and DANC. This effectiveness could be approached by a standard washdown system, but it is believed advisable to supplement the washdown by firehosing applied to areas which are heavily contaminated, poorly drained, not effectively reached by the washdown, or which must be occupied or touched by personnel.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the expert and effective cooperation of the following personnel of the ABC School, Treasure Island, in planning and carrying out the field experiments described in this report. The fact that the actual conduct of these successful experiments was exclusively in the hands of the school staff suggests the practicability of future cooperative studies of a similar nature.

Captain John H. Stover, Jr., MC, USN
Lieutenant Searcy G. Galing, USN
Kenneth R. Welton, DCC, 376 27 68, USN
Melvyn R. Skinner, GMCS, 356 39 78, USN
Elbert L. Foreman, GMC, 356 88 63, USN
Alton F. Minter, GMC, 393 39 58, USN

It is a pleasure also to point out that the active cooperation of Mr. William S. Brown of the Bureau of Ships was vital to the success of this project.

REFERENCES

1. Jackson, J.B., "Development of Decontaminating Solution, DS2," CWLR 2368, Chemical Warfare Lab., Army Chemical Center, April 1960 (Confidential Report, Unclassified Title)

2. "Final Engineering Testing of the E17R1 Decontaminating Apparatus and the DS2 Decontaminating Solution," U.S. Army DPGR 257, Aug. 1960

3. Fielding, G.H., Johnson, J.E., and Krynitsky, J.R., "Decontamination of Landing Craft at San Jose Island," NRL Report P-2914, July 30, 1946

4. Fielding, G.H., "The Vaporator, A Device for Measuring the Vapor Source of CW-Contaminated Surfaces, Part 1 - Background and Prototype," NRL Report 5361, Aug. 13, 1959

5. "Preservation of Ships in Service," Chapter 9190, Bureau of Ships Technical Manual, 1963

6. Pecorella, S.S., and Macy, R., "Vapor Pressure of Pure Mustard," TDMR 738, Army Chemical Center, Sept. 13, 1943

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

U.S. Naval Research Laboratory
Washington, D.C. 20390

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE

FIELD DECONTAMINATION STUDIES WITH CHEMICAL WARFARE DECONTAMINATING SOLUTION DS2

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
An interim report on one phase of the problem.

5. AUTHOR(S) *(Last name, first name, initial)*

Fielding, George H.

6. REPORT DATE
December 1964

7a. TOTAL NO. OF PAGES
26

7b. NO. OF REFS
6

8a. CONTRACT OR GRANT NO.
NRL Problem C08-22

b. PROJECT NO.
SF 011-08-09-1726

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)
NRL Report 6191

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. AVAILABILITY/LIMITATION NOTICES Unlimited availability. Copies available from Clearinghouse for Federal Scientific and Technical Information (CFSTI) Sills Building, 5285 Port Royal Road, Springfield, Virginia 22151.

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY
Department of the Navy
(Bureau of Ships)

13. ABSTRACT

The standard U.S. Army chemical warfare decontaminant DS2 has been studied for shipboard applicability. Experimentation was conducted by staff personnel of the ABC School, Treasure Island, California. Single and multiple treatments of DS2 and DANC were compared with water-washdown plus aeration in effectiveness against mustard gas absorbed in Navy paint. Residual mustard gas in paint was evaluated via the vapor source strength, as determined by the NRL Vaporator and the M15 CW Agent Detector kit. When all treatments were preceded by thorough washdown, single treatments with DS2 or DANC were two to four times as effective as simple aeration. Multiple applications of DS2 were of very limited value.

DD FORM 1 JAN 64 1473

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Chemical warfare decontamination						
Chemical warfare decontamination materials						
Washdown for CW agents						
Vaporator						
Chemical warfare agents						
Chemical decontaminants						
Rate of vaporization						
CW agent detector kit						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
________________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
________________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
________________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, *or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

UNCLASSIFIED

Naval Research Laboratory. Report 6191.
FIELD DECONTAMINATION STUDIES WITH CHEMICAL WARFARE DECONTAMINATING SOLUTION DS2, by G.H. Fielding, 24 pp. and figs., December 1964.

The standard U.S. Army chemical warfare decontaminant DS2 has been studied for shipboard applicability. Experimentation was conducted by staff personnel of the ABC School, Treasure Island, California. Single and multiple treatments of DS2 and DANC were compared with water-washdown plus aeration in effectiveness against mustard gas absorbed in Navy paint. Residual mustard gas in paint was evaluated via the vapor source strength, as determined by the NRL Vaporator and the M15 CW Agent Detector kit. When all treatments were preceded by thorough washdown,

UNCLASSIFIED (over)

1. Chemical warfare agents – Countermeas.
2. Naval vessels – Decontamination

I. DS2
II. DANC
III. Fielding, G.H.

UNCLASSIFIED

Naval Research Laboratory. Report 6191.
FIELD DECONTAMINATION STUDIES WITH CHEMICAL WARFARE DECONTAMINATING SOLUTION DS2, by G.H. Fielding, 24 pp. and figs., December 1964.

The standard U.S. Army chemical warfare decontaminant DS2 has been studied for shipboard applicability. Experimentation was conducted by staff personnel of the ABC School, Treasure Island, California. Single and multiple treatments of DS2 and DANC were compared with water-washdown plus aeration in effectiveness against mustard gas absorbed in Navy paint. Residual mustard gas in paint was evaluated via the vapor source strength, as determined by the NRL Vaporator and the M15 CW Agent Detector kit. When all treatments were preceded by thorough washdown,

UNCLASSIFIED (over)

1. Chemical warfare agents – Countermeas.
2. Naval vessels – Decontamination

I. DS2
II. DANC
III. Fielding, G.H.

UNCLASSIFIED

Naval Research Laboratory. Report 6191.
FIELD DECONTAMINATION STUDIES WITH CHEMICAL WARFARE DECONTAMINATING SOLUTION DS2, by G.H. Fielding, 24 pp. and figs., December 1964.

The standard U.S. Army chemical warfare decontaminant DS2 has been studied for shipboard applicability. Experimentation was conducted by staff personnel of the ABC School, Treasure Island, California. Single and multiple treatments of DS2 and DANC were compared with water-washdown plus aeration in effectiveness against mustard gas absorbed in Navy paint. Residual mustard gas in paint was evaluated via the vapor source strength, as determined by the NRL Vaporator and the M15 CW Agent Detector kit. When all treatments were preceded by thorough washdown,

UNCLASSIFIED (over)

1. Chemical warfare agents – Countermeas.
2. Naval vessels – Decontamination

I. DS2
II. DANC
III. Fielding, G.H.

UNCLASSIFIED

Naval Research Laboratory. Report 6191.
FIELD DECONTAMINATION STUDIES WITH CHEMICAL WARFARE DECONTAMINATING SOLUTION DS2, by G.H. Fielding, 24 pp. and figs., December 1964.

The standard U.S. Army chemical warfare decontaminant DS2 has been studied for shipboard applicability. Experimentation was conducted by staff personnel of the ABC School, Treasure Island, California. Single and multiple treatments of DS2 and DANC were compared with water-washdown plus aeration in effectiveness against mustard gas absorbed in Navy paint. Residual mustard gas in paint was evaluated via the vapor source strength, as determined by the NRL Vaporator and the M15 CW Agent Detector kit. When all treatments were preceded by thorough washdown,

UNCLASSIFIED (over)

1. Chemical warfare agents – Countermeas.
2. Naval vessels – Decontamination

I. DS2
II. DANC
III. Fielding, G.H.

UNCLASSIFIED

single treatments with DS2 or DANC were two to four times as effective as simple aeration. Multiple applications of DS2 were of very limited value.

UNCLASSIFIED

UNCLASSIFIED

single treatments with DS2 or DANC were two to four times as effective as simple aeration. Multiple applications of DS2 were of very limited value.

UNCLASSIFIED

UNCLASSIFIED

single treatments with DS2 or DANC were two to four times as effective as simple aeration. Multiple applications of DS2 were of very limited value.

UNCLASSIFIED

UNCLASSIFIED

single treatments with DS2 or DANC were two to four times as effective as simple aeration. Multiple applications of DS2 were of very limited value.

UNCLASSIFIED