Division 9

NATIONAL DEFENSE RESEARCH COMMITTEE

of the

OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

OSRD No. 5194

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OSRD No. 3620

Division 9
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Section 5

"THE MECHANISM OF CUTANEOUS INJURY BY MUSTARD GAS.
AN EXPERIMENTAL STUDY USING MUSTARD PREPARED WITH
RADIOACTIVE SULFUR."

Service Directive CWS-2

Endorsement (1) Homer W. Smith, Division Member in Charge to
W. R. Kirner, Chief, Division 9 .

Forwarding report and noting:

"This report presents in full the results of over three years study of the penetration and reaction of mustard gas, containing radioactive sulfur as a tracer, into the skin of animals and man.

"Among the more notable facts demonstrated are that:

(a) In man, a small fraction of the penetrating mustard rapidly reacts with the epidermis and corium to produce the cell injury that later leads to vesication, while the remainder is rapidly carried away by the circulation. At no time is there a significant quantity of free mustard in the skin, and hence therapeutic attempts based on destruction of penetrated mustard must necessarily be valueless. This is equally true of light and massive contamination.

(b) In the pig, and to a lesser extent in the rabbit, a considerable reservoir of unreacted mustard is present in the skin for some minutes after exposure, and hence agents designed to destroy free mustard in the skin can to some degree be effective when applied up to 10 minutes after surface decontamination. The transfer of therapeutic experiments from these animals to man is therefore unwarranted.

(c) Extensive evidence points to the conclusion that it is the rapidly completed, chemical combination of mustard with one or more cellular proteins (bound mustard) that is responsible for cellular injury.

Endorsement (Continued)

(d) Since intradermal decontamination offers no hope in man, possibilities for specific therapy are limited to reversal of the chemical reactions between mustard and the essential cellular proteins. The present studies, as well as those of other investigators, indicate that such reversal, under conditions compatible with the life of the cell, presents a very difficult if not impossible problem. Hence the therapy of mustard vesication is in practice limited to rapid and complete surface decontamination.

(e) The rate of penetration increases in direct relationship to the room temperature, probably in consequence of physiological alterations in the skin rather than of local temperature changes at the site of penetration, this increased penetration rate accounting in part for the increased vesicant power of mustard at high environmental temperatures.

"Among other important contributions of this work are pathological studies of a complete, progressive series of mustard burns in man, obtained by biopsy, and a comparison with a similar series from the pig and rabbit, data on the absolute rates of penetration in man, the pig and rabbit, and data on the distribution of fixed mustard in the epidermis and corium and in the nuclear tissue of the epidermis.

"Although the main conclusions of the study are discouraging, so far as the hope of obtaining a specific antidote for mustard is concerned, it is of great value in the vesicant problem, in that it establishes a precise frame of knowledge relative to the limits and requirements both for decontamination and specific therapy."

(2) from W. R. Kirner, Chief, Division 9 to Dr. Irvin Stewart, Executive Secretary of the National Defense Research Committee.

Forwarding report and concurring.

This is a progress report under Contract 9-93, NDCrc-169 with The President and Fellows of Harvard University.

Division
NATIONAL DEFENSE RESEARCH
of the
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

TESTS FOR VESICANCY ON HUMAN SKIN

to
January 1, 1945
by

John F. Thomson, Hoylande D. Young, Joseph Savit, Eugene Goldwasser, Raymond G. Murray, Peter DeBruyn (E.M.K. Geiling, Official Investigator; R. Keith Cannan, Director of Laboratory; William Bloom, in Charge of Vesicant Studies)

Report OSRD No. 5194
Copy No. 29
Date: June 1, 1945

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Division 9
NATIONAL DEFENSE RESEARCH COMMITTEE
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Section 9:4:1

TESTS FOR VESICANCY ON HUMAN SKIN

Service Directive: CWS-2

Endorsement (1) Birdsey Renshaw, Technical Aide, Section 9:4 to Walter R. Kirner, Chief, Division 9.

Forwarding report and noting:

"In this report are assembled the data of all vesicant screening tests carried out by the University of Chicago Toxicity Laboratory (Contract NDCrc-132). Medical officers of the Navy Department participated in the tests which were carried out on volunteers at the Great Lakes Naval Training Station.

"Over 400 compounds have been examined by the application of small amounts of liquid to the human forearm. Data for compounds tested prior to 1944 are given on pages 57-171. A Supplement (pp. 177-184) covers compounds tested during 1944. Only a single compound was tested in 1945 before the termination of the contract; C_6NHCl_4 (TL 1519, a product of thermal destruction of cyanogen chloride) produced only 2/18 erythemas when tested at a dosage of 0.24 mg. (NDRC 9:4:1-25). The testing methods are described (pp. 1-12) and the investigators' impressions of the variables influencing the results of tests are recorded (pp. 13-27).

"Survey of the data fails to reveal promising candidate vesicants which have not received special study.

"A separate section (pp. 39-57) deals with the relative potencies of H and other vesicants of particular interest (see also OSRD 4230), with vesicant mixtures, and with the unsuccessful attempts to augment the vesicancy of H by wetting agents and other additives.

"Attention is directed to the following reports which also contain vesicancy data obtained at the University of Chicago: OSRD Nos. 3586, 3501, 3942, 3943, 3944, 4176, and 4658. OSRD Nos. [illegible] and 4230 describe devices for the delivery of small doses of liquid vesicants to the skin."

UNCLASSIFIED

Division 9
NATIONAL DEFENSE RESEARCH COMMITTEE
of the
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

Section 9:4:1

TESTS FOR VESICANCY ON HUMAN SKIN

(2) from Walter R. Kirner, Chief, Division 9 to Dr. Irvin Stewart, Executive Secretary of the National Defense Research Committee.

Forwarding report and noting:

"This report, in conjunction with OSRD report number 4176, 'Status Report on Toxicity and Vesicant Tests of Compounds Referred to the University of Chicago Toxicity Laboratory' summarizes the screening of candidate chemical warfare agents carried out by Division 9 NDRC during the present war. These two reports should be of value as a guide to the direction which future research should take in seeking new candidate chemical warfare agents as well as to attempts at correlating toxicity and vesicancy with chemical structure.

"Grateful acknowledgement is made for the assistance rendered by the Bureau of Medicine and Surgery, Navy Department, through Captain E. W. Brown, in providing human volunteers from the Great Lakes Naval Training Station for the vesicancy studies as well as assistance by Naval officers in the actual conduct of the tests."

This is a progress report under Contract NDCrc-132 with the University of Chicago.

SECRET

COPY NO. 29

University of Chicago Tox city Laboratory Report No. 48
NDCrc 132, Division 9, NDRC

TESTS FOR VESICANCY ON HUMAN SKIN
to January 1, 1944
(with supplement to January 1, 1945)

by

John F. Thomson
Hoylande D. Young
Joseph Savit
Eugene Goldwasser
Raymond G. Murray
Peter DeBruyn

Eugene M. K. Geiling, Official Investigator
R. Keith Cannan, Director, U.C.T.L.
William Bloom, In Charge of Vesicants, U.C.T.L.

The facilities for the tests requiring human volunteers were furnished by the Senior Medical Officer of the Ninth Naval District.

The following Medical Officers were assigned by the Navy Department as collaborators on the Vesicant Testing Program:

Lt. Comdr. A. F. Abt, M.C., U.S.N.R. - January 21, 1942 to June 30, 1943
Lt. Comdr. T. B. Friedman, M.C., U.S.N.R. - July 7, 1942 to May 25, 1944
Lt. J. H. Heinen, M.C., U.S.N.R., January 11, 1943 to September 21, 1944

The tests reported here were carried out by the Naval Officers and W. Bloom, P. DeBruyn, E. Goldwasser, P. Johnson, J. Last, R. G. Murray, R. Merrill, J. Savit, J. F. Thomson

None of these persons participated in all of the tests. Most of the work was done while Dr. F. C. McLean (now Lieut. Col., M.C., A.U.S.) was director of U.C.T.L.

UNIVERSITY OF CHICAGO
TOXICITY LABORATORY
CHICAGO, ILLINOIS

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TESTS FOR VESICANCY ON HUMAN SKIN

SUMMARY

This report covers our results with: (1) criteria and methods of vesicant testing and some of the variables involved, (2) cumulative data on mustard and lewisite, obtained from February, 1942, through December 1943, (3) spot tests for vesicant action of over 400 compounds, carried out on several thousand men, and (4) studies of some mixtures of vesicants and vesicant comparisons.

The action of vesicants on human skin is affected by temperature and humidity, exercise, and condition and type of skin. Variations in individual sensitivity require that large groups of men be used for accurate comparisons of vesicants.

The data on H and L, compiled largely upon untreated controls of tests of decontamination and protection against liquid vesicants, are presented to show the variations which appear from day to day and even among series performed on the same day.

With a prescribed upper dose limit of 0.2 mg., we have found that 107 compounds tested are vesicants, 43 are irritants, 21 are mild or doubtful irritants, and the remainder have no effect on human skin.

In general, the powerful vesicants are certain members of the mustard and sesquimustard series, many of the dichloroarsines, and a few dichlorodiethylamines.

Mixtures of vesicants are no more powerful than their more active compnents.

TESTS FOR VESICANCY ON HUMAN SKIN

Contents

TESTS FOR VESICANCY ON HUMAN SKIN

I. INTRODUCTION

Criteria of Vesicant Testing

Laboratory tests, consisting of the application of small amounts of the compounds to human skin, or large doses to animals are used to ascertain the relative potency of various compounds as vesicants. These may be carried out with liquids or vapors. More important and final tests must be carried out on men (or on animals) in chambers and in the field. In this report, we are concerned only with laboratory tests for vesicant action on human skin.

Selection of Dose - The first step in the evaluation of a new compound submitted to this laboratory has been the application of it to the skin of animals to obtain a general idea of the potency of the new material.[1] The dosage for the first tests on man is estimated from the results so obtained. In our experience with several hundred compounds, there have been only a few instances in which the animal skin became necrotic and the human skin did not blister, and only one case in which the human skin was more sensitive than the animal.

A committee composed of representatives of the armed services of Britain and Canada, and of the OSRD, which met in Boston in September, 1942, prescribed for us a dosage limit of 0.2 mg. For screening purposes we have adopted the following routine: 0.2 mg. of the agent, either undiluted or in a solvent is applied to the shaved back of a mouse. If no irritation is produced, a like quantity of the agent is applied to the flexor surfaces of the forearms of a group of men. If none of the men is irritated, the compound is classed as a nonvesicant (NV). Compounds which give only erythemas at 0.2 mg. on

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[1] One of the objections to the use of animal skin is that it does not blister as the result of the application of heat or chemical agents. This failure of animal skin to blister is due, in part, to the fact that skins of animals have a thin stratified epithelium. Apparently, the vesicant, or heat, as the case may be, injures this thin epithelium and the underlying derma so rapidly that blistering does not occur. If, however, the epithelium has previously been thickened, the application of a small amount of vesicant produces typical blisters in the epithelium and at the line of junction of the epithelium with the derma. (U.C.T.L. Informal Progress Report, July, 1942).

men are classed as irritants (E), and those that produce blisters at this level or less are classed as vesicants (V). This upper dose limit has been used throughout the year, although some compounds only mildly irritant at 0.2 mg. in cold weather may be capable of producing blisters at that dose in the summer.

If the application of the vesicant to the skin of the mouse produces some damage, the first dose selected for application to human skin will vary from 50 to 100 micrograms, depending on the severity of the reaction of the mouse's skin.

Reactions of Human Skin - Small amounts of an irritant may produce no reaction or an erythema of varying intensity. Within this erythematous area a papule or blister may develop. Occasionally, an area of necrosis without vesication or with vesication at the periphery only, may result.[2] With small doses of mustard, instead of a single vesicle there may be numerous pinhead sized vesicles in the center of the erythematous area.

For simplicity in recording and evaluating data, we use the three categories "nil," "erythema," and "blister." In most cases, the men are inspected at 24 and 48 hours, and only the latter readings are reported. Unfortunately, in the vast majority of the tests, we have been unable to make readings later than 48 hours. Readings are made by the Naval Medical Officers or by hospital corpsmen under the officers' supervision. The greatest diameters of erythema and of blister are recorded in millimeters. From the size of the lesions and from the percentage of each, a satisfactory evaluation of the relative vesicancy can be made.

Those compounds which show intense irritancy (i.e. give a percentage of blisters in the range of mustard) have been evaluated further by direct comparisons with the standard vesicants.

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[2] The frequency of those types of lesions may be gauged from the following data. Of 678 men receiving 0.13 mg. of mustard, during the months of February and March, 1943, 6-3 (or 9%) developed necroses without blister formation. The percentage that blistered for this same period was 89.4 (including the 63 men with necroses in the blister total). The necroses are tabulated as blisters because (1) most of the tests were conducted on a 48-hour basis, (2) blisters and broken small blisters are hard to separate from each other, and (3) what seems to be a small area of necrosis may develop into a small blister a day later.

Methods Used for Application of Vesicants:

Because of the great potency of some of the chemical compounds used as vesicants, it has been necessary to deliver exceedingly small amounts of these substances. Many difficulties are involved in the case of undiluted compounds. For the purpose we have modified and used two devices of other workers. One of these is the Edgewood Rod; the other the microburette or micropipette.

Rods - The use of rods of standard delivery area and weight has been described by G. C. Armstrong (1937) of Edgewood Arsenal. A series of seven stainless steel rods are machined and polished to sizes ranging (at the tip) from 0.60 to 2.68 mm. in diameter, and calibrated to deliver from 0.015 mg. to 0.15 mg. of mustard. The dose delivered to the skin by each rod follows:

Rod No.	Area Sq.mm.	Dose H delivered	
		Total mg.	mg./sq.mm.
1	0.28	0.015	0.053
2	0.78	0.023	0.029
3	1.23	0.032	0.026
4	1.72	0.050	0.029
5	2.69	0.060	0.022
6	3.63	0.088	0.020
7	5.64	0.150	0.027

In use the rod is rested by its own weight (about one ounce) on a specially prepared pad saturated with the vesicant and is then applied in a similar way to the skin. The pad must be nonfriable so that small pieces of lint do not adhere to the rod and carry excess vesicant to the skin. The pad must not react with the agent to be tested. The Edgewood pads, prepared from macerated paper, may be used for mustard over a period of several months. In our laboratory, new leather pads are used and discarded each day. The pads are punched from leather prepared by the Eagle-Ottowa Leather Co. of Grand Haven, Michigan, who write: "The leather is tanned with approximately 50% hemlock bark and 50% quebracho extract. It is later given a light tannage with a synthetic tannin called 'Lenkanol' and sumac leaves. The sumac is now off the market, due to war conditions, and is being replaced by a South American shrub sold under the trade name of 'Sutan'."

Only if the steel rods are carefully cleaned after each application and occasionally machine polished, may they be used with L and other arsenicals, since these agents corrode the steel. In addition to the steel rods, glass rods of similar size have been made and calibrated for use with L. The fragility of the glass rods is their principal shortcoming.

Delivery of vesicants by rods of the Edgewood type has several advantages. The method is applicable to all liquid vesicants and solutions except those of high vapor pressure. A wide range of dosage is possible and delivery is easy and rapid. The rods and the small amounts of vesicants necessary are easily transported and can be used anywhere without auxiliary equipment. The delivery of H by these rods is fairly constant under carefully controlled conditions.

The rods have certain disadvantages, the greatest of which are variability of dose by weight delivered with slight changes in the conditions of the experiment and the necessity of calibrating the rods for each compound tested. Changing the type of pad, for example, may alter the dose by 50% or more, and there is the possibility of reaction of some of the vesicants with the pad when several of different types are to be tested. Viscosity and temperature affect the amount of vesicant picked up and delivered by the rod. The amounts of moisture and grease on the skin also influence transfer of vesicant to the skin from the rod surface. These variations may affect the results obtained from one vesicant much more than those from another.

Pipettes and Burettes - Many types of pipettes and burettes have been used to deliver vesicants. One of the types used in this laboratory is a length of mercury thermometer tubing with one end drawn to a fine tip. One degree on this thermometer pipette equals 0.031 mg. of water, or 40 micrograms of mustard. This instrument is difficult to handle, and cannot be controlled accurately within 0.5 degree. For compounds of low irritancy (or for very dilute solutions), where relatively large amounts (multiples of 1 cu.mm.) can be used, a micro Kahn pipette is satisfactory. The delivery of the powerful vesicants requires a more delicate apparatus.

Drod - This is a modification of a micrometer syringe described by Trevan (1922). McMaster (1942) has applied it to the delivery of small quantities of vesicants. A micrometer is attached to the barrel of a 0.25-cc B-D tuberculin syringe in such a way that, as the micrometer head is turned, the plunger of the syringe is forced forward. Each revolution of the micrometer has been divided into twelve parts, and a click-stop arrangement provides for easy delivery of multiples of 0.2 cu.mm. (or 0.26 mg.) of H.

The delivery tip is a stainless steel surface perforated by a fine capillary opening, pressed over the stump of a #27-gauge syringe needle. A similar glass tip has been developed for delivering steel-corroding liquids such as L. In the latest model the driving portion of the micrometer is attached to the head of the syringe plunger by a ball-and-socket joint. This permits filling the syringe by reverse revolution of the micrometer, without the necessity of a spring as in the first model. The spring has been unsatisfactory because of a tendency toward corrosion.

Our Modification of the "Drod" -- the "Micrometer Burette" of this Report - We have modified the "drod" so that a single instrument can be used to test a large number of vesicants (frequently 20 in a morning on groups of 20 men each). The alterations we have made enable us to change rapidly from one vesicant to another without the dealy which would be necessary if the "drod" had to be decontaminated after theuse of each vesicant. This apparatus has been described recently (Bloom, Murray, Savit, Thomson, OSRD No. 1899, September 14, 1943). The "drod", without delivery tip and filled with mercury, acts as the driving mechanism. It is attached by a ground-glass joint to a two-way stopcock to which the delivery tip is also attached. The L-shaped bore of the core of the stopcock permits the delivery arm of the pipette to be connected either with a waste bottle and aspirator or with the drod, thus allowing liquids to be either drawn up into the delivery tube by aspiration or expelled by turning the micrometer.

The two original "drod" micrometers which we had were calibrated to deliver 0.2 cu.mm. of liquid (or 0.26 mg. of H) per "click" (1/12 revolution). We have divided each of these intervals into four, so that one "small click" (1/48 revolution) delivers 0.05 cu.mm. of liquid. It has also been possible by the addition to the micrometer head of a pointer arm and a 6-inch indicator disc marked off in 192 divisions, to deliver 1/2 or 1/4 of a "small click". These are equivalent to deliveries of 0.025 cu.mm. or 0.0125 cu.mm. of liquid respectively.

Inequalities in delivery render the accuracy of individual doses at a given range questionable, but the average dose over a series of applications must be nearly constant. Deliveries of amounts greater than 0.05 cu.mm. have produced reasonably uniform lesions in most of our experiments.

Benesh Micropipette - During a great part of the year, even the modified drod delivers too much liquid for the evaluation of the relative potency of the most effective compounds. We have modified the apparatus with the aid of Mr. M. E. Benesh, and M.E. Benesh, Jr., who have made for us a precision micropipette that advances 2.5 γ of H with each cog of the ratchet on the micrometer. This apparatus is provided with replaceable delivery tips so that we are able to test a large number of vesicants in rapid succession. From our calibration of the apparatus, there can be no question of the efficiency of this machine in advancing small amounts of liquids. We have used this machine on about 10,000 men and are convinced that it will be a decided aid in evaluating differences between the potent vesicants. Striking and constant differences have been obtained between 2½, 5, 7½, 10, 12½, 15, and 20 micrograms of H and other compounds. Some of our findings have been published together with a detailed description of the apparatus (OSRD No. 4230, October 1944) All of the data obtained with this machine have appeared in UCTL Informal Reports of 1944.

There is still the problem of the delivery of the small amounts of liquids from the delivery tips onto the skin. Only a part of the vesicant is delivered on single applications, a small amount remaining on the delivery tip. This we have verified by two methods. In one, with the aid of a binocular microscope, we examined the delivery tip after application to skin of propylene glycol colored with Nile blue sulfate. On the polished glass-tipped surfaces, after each application to the arm, a small amount of blue liquid was seen, even after delivery of 2 micrograms. The amount seemed to be constant after each application. In another test, in a group of 20 men, after the last application to an arm, the delivery tip was touched once more to the arm without having more vesicant brought to the tip. It was found that the small amount of the vesicant remaining on the delivery tip was sufficient to cause traces of transient erythema in a fair percentage of the cases.

The Benesh micropipette does deliver approximately the same amount of liquid on successive applications at each dosage level so that the resulting lesions are satisfactorily comparable as to size and intensity. Hence, this apparatus offers us a means of compering undiluted liquid vesicants in amounts smaller than those obtainable with either the drod or the Edgewood rods. As mentioned above, it is necessary to be able to deliver these small amounts without solvents, for the addition of a solvent has changed the vesicancy of some compounds.

Vesicant Vapors -- Static System - The vesicant vapors may be tested in static or dynamic systems. The simplest method of exposing the skin to vesicant vapors is by means of a vapor cup similar to that in use at Edgewood Arsenal. A thimble-sized cup containing a pad saturated with mustard is made with an inward-curling lip so that free liquid from the pad will not run down the sides of the cup and contaminate the subject's arm. The air in the cups is saturated with vesicant vapor. The concentration of vapor, of a particular compound, in such cups depends on the environmental temperature as well as that on the skin of the subject. The effectiveness of the vapor also depends on the amount of moisture within the cup.

Our main use of the Edgewood cups has been in the tests of protective ointments for persistency of protection against H vapor. The results of these tests have been reported by Savit, Thomson, Goldwasser, DeBruyn, and Margaret Bloom (OSRD No. 3386, March 1944)

A modification of this vapor cup is a small vial placed in a thermos bottle filled with fluid, the temperature of which can be controlled and stabilized over a wide range. A more accurate control can be obtained by immersion of the vials in a thermostatically controlled water bath. Such an apparatus, in use in Britain and Canada, necessitates bringing the men to the laboratory, whereas the thermos bottles may be transported (as we have had to do).

In the winter and spring of 1943, we made a few attempts to evaluate vesicant vapors in this static system. The technique consisted first in lining the small glass vial (16 x 50 mm.) with filter paper and saturating the paper with the liquid vesicant. The vial was capped, and placed in an ordinary thermos bottle filled with water, so that the temperature of the vial remained constant. A strip of cellulose tape with an 8 mm. hole punched out was placed on the man's arm in order to eliminate rim burns, and the mouth of the vial was set against the tape. The time of exposure was carefully regulated with the aid of a stop-watch.

The results obtained, although consistent within themselves, do not agree with those obtained in a dynamic system. We were unable to produce more than 25% blisters with mustard at a 6' exposure at 27°C. (Ct - 6700 mg.min./m^3, assuming saturated vapor), and could not get 50% erythemas with lewisite vapor at a Ct of approximately 4600.

Vesicant Vapors -- Dynamic Flow Apparatus - The apparatus used at the University of Chicago Toxicity Laboratory for testing vesicant vapor consists of a bubbler of vesicant through which a stream of nitrogen is passed. The degree of saturation of the nitrogen is calculated from the weight loss of the bubbler and the rate of flow. The stream of vapor is led to four orifices so designed that the gas flows out against the skin from an opening about 8 mm. in diameter and flows away in an outer jacket about 15 mm. in diameter. When the skin of the subject, mouse or human, is applied to this orifice, only the outer jacket is in contact with the skin although only a millimeter or two separates the skin from the lip of the inner (delivery) orifice. The exhaust gas is collected by bubbling through a suitable absorbent and an analysis of the concentration made to check the calculated nominal concentration of vapor. A bubbler containing water is used for adding moisture to the vapor. (For a description of the apparatus and the results obtained with it see Black, DuBois and Lipton, OSRD No. 3944, July 1944).

The Ct's (mg.min./m^3) which will cause erythemas and blisters on human skin, in 50 or 100% of the cases, may be taken as end points. Vapors of other vesicants may be compared with that of a standard vapor, such as H.

A similar apparatus was constructed at the Naval Research Laboratory, but was not used extensively, having been superceded by the arm chamber and the man chamber, both of which are agitated static systems.

[redacted]CRET-

[redacted]

MUSTARD VAPOR

Series	Temp. Vapor Cup	Time on	Temp. R. H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
2/15/43								
V	21.5°C	3 min.	62°F. 28%	8	1	5	0	-
W		4 min.		10	3	7	0	-
X		6 min.						
2/17/43								
I	20°C	5 min.	69°F. 51%	10	10	3	1	3
J		6 min.		10	10	3	0	-
K		7 min.		10	10	8	0	-
2/22/43								
A	24.5°C	4 min.	72°F. 31%	10	10	7	0	-
B		5 min.		8	8	9	1	6
C		6 min.		10	10	9	2	5
3/2/43								
W	27°C	6 min.	69°F. 18%	28	27	9	6	7
			LEWISITE VAPOR					
3/17/43								
FF	20°C	45 sec.	65°F. 41%	14	0	-	0	-
4/27/43								
L	21°C	60 sec.	67°F. 62%	9	0	-	0	-
M	21°C	75 sec.	67°F. 62%	10	2	5	0	-
N	21°C	90 sec.	67°F. 62%	10	2	10	0	-
5/4/43								
C, D	21°C	120 sec.	76°F. 28%	20	8	9	5	7

[redacted]

Absolute Vesication - Loss of a compound by evaporation from the skin is a factor in determining its vesicant power, and this factor becomes increasingly critical as the dose is lowered. Accordingly, it is sometimes desirable to determine the absolute vesicancy of agents under consideration. To do this, evaporation is controlled by application of a piece of cellophane or a glass coverslip over the droplet of vesicant after it has been applied to the skin. The cover is left in place for intervals varying from 5 to 10 minutes. Some volatile agents which do not blister the skin even when applied in large amounts will cause blisters at low doses under conditions of "absolute" or "closed" vesication, and it is probable that the vesicancy of all compounds is increased under these conditions. We should run closed tests on all of the very volatile compounds which have been found to be nonvesicant in open tests.

By our routine methods of testing ED would have been classed nonvesicant; in a dose of 0.4 mg. it failed to produce any irritation on 10 men in a test on October 14, 1942, Series I. However, by the "closed" or "absolute" method of test, ED is a potent vesicant.

On September 14, 1942, ED was applied with the Edgewood Rod #3 to two sites on the same arm of 9 men. The lower site was covered for 5 minutes by a glass coverslip held down with cellulose tape. Care was taken to select an area without hair so that the coverslip would be directly against the skin. The upper site was left uncovered.

The results show that ED is a very good vesicant when it is not allowed to evaporate (cf. September, 1942, data for L).

Dose: #3 Rod
Indoor Temp. 75°F. Indoor R. H. 72%

Series	Vesicant - ED	No. Men	48-Hour Readings			
			Erythemas		Blisters	
			No.	Size	No.	Size
9/14/42 Y	open vesication	9	0	-	0	-
	closed vesication		9	9	9	5

Other series with ED show the same striking difference, for example the following:

Series	Dose	Temp. and R. H.	No. Men	48-Hour Readings			
				Erythemas		Blisters	
				No.	Size	No.	Size
Open							
10/7/42 F	0.2 mg.	62°F 74%	10	0	-	0	-
10/14/42 I	0.4 mg.	74°F 52%	10	0	-	0	-
Closed 5 Minutes							
10/7/42 G	#3 Rod	62°F 74%	18	12	5	10	4
10/26/42 P	#3 Rod	57°F 29%	20	16	7	14	4
Closed 10 Minutes							
10/14/42 KK	#3 Rod	74°F 52%	10	9	7	7	7
10/14/42 LL	#3 Rod	74°F 52%	10	10	7	6	7

Further evidence of the difference between closed and open vesication may be found in the following two series in which H was compared with three of its homologues under conditions of open and closed vesication.

On September 14, 1942, a comparison was made of redistilled Levinstein H (TL 328) with Q (TL 86), 1,2-bis(2-chloroethylmercapto)-propane (TL 153), and 1,3-bis(2-chloroethylmercapto)-2-chloropropane (TL 258), on opposite arms of the same individuals. The vesicants, diluted in diphenyl ether, were applied with the #3 Rod.

Dose: Rod #3 of indicated dilution
Indoor Temp. 75°F. Outdoor Mean Temp. 78°F. R. H. 72%

Series	Concn.	No. Men	Mustard Erythemas No.	Mustard Erythemas Size	Mustard Blisters No.	Mustard Blisters Size	No. Men	Homologues Erythemas No.	Homologues Erythemas Size	Homologues Blisters No.	Homologues Blisters Size
	TL 328							TL 86			
P	15%	15	0	-	0	-	15	15	16	14	10
Q	10%	15	1	5	0	-	15	15	11	14	8
R	3%	15	0	-	0	-	15	12	4	1	2
	TL 328							TL 153			
S	30%	15	6	5	0	-	15	15	10	13	3
T	10%	15	1	3	0	-	15	15	7	4	4
U	3%	15	0	-	0	-	15	4	3	1	1
	TL 328							TL 258			
V	30%	15	10	3	0	-	15	15	10	15	8
W	10%	14	3	3	0	-	14	14	10	14	8
X	3%	15	0	-	0	-	15	15	7	6	5

Extensive analysis of these figures is not warranted because of the small number of men in each series. It is clear, however, that all three related compounds are several times more potent than H under the conditions of this experiment.

On February 8, 1943, these same vesicants were applied undiluted or diluted with diphenyl ether, to opposite arms of the same men with a #3 Rod and covered for 10 minutes by a glass coverslip held down with cellulose tape.

Dose: Rod #3 of indicated dilution
Outdoor Mean Temp. 32°F. Indoor Temp. 62°F. R.H. 36%

Series	Concn.	No. Men	Mustard Erythemas No.	Mustard Erythemas Size	Mustard Blisters No.	Mustard Blisters Size	No. Men	Homologues Erythemas No.	Homologues Erythemas Size	Homologues Blisters No.	Homologues Blisters Size
	TL 328							TL 86			
L	15%	14	13	6	3	4	14	14	10	11	6
M	10%	16	8	5	1	3	16	16	8	2	3
N	3%	-	-	-	-	-	15	7	5	0	-
	TL 328							TL 153			
F	100%	15	15	12	13	8	15	15	12	12	8
O	30%	15	15	9	2	5	15	15	12	4	6
P	10%	15	3	5	0	-	15	10	6	0	-
Q	3%	14	0	-	0	-	14	1	4	0	-
	TL 328							TL 258			
G	100%	15	15	10	13	6	15	15	13	9	5
R	30%	16	15	9	4	4	16	16	9	6	6
S	10%	11	8	6	1	4	11	11	7	1	7
T	3%	15	0	-	0	-	15	6	7	0	-

The wide differences in potency indicated in the open tests is not quite so apparent in the closed tests. It is probable that the differences between the tests reflect the higher volatility of H as compared with the other compounds tested.

It should be pointed out that on September 14, 1942, the date of the first comparison, undiluted H was much more effective than on the date of the second test, and that the "closed" series on February 8 approximately equals the open series on September 14.

Series	Compound	Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
9/14/42-K	Mustard, open	20	20	12	20	9
2/8/43-E	Mustard, closed	15	14	12	14	8
	Mustard, open		13	5	4	3

Vesicancy through Cloth - Vesicants may be modified in their action on skin if contamination takes place through clothing, since liqui in small amounts on clothing acts as vapor on the underlying skin. We have not tested many compounds for vesicant action through cloth, and those which we have tested will be reported elsewhere.

[redacted]

Variables

Condition of the Skin - One of the first problems to be faced in testing vesicants on the skin is that of whether the arms should be washed with a solvent before application of the vesicant. Some authorities recommend that the arm be swabbed with acetone to remove all fatty materials because these substances, if present, greatly facilitate the penetration of the vesicants into the skin; washing with acetone will tend to give a more homogeneous test materi Others object to this procedure as being too much of a "hot-house" test. In practically all of our tests for vesicant action the arms were not swabbed.

Individual Sensitivity - If a small dose of mustard is applied to 10 or 20 individuals under controlled conditions, a variety of reactions is produced. Some of these men may develop blisters while others show only a very small erythema or no reaction. The same is true in varying degree with all materials tested for vesicant action. Any determination of irritancy must then be carried out on a sufficient number of men so that the effect of individual sensitivity is minimized. Under comparable conditions, several groups of 20 men each usually will show similar averages for the number and size of blisters. For final quantitative determinations with the more important gases, larger groups are desirable but are not always available.

An example of the man-to-man variation in a large group (145 men) is the distribution of sizes of lesions produced by 65 γ of H, given in the following table and in Figure 1. (These data are discussed again on page 17).

Experimental Conditions	Diameter (mm.)	No. of Men Erythemas	No. of Men Blisters
Delivery by micrometer buretto	0	-	20
	1	-	1
Date: 4/13/43, Series O,P,Q	2	-	4
Right arm	3	1	11
48-Hour Readings	4	-	27
Temperature:	5	7	33
Indoor 65°F.	6	6	23
Outdoor 34°F.	7	39	21
Indoor R. H. 27%	8	31	4
	9	31	1
	10	21	-
	11	8	-
	12	1	-
	Total	145/145	125/145*
	Aver. Size	9.1 mm.	5.1 mm.*

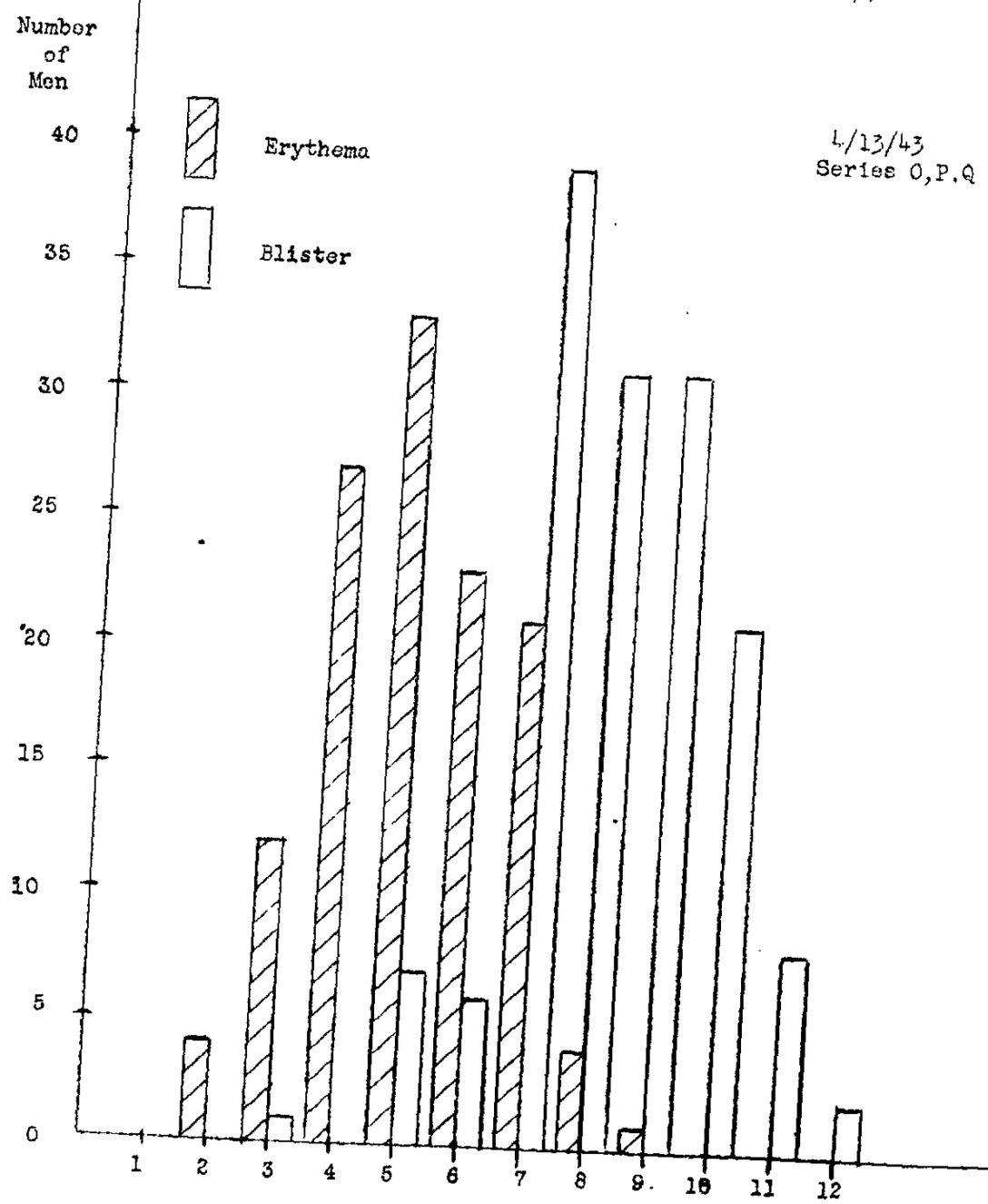
The extremes were a 3-mm. erythema with no blister, and an 11-mm. erythema wi a 9-mm. blister.

It is possible that some of the spread was attributable to slight irregularities in the delivery of the vesicant. Even if all of the men were not under identical conditions, the variation is typical of our results.

* excluding zeros

Figure 1

Distribution of Erythema and Blister Sizes
Among 145 men receiving 65 γ of H
(Delivery by micrometer burette: Temp. 34°F. outdoors,
:5° indoors: relative humidity indoors 27%)



Variations in Size of Lesions at Given Doses Delivered by Micrometer Burette (Modified "Drod")

In order to check the consistency of delivery of the micrometer burette, we applied 0.1 cu.mm. of redistilled Levinstein H (150 γ) to both arms of 41 men.

The 48-hour readings on each man are given in the table below. The tabulation is not in order of consecutive application.

Series M, 2/1/43, Indoor Temp.: 73°F., Indoor R.H.: 25%, Outdoor Temp.: 20°F.

Subject	Right Arm E (mm.)	Right Arm B (mm.)	Left Arm E (mm.)	Left Arm B (mm.)	Subject	Right Arm E (mm.)	Right Arm B (mm.)	Left Arm E (mm.)	Left Arm B (mm.)
1	10	5	10	7	23	14	8	12	8
2	12	7	12	6*	24	20	14	15	9
3	14	10	15	12	25	10	6	14	7*
4	14	8*	15	7*	26	7	-	7	-
5	10	7	10	6	27	9	5	14	9
6	14	9	11	8	28	13	8	12	7
7	14	10*	15	11*	29	17	12	16	10
8	18	12	14	10	30	14	10	12	8
9	10	-	14	10*	31	14	12	10	7
10	11	4	7	5	32	14	10	14	9
11	15	10	12	7	33	14	10	10	7
12	12	9	12	10	34	10	6*	12	8
13	11	8	11	6	35	10	7	12	8
14	9	-	7	-	36	10	6	9	5*
15	15	11	14	10*	37	18	12	17	8
16	15	12	12	8	38	8	6	7	-
17	11	7	10	7	39	12	9	9	7
18	10	7	9	6	40	12	9	10	-
19	9	7*	10	5	41	9	5	10	5
21	10	-	10	-	Average Size:	12.5	8.6	11.9	7.8
22	6	-	12	7*	No.:	(41/41)	(36/41)	(41/41)	(36/41)

* Denotes necrosis

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The distribution of lesion diameters was as follows:

Size in mm.	Right Arm E	Right Arm B	Left Arm E	Left Arm B	Size in mm.	Right Arm E	Right Arm B	Left Arm E	Left Arm B
0	-	5	-	5	11	3	1	2	1
1	-	-	-	-	12	4	5	10	1
2	-	-	-	-	13	1	-	-	-
3	-	-	-	-	14	9	1	6	-
4	-	1	-	-	15	4	-	5	-
5	-	3	-	4	16	-	-	1	-
6	1	4	-	4	17	1	-	1	-
7	1	6	4	10	18	2	-	-	-
8	1	4	-	7	19	-	-	-	-
9	4	4	3	4	20	1	-	-	-
10	9	7	9	5					
				Average:		12.5	8.6	11.9	7.8
				No. Men:		41/41	36/41	41/41	36/41

The average sizes were larger on the right arm than on the left arm. The spread was greater on the right arm (4-14 mm. B) than on the left (5-12 mm. B). Twenty-four of the men had larger blisters on the right arm than on the left, 11 had larger blisters on the left arm, and 6 had the same sized blisters on both arms, including 3 men who had no blisters.

In many of our series, the distribution of lesion size is much more even and over a smaller range than in this particular experiment; however, this case is illustrative of the errors inherent in our work.

Statistical examination of these data shows that the coefficient of correlation for blister diameters on the right arms with those on the left arms is +0.553, and that the difference between the average sizes is not significant ($p = 0.2$). The coefficient of correlation for erythemas is +0.555, and the discrepancy in average diameter is of little significance.

On April 13, 1943, we compared the delivery of 65 γ II by the drod with a No. 27-gauge needle tip, by the drod with the flat tip (7 mm. in diameter) and by two micrometer burettes. The summary of the comparison is given below

Series	Mode of Application	No. Men	48-Hour Readings			
			Erythemas		Blisters	
			No.	Size	No.	Size
4/13/43 Temp. 34°F. outdoors, 65°F. indoors; R.H. 27% indoors						
O	Micrometer burette 3.5 mm. tip (right arm)	48	48	7.9	39	5.1
	Micrometer burette 2 mm. tip (left arm)		48	8.2	43	5.2
P	Micrometer burette 3.5 mm. tip (right arm)	45	45	7.8	40	5.4
	Drod, No. 27 gauge needle tip (left arm)		45	9.0	39	5.9
Q	Micrometer burette 3.5 mm. tip (right arm)	52	52	8.2	46	5.0
	Drod, 7 mm. flat tip (left arm)		52	8.6	39	5.2

Both the number and average size of the blisters produced by the four instruments are comparable. Neither the difference in size observed in Series P nor the difference in number observed in Series Q is statistically significant ($p = 0.10$ for the former, $p = 0.07$ for the latter). The differences in erythema sizes in Series P, however, are significant.

The 48-hour readings on each man are given in the following three tables. The arrangement is at random and does not follow the original order of consecutive application.

The correlation coefficient for blister size was found to be +0.539 for the entire series. The difference in average size for the 145 men is of no consequence ($p = 0.51$). In the case of the erythemas, the correlation is slightly poorer and the differences between the sizes on opposite arms are greater, although not significantly so; much of this difference is in Series P, where the average erythema size on the left arm is significantly greater than that on the right arm ($p = 0.05$).

Arm	Right		Left		Right		Left		Right		Left	
No.	E.	B.	E.	B.	E.	B.	E.	B.	E.	B.	E.	B.
1	8	4	10	7	7	3	7	3	7	4	7	4
2	9	5	8	5	7	4	10	7	7	5	9	7
3	7	5	10	7	8	4	6	3	8	4	8	4*
4	10	8	7	2	7	-	7	-	8	6	10	6
5	7	3	12	10	9	5	6	4	8	4*	7	-
6	6	-	5	-	10	6	9	4	12	7	12	5*
7	9	4	6	3	9	6	14	10	10	4	10	-
8	9	5	9	6	8	4	7	4*	11	7	12	8
9	9	4	12	6	9	5	8	5	11	8	8	5
10	10	6	9	5	9	6	9	6	8	4*	8	6*
11	9	5	9	7	10	6	12	7	8	2	10	7
12	8	5	10	4	10	7	8	4	10	6	9	6
13	5	-	8	6	9	5	11	7	9	5	11	4
14	7	4	6	5	7	-	12	-	11	8	12	7
15	11	7	9	5	8	4	8	5*	7	4	7	5*
16	7	4	8	5	9	5	10	7	5	-	10	5
17	9	7*	12	9	9	3	10	7	8	5	10	5
18	8	6	7	5	9	7	12	9	9	6	8	5
19	7	5	7	5	10	6	15	8	5	2	7	4
20	8	5	6	3*	7	4*	9	5*	7	5*	8	5*
21	6	-	10	-	7	-	8	-	7	4	9	6
22	7	5*	9	6*	7	-	7	-	8	6	9	5
23	8	5	8	7*	10	4*	10	6*	10	7	8	4*
24	7	5	7	5	7	5	8	5	9	7	8	-
25	3	-	7	5*	9	6*	8	5	10	7	8	6
26	9	6	10	7	10	8*	9	7*	11	7	8	5
27	9	6	10	7	10	6	10	6	7	-	7	-
28	5	-	7	4*	7	5	10	7	5	-	7	-
29	9	7	9	6	10	7	9	7*	10	7	11	8
30	8	6	10	7	8	6	7	4*	10	7	11	7
31	10	5*	7	3*	7	5	8	5	9	6	11	2
32	10	7	10	7	7	5	9	5	7	4	6	-
33	9	-	10	8	7	-	6	-	6	3	8	-
34	8	3	7	1	7	5*	4	-	9	3	8	-
35	9	5*	7	4	7	5*	8	6*	7	3	8	3
36	5	-	8	4	8	6*	10	7*	9	7	8	5
37	7	4	8	5	11	9	8	5	8	6	8	6
38	10	7	10	7	7	4	9	6*	7	1	8	2
39	10	7	5	-	8	5	9	5	7	5	9	7
40	8	-	5	-	8	4	10	6	7	3	7	-
41	7	4	10	8	9	5	10	8	8	5	7	-
42	6	4*	9	5*	8	5	9	4	7	5	8	7
43	8	4*	3	-	11	6	10	7	11	5	10	7
44	7	-	5	3*	9	7	11	8	9	6	9	6
45	10	6	7	3	9	7	10	7	9	-	9	-
46	5	2*	8	5					8	5	9	5
47	8	2	9	4*					7	3*	9	5
48	9	7	3	4					6	4	7	-
49									6	-	7	2
50									7	-	8	-
51									8	3	7	3
52									8	3*	9	3
Average	7.9	5.1	8.2	5.2	7.8	5.4	9.0	5.9	8.2	5.0	8.6	5.2
Total	48/48	39/48	48/48	43/48	45/45	40/45	45/45	39/45	52/52	46/52	52/52	39/52

* Denotes necrosis

On May 11, 1945 (Series L), we attempted to deliver 1/96 of a revolution of L (0.025 cu.mm., ca. 48 γ) to both arms of a group of 25 men. The temperature indoors was 65°F., outdoors 47°F.,: indoor relative humidity was 60%. A tabulation of the 48-hour readings shows a very poor agreement between the two arms. The lesion sizes are 1 mm. larger on the left arm, and the average discrepancy in blister diameter between the arms (on 16 men who had blisters on both arms), is 2.4 mm., or 60% of the average blister diameter (4.0 mm.). Under similar conditions on the same day we carried out a similar test (Series N) with 35 γ (0.25 cu.mm.) of tris(2-chloroethylmercapto)phosphine (TL 645).

Dose	0.025 cu.mm. (ca. 48γ)L				0.025 (35 γ) TL 645			
No.	Right Arm		Left Arm		Right Arm		Left Arm	
	E	B	E	B	E	B	E	B
1	5	4	8	7	7	3	4	2*
2	7	6	4	3	10	5	8	5
3	3	1	6	2	6	-	11	8
4	6	6	7	6	13	8	9	5
5	2	-	-	-	10	7	10	7
6	2	-	3	1	8	6	8	4
7	4	3	3	2	10	8	12	10
8	4	3	4	-	12	5	9	7
9	5	4	7	6	10	6	8	4
10	2	1	-	-	12	7	11	7
11	5	4	11	10	13	8	9	6
12	3	1	8	7	8	4	14	10
13	5	5	6	6	8	4	7	-
14	8	7	7	6	12	8	8	5
15	6	5	2	-	8	5	10	7
16	4	2	7	6	14	10	14	9
17	3	-	4	2	10	4	111	8
18	-	-	7	5	10	6	10	7
19	7	5	5	4	9	5	7	4
20	2	1	6	4	9	7	12	10
21	3	2	7	5	9	5	8	6
22	6	3	2	1	12	8	13	9
23	8	5	6	5	9	5	9	5
24					10	7	12	9
25					7	3	13	8
26					11	5	9	4
Average	4.5	3.6	5.6	4.6	9.9	6.0	9.7	6.5
Total	22/23	19/23	22/23	19/23	26/26	25/26	26/26	25/26

* Denotes necrosis

In the experiment with TL 645, the average blister sizes were very close ($p = 0.27$) but the correlation coefficient for blisters was low (+0.218), thus indicating a considerable lack of uniformity of blister diameters on the individual subjects.

The opposite situation holds for the group of men treated with L: a high coefficient of correlation, +0.590, was calculated, but a significant difference in blister sizes was found ($p = 0.04$). It appears that this difference in blister diameter was fairly consistent.

Since relatively few men were used in these tests, too much importance should not be attached to the statistical analyses; however, it is clear, not only from the limited statistical treatment but also from empirical examination of the results, that delivery of 0.025 cu.mm. with the micrometer burette is erratic and hazardous.

We used TL 645 one week later (5/18/43, Series KK) in attempts to deliver $\frac{1}{4}$ small click (0.0125 cu.mm., 17 % of TL 645). The outdoor temperature was 57°F., the indoor temperature 65°F., and the relative humidity 57%. The 48-hour readings were as follows:

	Right Arm		Left Arm			Right Arm		Left Arm	
Subject	E	B	E	B	Subject	E	B	E	B
1	8	-	7	-	6	5	-	5	-
2	10	4	10	5	7	5	-	10	6
3	7	-	7	-	8	10	5	5	-
4	5	-	8	5	9	10	-	6	-
5	10	5	10	5	Average	7.8	4.7	7.7	5.2
					Total	9/9	3/9	9/9	4/9

Since only 9 men were used in this test, no quantitative evaluation of the results may be made. Nevertheless, appreciable discrepancies in size or severity of the lesions on opposite arms of the same man are obvious in four instances (Subjects 4, 7, 8, and 9).

We have reported a few tests in which we delivered 0.025 or 0.0125 cu.mm. with the micrometer burette, but we distrust their validity. We place much more reliance on data obtained at this dose range with the Benesh micropipette.

Effect of Temperature and Exercise

A test carried out on June 1, 1943 revealed how much the effect of H can be varied by exercise prior to application. Two groups of men were chosen from the same company, and consequently were presumed to have had similar activities throughout the day. One group was exercised outdoors (temp. 83°F.) for 15 minutes before the vesicant was applied; all of these men were perspiring freely. The other group remained at rest indoors (temp. 80°F., R.H. 59%) for the same period. Thirty-two micrograms were delivered by micrometer burette. The following readings were made at 48 hours.

Series	Condition of Men	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	%
Series AA	Men exercised	38	38	9	37	6	97
Series BB	Men at rest	47	47	8	26	5	55

The above results indicate what can happen, and doubtless has happened at other times, under our present working conditions: namely, two companies of men tested on the same day have dissimilar activities before reporting for tests, and react differently to the test.

The phenomenon is most apparent in hot weather. A previous experiment of this type, attempted on October 26, 1942, using both H and L, revealed no differences among seven series with varying conditions of exercise and temperature.

Dose: Rod #3 Indoor temp.: 58°F.
Outdoor mean temp.: 30°F. Indoor R. H.: 29%

Series 10/26/42	TL No.	Exercise before application (min.)	Time in hall after application (hrs.)	Exercise after application (min.)	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
A	328 H	0	2	0	10	10	6	6	3
D		5	2	0	15	15	6	7	3
F		0	2	20	9	9	6	3	2
H		0	1	0	10	10	6	6	3
J		5	1	0	7	6	5	3	3
L		0	0 (men outdoors for 1 hr.)	0	11	11	5	4	3
N		5	0 " "	0	10	10	4	4	5
B	327 L	0	2	0	10	10	5	10	4
E		5	2	0	22	22	7	20	5
G		0	2	20	10	10	7	10	5
I		0	1	0	10	10	7	10	5
K		5	1	0	10	10	7	10	5
M		0	0 (men outdoors for 1 hr.)	0	9	9	7	9	6
O		5	0 " "	0	10	10	7	8	5

The effect of temperature was brought out on January 11, 1943, in the course of an experiment planned for another purpose. At 1:00 P.M., four companies of men arrived in a drill hall. Each company made up one group, and the groups were run through H-decontamination tests at approximately 30-minute intervals, so that at the time of test the fourth group had been indoors about 90 minutes longer than the first. The outdoor temperature was 30°F.; the indoor temperature was 63°F.; the indoor relative humidity, 33%. Below are the 48-hour readings on the untreated controls each of whom had received 130 γ of redistilled Levinstein H. Note that there is a progressive rise in blister percentages with increased time indoors, and that the percentage of blisters x blister diameter increases progressively.

Series 1/11/43	Time indoors before application (min.)	Dose (γ)	No. Men	48-Hour Readings					Av. Size Blisters x %
				Erythemas		Blisters			
				No.	Size	No.	Size	%	
B	15	130	70	70	7	43	4	62	250
C	45	130	88	88	9	58	6	66	400
D	75	130	65	65	9	46	7	69	450
E	105	130	65	65	10	56	6	86	520

The effect of a slight increase in temperature in hot weather is demonstrated by the following experiment performed July 20, 1943. Two groups were tested, one in the morning (AAA-1) and one in the afternoon (AAA-2). Mustard was applied to both arms, by Rod #3 to the right and by Rod #5 to the left. Meterological data were as follows:

	A.M.	P.M.
Outdoor temperature	85°F.	92°F.
Indoor temperature	80°F.	86°F.
Relative humidity (indoors)	62%	50%

Neither group had been exercised strenously, and both groups had been indoors about the same length of time before application of mustard.

Series 7/20/43	Dose	No. Men	48-Hour Readings			
			Erythemas		Blisters	
			No.	Size	No.	Size

[redacted]

Seasonal Effects

Effects of Diluents on the Vesicant Action of Mustard

In the quantitative evaluation of one vesicant in terms of another, it is necessary to relate both to the same standard. At the beginning of the work in this laboratory, that dilution of vesicant in diphenyl ether[1] which blistered 50% of the men with a Rod #5 was chosen as the arbitrary standard.

The objections to this method are several: first, the fact that the dose delivered by a rod is not known until time-consuming calibrations have been carried out for each compound and each dilution tested; second, the effect of a solvent on the penetrability of the vesicant; and third, the effect of variable doses per unit volume and doses per unit skin area.

This first objection has been circumvented by the use of the micrometer burette, which, since it delivers a constant unit volume, can be relied upon to deliver a known dose.

An experiment performed on April 27, 1943, brings out the second and third objections in striking fashion. The data show (1) that mustard diluted in dioxane is more vesicant than mustard diluted in diphenyl ether (D.P.E.); and (2) that a given volume of a 50% solution (in either dioxane or D.P.E.) is not equal to half of the volume of undiluted mustard; and similarly, that a given volume of 50% solution is more potent that twice the volume of a 25% solution.

Such striking discrepancies resulting from the use of solvents have led us to develop methods by which small amounts of vesicants may be applied full strength. Our comparisons are now carried out with the Benesh micropipette.

When it is necessary for us to examine a solid, we use a relatively nonvolatile solvent (D.P.E. dioxane, propylene glycol, cellosolve), since evaporation at the delivery tip of the micrometer burette would clog the capillary if acetone, benzene, chloroform, or ether was used.

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[1] The use of a nonvolatile solvent such as diphenyl ether was essential in the case of a solid delivered by rod, since a volatile solvent would evaporate, leaving the solid material on a dry pad.

Vesicant: H, delivered by micrometer burette Outdoor temp. 62°F.
Indoor R. H. 62% Indoor temp. 67°F.

Series 4/27/43	Vol. Del. (cu.mm.)	Dose (γ)	Concn. and Solvent	No. Men	48-Hour Readings			
					Erythemas		Blisters	
					No.	Size	No.	Size
AA	0.05	65	100%	18	18	7	12	6
	0.10		50% D.P.E.		17	7	0	-
BB	0.05	65	100%	17	17	7	13	5
	0.10		50% dioxane		17	6	7	5
CC	0.05	65	100%	19	19	8	14	5
	0.20		25% D.P.E.		9	5	1	4
DD	0.05	65	100%	19	19	8	14	5
	0.20		25% dioxane		18	7	2	5
EE	0.05	32	50% dioxane	16	16	4	2	2
	0.05		50% D.P.E.		14	4	0	-
GG	0.05	32	50% dioxane	18	17	5	4	7
	0.10		25% dioxane		16	4	0	-
HH	0.05	32	50% D.P.E.	18	17	3	0	-
	0.10		25% D.P.E.		4	3	0	-
FF	0.05	32	50% dioxane	20	20	5	4	4
	0.10		25% D.P.E.		3	4	0	-
II	0.05	32	50% D.P.E.	15	14	3	1	1
	0.10		25% dioxane		15	4	0	-

When pentane is added to H in a ratio of 1:9, at the dose used in the test, there is practically no change in the vesicant action as compared with undiluted H.

Temp.: 78°F. R.H. 65%

Series	Vesicant	Dose (γ)	No. Men	48-Hour Readings			
				Erythemas		Blisters	
				No.	Size	No.	Size
8/3/43 M	H, 100%	32	15	15	8	15	4
	H, 90% in pentane			15	8	13	4

[redacted]

Solutions of Lovinstein redistilled H, 1% and 25% in ethyl cellosolve, were compared with undiluted mustard at doses of 0.025 and 0.1 cu.mm. Deliveries were made with the micrometer burette.

In every case, undiluted H was far superior to an equal volume of the dilution. However, delivery of 30 γ of H as 0.1 cu.mm. of a 25% solution produced approximately the same percentage and size of blisters ad did delivery of 0.025 cu.mm. (32 γ) of 100% H. This observation may be criticized since the two series were not run on the same day. It should be repeated on the same group of men

Series	Concn. H	Vol. Del. (cu.mm.)	Wt. H Del. (γ)	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
	Temp.: 66°F., R.H. 34%							
11/9/43 S	1% in cellosolve	0.025	0.3	30	0	-	0	-
	100%		32		29	7	12	4
	Temp.: 60°F., R.H. 63%							
11/22/43 O	1% in cellosolve	0.1	1	18	0	-	0	-
	100%		130		18	13	17	8
	Temp.: 60°F., R.H. 63%							
11/22/43 P	25% in cellosolve	0.1	30	19	19	7	6	5
	100%		130		19	13	19	8

Effect of Race -- Reaction of Negro Skin to H, L, and HN2

That Negroes are less sensitive to the vesicant actions of H, L, and HN2 was demonstrated on March 23, 1943. There was an impressive difference between Negroes and whites in the number and sizes of erythemas and blisters with both H and HN2. In the case of L, nearly all of the Negroes blistered, but the lesion sizes were appreciably smaller. The indoor temperature was 75°F. and the indoor relative humidity 40%. The outdoor temperature was 50°F.

Series 3/23/43	Vesicant	Dose	Race	No. Men	48-Hour Readings			
					Erythemas		Blisters	
					No.	Size	No.	Size
T	H (redistilled Levinstein)	65	Whites	38	38	9	32	6
W	H	65	Negroes	30	29	6	8	3
S	L (redistilled)	Rod #3	Whites	30	30	9	30	7
V	L	Rod #3	Negroes	33	33	6	32	4
R	HN2	170	Whites	35	26	6	6	3
U	HN2	170	Negroes	30	8	4	0	-

Complexion

Between February and December, 1942, records were kept on 20,000 men, involving hair and eye color, sensitivity to poison ivy, and sensitivity to sunlight. These data have not been subjected to statistical analysis.

Nutritional State

We have no data on nutritional effects; all of our human volunteers are presumably well-nourished and are obtaining all dietary essentials in abundance.

II. REDISTILLED LEVINSTEIN MUSTARD

A large number of data have been accumulated from untreated controls of decontamination and protection tests. Those for H, together with the other data on this vesicant, are presented here. A similar collection of tests with L are given in Section III.

The first tables are summaries of daily and monthly blister percentages, and the others are compiled by individual tests.*

The first part of the work was done with an Edgewood Rod #3, which was supplanted by a Rod #5 and then Rod #6 as the weather became colder. In January, 1943, the micrometer burette was used routinely for the application of mustard.

The graphs of monthly variations (Figures 2 and 3) show a parallelism among the rods, and another between the two doses of 130 and 65 micrograms. The variations from month to month, however, are very difficult to explain. With both 65 and 130 micrograms, for example, the percentages of blisters fall from March through May. It was expected that the percentage would be lowest in December and January, and that it would begin to rise during February and March, but the decline in April and May is unexplainable. Similarly, with the rods, there is an unexplainable minimum in October, followed by a rise to a November average above that for September.

The second table is arranged by dose -- first the miscellaneous data of mustard in dilutions, and then the data with Rod #3, Rod #5, Rod #6, and micrometer burette.

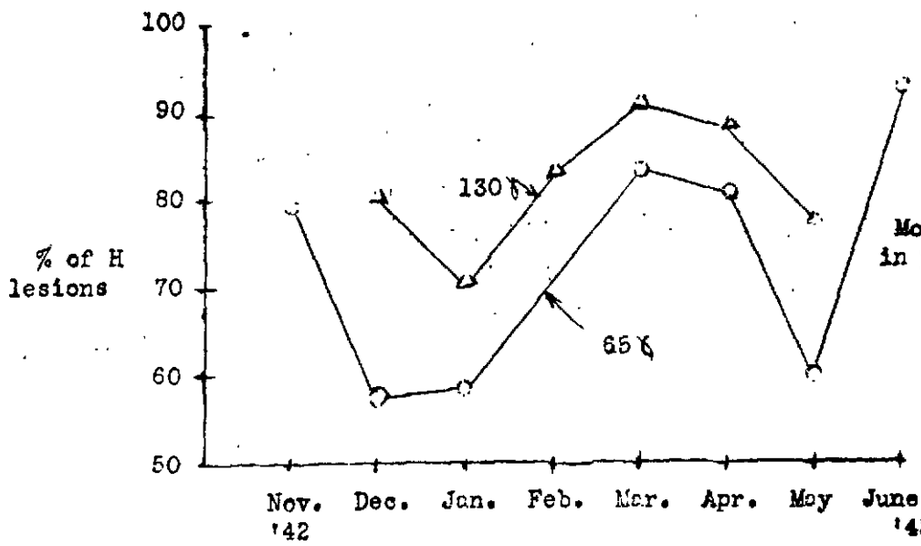

Figure 3

Monthly variation in % of H lesions

* These same data were used by Dr. Sewall Wright in his discussion of seasonal effect.

SECRET

Daily and Monthly Percentages of Blisters
In 48-Hour Tests With Mustard

Dose. Pad #3 (32 micrograms)

Date	Blisters (at 48 hours) No.	Av. Size (mm.)	%	Indoor Temp. (°F)	Indoor R.H. (%)	Outdoor Mean Temp. (°F)
2/24/42	7/3	5	88	-	-	46
3/2/42	39/39	5	100	-	-	34
3/17/42	36/40	5	90	-	-	42
3/26/42	37/39	5	95	-	-	52
3/31/42	10/15	5	67	-	-	39
Totals for March '42	122/133	5	92			
4/3/42	9/9	6	100	-	-	39
4/9/42	19/22	6	86	-	-	38
4/16/42	31/33	7	94	-	-	68
Totals for April '42	59/64	6	92			
6/9/42	37/37	6	100	-	-	64
6/22/42	48/52	3	92	-	-	67
Totals for June '42	85/89	4	96			
7/14/42	85/101	3	85	66	-	56
8/5/42	118/122	6	97	-	-	70
8/31/42	10/10	5	100	-	-	79
Totals for August '42	128/132	6	97			
9/14/42	61/61	9	100	82	64	78
9/16/42	154/158	7	97	76	72	76
9/22/42	78/232	3	34	59	47	52
9/29/42	15/22	3	68	74	42	48
Totals for Sept. '42	308/473	6	65			
10/19/42	18/60	4	30	68	41	58
11/9/42	64/79	6	81	73	46	54
11/11/42	59/87	3	68	73	31	35
Totals for Nov. '42	123/166	4	74			
12/14/42	13/27	4	48	55	-	16
2/8/43	4/15	3	27	62	36	32
4/6/43	12/16	6	75	76	28	38
7/20/43 (A.M.)	10/15	3	67	80	62	80
7/20/43 (A.M.)	25/26	6	96	86	50	
Totals for July '43	35/41	5	85			

(Table con't. on next page)

Dose: Rod #5 (60 micrograms)

Date	Blisters (at 48 hrs.) No.	Av. Size (mm.)	%	In-door Temp. (°F.)	In-door R.H. (%)	Out-door Mean Temp. (°F.)
9/8/42	8/10	6	80	73	78	71
9/9/42	8/10	6	80	75	87	71
Totals for September '42	16/20	6	80			
10/21/42	17/20	4	85	71	45	50
10/26/42	33/72	3	46	58	29	30
Totals for October '42	50/92	3	54			
11/9/42	49/55	7	89	73	46	54
12/7/42	17/20	6	85	--	--	16
12/14/42	16/21	5	76	55	--	16
Totals for December '42	33/41	6	80			
4/6/43	10/20	5	50	76	28	38
7/20/43 (A.M.)	13/15	5	87	80	62	80
7/20/43 (P.M.)	24/26	8	92	86	50	
Totals for July '43	37/41	7	90			
11/22/43	5/9	7	55	60	63	35

Dose: Rod #6 (88 micrograms)

11/9/42	218/236	6	92	73	46	54
12/7/42	103/119	5	87	--	--	16
12/8/42	146/183	5	80	--	--	18
12/9/42	149/190	6	78	55	54	25
12/14/42	283/336	7	84	55	--	16
12/28/42	15/30	5	50	68	--	34
Totals for December '42	696/858	6	81			
1/4/43	21/40	7	53	68	25	16
2/16/43	19/20	5	95	63	21	12
2/24/43	10/11	7	91	69	48	30
Totals for February, '43	29/31	6	93			
3/2/43	149/161	6	93	69	18	6
4/5/43	102/111	7	92	74	11	42

(Table con't. on next page)

Dose: .5 micrograms (micrometer burette)

Date	Blisters (at 48 hrs.) No.	Av. Size (mm.)	%	Indoor Temp. (°F.)	Indoor R.H. (%)	Outdoor Mean Temp. (°F.)
11/9/42	1[illegible]/18	4	89	73	46	54
12/7/42	13/20	3	65	-	-	16
12/14/42	14/27	5	55	55	-	16
Totals for December '42	27/47	4	57			
1/6/43	70/119	5	58	69	42	26
3/17/43	18/20	5	90	65	41	30
3/23/43	52/63	6	83	75	40	38
Totals for March '43	70/83	6	84			
4/13/43	245/2[illegible]	5	85	65	28	32
4/27/43	53/73	5	73	67	62	60
Totals for April '43	29[illegible]/36[illegible]	5	82			
5/4/43	92/148	5	62	73	27	55
5/18/43	12/17	6	71	73	50	52
5/25/43	2/10	11	20	75	40	54
Totals for May '43	10[illegible]/17[illegible]	5	61			
6/1/43	12/12	7	100	78	73	78
6/8/43	12/15	7	80	62	75	56
6/15/43	68/72	6	94	84	56	78
Totals for June '43	9[illegible]/99	6	94			

(Table con't. on next page)

Dose: 130 micrograms (approximately)

Date	Blisters (at 48 hours) No.	Av. Size (mm.)	%	Indoor Temp. (°F.)	Indoor R.H. (%)	Outdoor Mean Temp. (°F.)
12/12/42	39/47	6	81	55	-	15
1/5/43	343/405	6	85	71	17	13
1/6/43	5/9	6	45	69	24	26
1/11/43	208/288	6	72	63	33	24
1/12/43	167/215	7	78	64	33	10
1/18/43	122/295	6	41	70	46	24
1/20/43	16/30	6	53	63	37	2
1/26/43	176/184	7	95	67	15	10
Totals for January '43	1032/1242	6	73			
2/1/43	124/140	8	89	73	25	14
2/2/43	43/47	7	91	70	21	26
2/3/43	23/27	6	85	72	31	38
2/8/43	16/19	6	89	62	36	32
2/9/43	23/29	7	79	60	34	41
2/10/43	11/22	7	50	59	20	32
2/15/43	15/18	6	83	62	28	7
2/23/43	72/86	7	83	67	30	42
2/24/43	14/15	8	94	69	48	30
Totals for February '43	341/403	7	84			
3/3/43	55/63	7	87	71	23	8
3/9/43	60/61	9	98	74	72	32
3/17/43	151/166	9	92	65	41	30
3/23/43	127/131	9	97	75	40	38
3/30/43	14/15	10	87	71	-	64
Totals for March '43	401/439	8	92			
4/6/43	23/29	7	79	76	28	38
4/13/43	219/233	8	94	65	28	32
4/27/43	42/58	9	73	67	62	60
Totals for April '43	284/320	8	89			
5/4/43	58/89	7	65	76	28	55
5/11/43	49/54	9	90	65	40	48
5/18/43	23/24	10	96	65	70	52
5/25/43	20/29	7	69	70	48	54
Totals for May '43	150/196	8	77			
11/2/43	40/50	7	80	64	38	44
11/9/43	60/67	8	90	66	34	32
11/16/43	166/194	8	86	65	47	26
11/22/43	69/73	8	91	60	63	37
Totals for November '43	335/384	8	87			

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Tabulation of Individual Tests With Mustard

Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Rod No. 3 (3% D.P.E.)							
9/14/42	R	76°72%	15	0	-	0	-
	U	"	15	0	-	0	-
	X	"	15	0	-	0	-
(10% D.P.E.)							
	Q	76°72%	15	1	5	0	-
	W	"	14	3	3	0	-
	T	N.R.	15	1	3	0	-
(15% D.P.E.)							
	P	76°72%	15	0	-	0	-
(25% D.P.E.)							
7/6/43	AA	76°28%	15	2	5	0	-
(30% D.P.E.)							
9/14/42	S	76°72%	15	6	5	0	-
	V	"	15	10	3	0	-
9/29/42	C	74°42%	10	10	4	0	-
(50% D.P.E.)							
4/6/43		76°28%	15	15	7	4	1
9/29/42	B	74°42%	11	10	5	2	2
	E	"	10	10	5	1	1
Rod No. 5 (2½% D.P.E.)							
1/11/43	A-2	63°33%	10	0	-	0	-
(5% D.P.E.)							
1/11/43	A-1	63°33%	10	0	-	0	-
(10% D.P.E.)							
1/18/43	A	71°48%	10	0	-	0	-
(15% D.P.E.)							
1/18/43	B	71°48%	8	0	-	0	-
(35% D.P.E.)							
2/16/42	A	N.R.	24	22	N.R.	5	N.R.
2/24/42	D	"	9	8	"	2	7
(40% D.P.E.)							
2/16/42	A	N.R.	24	23	N.R.	4	N.R.
(45% D.P.E.)							
2/17/42	A	N.R.	20	20	N.R.	15	4
(50% D.P.E.)							
2/17/42	A	N.R.	20	20	N.R.	5	6
3/3/42	B	"	20	19	"	13	4
(60% D.P.E.)							
2/23/42	A	N.R.	49	47	N.R.	22	5
2/24/42	D	"	9	9	"	5	5
2/25/42	A	"	24	24	"	9	4
2/25/42	A	"	24	24	"	10	4
(70% D.P.E.)							
2/25/42	A	N.R.	24	24	N.R.	10	4
3/11/42	A	"	51	49	"	41	5
(80% D.P.E.)							
3/3/42	B	N.R.	20	20	N.R.	20	5
(90% D.P.E.)							
3/3/42	B	N.R.	20	20	N.R.	20	5

Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Rod No. 6 (20% D.P.E.)							
2/2/43	M	71°21%	20	9	4	0	-
(25% D.P.E.)							
2/2/43	N	71°21%	17	8	6	0	-
Rod No. 5 (100% H)							
2/24/42	A	N.R.	8	8	N.R.	7	5
3/2/42	A	"	19	19	"	19	6
	B	"	20	20	"	20	5
3/17/42	B	"	10	10	"	10	5
	C	"	10	10	"	6	4
3/26/42	A	"	11	11	"	11	5
	B	"	9	9	"	8	4
	C	"	9	9	"	8	4
	D	"	10	10	"	10	5
3/31/42	D	"	15	15	1	10	5
4/8/42	B	"	9	9	N.R.	9	6
4/9/42	A	"	8	7	"	7	5
	B	"	6	6	"	5	7
	C	"	8	8	"	7	6
4/16/42	A	"	9	9	1	9	7
	B	"	7	7	1	5	7
	C	"	8	8	1	8	7
	D	"	9	9	1	9	6
5/8/42	A-1	"	37	37	N.R.	37	6
6/22/42	A-1	"	52	52	"	48	3
7/14/42	H	66°	55	55	6	43	3
	I	"	46	46	7	42	3
8/5/42	Q	N.R.	20	20	10	19	6
	R	"	20	20	13	20	7
	S	"	20	20	13	20	8
	T	"	20	20	9	19	5
	U	"	22	22	10	21	6
	V	"	20	20	10	19	6
8/31/42	A	"	10	10	10	10	5
9/2/42	A	82°64%	10	10	11	10	7
9/14/42	L	76°72%	2	2	14	2	10
	K	"	20	20	12	20	9
	J	"	20	20	11	20	8
9/16/42	K	74°78%	20	20	11	20	8
	L	"	20	20	10	20	7
	N	"	20	20	8	20	6
	R	"	10	10	11	10	6
	S	"	10	10	11	10	7
	U	"	10	10	12	10	9
	O	"	19	19	9	19	6
	V	"	10	10	12	9	7
	Q	"	20	20	9	19	6
	P	"	19	19	10	18	7

Series		Temp. F. & R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Rod No. 3 (100% H)							
7/[illegible]/42	J	[illegible]	20	20	5	5	2
	K	"	20	19	5	3	1
	L	"	19	18	4	5	2
	M	"	20	18	5	1	1
	N	"	20	20	4	2	3
	O	"	19	19	4	2	2
	P	"	19	19	4	3	4
	Q	"	19	18	5	2	4
	R	"	20	20	6	14	2
	S	"	19	19	5	12	3
	T	"	19	19	5	15	3
	U	"	18	18	5	11	2
9/29/42	A	74°42%	11	11	6	7	4
	D		11	11	7	8	3
10/19/42	I	68°41%	21	21	5	7	4
	J	"	19	19	6	4	2
	K	"	20	20	5	7	2
11/9/42	O	73°46%	58	57	8	47	6
	Q	"	21	21	7	17	5
11/11/42	A	73°31%	14	14	5	7	2
	B	"	15	15	6	10	3
	C	"	15	15	6	10	3
	D	"	14	14	5	12	2
	E	"	15	15	5	10	3
	F	"	14	14	6	10	3
12/14/42	S	55°	27	27	7	13	4
2/[illegible]/43	E	62°36%	15	13	5	4	3
4/5/43	Y	76°28%	16	16	10	12	6
7/20/43							
	AAA-1	80°62%	15	15	5	10	3
	AAA-2	86°50%	26	26	9	25	6
Rod No. 5 (100% H)							
9/8/42	P	73°78%	10	10	10	8	6
9/9/42	A	76°87%	10	10	11	8	6
10/21/42	D	71°45%	20	20	7	17	4
10/26/42	A	58°29%	10	10	6	6	3
	D	"	15	15	6	7	3
	F	"	9	9	6	3	2
	H	"	10	10	6	6	3
	J	"	7	6	5	3	3
	L	"	11	11	5	4	3
	N	"	10	10	4	4	4
11/9/42	P	76°46%	17	17	10	16	8
	P	"	19	19	10	17	7
	P	"	19	19	8	16	6
12/7/42	O	N.R.	20	20	10	17	6
12/14/42	T	55°	21	21	10	16	5
4/6/43	X	76°28%	20	20	10	9	7
7/20/43							
	AAA-1	80°62%	15	15	7	13	5
	AAA-2	86°50%	26	26	11	24	8
11/22/43	E	60°63%	9	9	7	5	9

Series		Temp. F. & R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Rod No. 6 (100% H)							
11/9/42	A	73°46%	10	10	6	7	4
	B	"	10	10	8	10	4
	C	"	10	10	8	9	4
	D	"	9	9	7	7	3
	E	"	20	20	8	14	4
	F	"	20	20	10	19	4
	G	"	19	19	8	18	4
	H	"	20	20	11	20	4
	I	"	20	20	8	20	4
	J	"	20	20	7	19	4
	K	"	19	19	9	18	4
	L	"	19	19	8	19	4
	M	"	20	20	9	19	4
	N	"	20	20	8	19	4
12/7/42	L	N.R.	39	38	9	35	4
	M	"	40	40	8	36	4
	N	"	40	39	7	32	4
12/8/42	A	"	19	19	8	13	4
	B	"	18	18	9	17	4
	C	"	20	20	9	19	4
	D	"	17	17	10	16	4
	E	"	20	20	9	16	4
	F	"	20	20	8	18	4
	G	"	20	20	8	15	4
	H	"	20	20	8	13	4
	I	"	19	19	7	12	4
	J	"	10	10	8	7	4
12/9/42	M	55°54%	10	10	10	9	4
	O	"	35	35	8	27	4
	P	"	26	26	8	26	4
	Q	"	30	30	8	23	4
	R	"	29	29	9	26	4
	S	"	30	30	10	17	4
	T	"	30	30	8	21	4
12/14/42	A	55° est.	20	20	6	20	4
	B	"	21	21	11	21	4
	C	"	18	18	9	15	4
	D	"	20	20	8	16	4
	E	"	19	18	8	12	4
	F	"	20	20	12	18	4
	G	"	19	19	12	19	4
	H	"	19	19	12	16	4
	I	"	18	18	12	13	1
	J	"	19	19	10	18	4
	K	"	22	22	11	20	4
	L	"	18	18	8	16	4
	M	"	27	27	11	22	4
	N	"	26	26	12	23	4
	O	"	24	24	10	15	4
	U	N.R.	26	25	9	19	4

Series		Temp. F. P.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Pol No. 5 (100% H).							
12/23/42	S	68°	15	15	6	7	4
	T	"	15	15	7	8	5
1/1/43	G	68°25%	20	19	5	11	7
	H	"	20	20	6	10	6
2/16/43	J	63°21%	10	10	8	9	5
	K	"	10	10	5	10	5
2/24/43	I	66°48%	11	11	11	10	7
3/2/43	E	69°18%	10	10	10	10	6
	F	"	10	10	11	9	7
	G	"	9	9	13	9	7
	H	"	11	11	10	11	6
	I	"	22	22	11	21	6
	J	"	20	20	8	19	5
	K	"	20	20	11	19	6
	L	"	19	19	7	18	4
	M	"	21	21	9	19	5
	N	"	19	19	7	16	4
4/5/43	D	74°21%	13	13	11	12	7
	E	"	25	25	12	22	8
	F	"	26	26	13	25	9
	G	"	25	25	13	25	8
	H	"	22	22	10	18	6
3% (5% dioxane)							
5/4/43	Q	76°28%	21	0	-	0	-
7% (0% dioxane)							
5/4/43	P	76°28%	23	14	3	0	-
16% (25% dioxane)							
5/4/43	O	76°28%	22	18	4	0	-
32% (50% dioxane)							
5/4/43	N	76°28%	23	22	5	1	5
16% (100% H)							
5/25/43	M	70°48%	11	7	5	1	2
	Q	"	14	0	-	0	-
5/25/43	EE	75°40%	14	10	6	2	4
6/1/43	J	78°73%	29	26	7	12	4
6/22/43	S	79°66%	24	21	5	8	3
6/29/43	N	69°53%	48	40	6	12	2
32% (100% H)							
5/25/43	N	70°48%	15	8	4	0	-
	R	"	19	14	6	3	4
	DD	75°40%	19	5	4	0	-
7/6/43	VV	74°77%	28	27	3	25	5
	WW	"	30	30	8	27	4
8/3/43	K	78°65%	17	17	9	17	6
	L	"	17	17	8	17	4
	M	"	15	15	8	15	4
10/13/43	A	69°72%	152	127	9	108	5
11/9/43	R	66°34%	30	29	7	12	4

Series		Temp. F. P.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
65% (100% H)							
11/9/42	R		18	18	7	16	8
	S		20	20	7	13	5
12/7/42	O	N.R.	20	19	7	13	3
12/14/42	S	55°	27	26	7	14	5
1/6/43	A	69°24%	20	20	8	12	4
	B	"	20	20	8	16	6
	C	"	19	19	7	13	4
	D	"	20	20	7	11	5
	E	"	20	20	8	7	5
	F	"	20	13	7	11	6
3/17/43	LL	65°41%	20	20	8	18	5
3/23/43	J	75°40%	25	25	10	20	8
	T	"	38	38	9	32	6
	W	"	30	29	6	8	3
4/13/43*	O	65°28%	48	48	8	39	5
" **	O	"	48	48	9	43	5
4/13/43*	P	"	45	45	9	40	9
" ***	P		45	45	9	38	6
4/13/43*	Q	"	52	52	8	46	5
" ****	Q	"	52	52	8	39	6
4/27/43	AA	67°62%	18	18	7	12	6
	BB	"	17	17	7	13	5
	CC	"	19	19	8	14	5
	DD	"	19	19	8	14	5
5/4/43	AA	73°27%	15	15	7	12	4
	BB	"	12	12	9	9	6
	CC	"	14	14	7	9	5
	U	"	15	15	7	10	5
	M	76°28%	24	24	6	7	4
	V	73°27%	13	13	8	11	5
	W	"	12	12	9	9	5
	X	"	14	13	7	9	4
	Y	"	14	14	7	7	4
	Z	"	15	15	8	9	3
5/18/43	H	73°50%	7	6	9	4	4
	L	"	10	9	11	8	7
5/25/43	CC	75°40%	10	3	13	2	11
6/1/43	I	78°73%	12	12	11	12	7
6/8/43	R	62°75%	15	15	10	13	7
6/15/43	T	80°61%	62	62	12	61	6
	SS	84°56%	10	10	8	7	5
98% (100% H)							
5/25/43	BB	75°40%	11	7	11	4	10

* Microburette (3.5-mm. tip)
** Microburette (2-mm. tip)
*** Drod (needle tip)
**** Drod (flat tip)

-SECRET-

Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
130? (100% H)							
12/14/42	U		26	26	10	23	6
	T		21	20	10	15	6
1/5/43	A	71°17%	20	20	10	20	7
	B	"	20	20	10	17	7
	C	"	20	20	9	17	6
	D	"	20	20	11	20	8
	E	"	19	18	9	14	5
	F	"	20	20	8	16	6
	G	"	20	20	8	16	6
	H	"	20	20	11	20	8
	I	"	20	20	10	18	5
	J	"	20	20	10	19	8
	K	"	20	20	7	13	6
	L	"	20	20	7	16	5
	M	"	20	20	7	13	6
	N	"	19	19	7	14	6
	O		20	20	7	16	7
	P	"	19	19	10	17	7
	Q	"	21	21	10	19	7
	R	"	16	16	10	15	7
	S	"	15	15	9	15	4
	T	"	18	18	9	14	5
	U	"	17	17	10	13	6
1/6/43	R	69°24%	9	9	8	5	6
1/11/43	B	63°33%	70	70	7	43	4
	C	"	88	88	9	58	6
	D	"	65	65	9	46	7
	E	"	65	65	10	56	6
1/12/43	A	64°33%	38	38	10	30	6
	B	"	38	38	11	28	7
	E	"	8	8	9	8	5
	F	"	10	10	9	7	6
	G	"	19	19	10	16	6
	H	"	10	10	9	5	9
	I	"	8	8	9	8	8
	J	"	7	7	10	6	8
	K	"	9	9	9	6	6
	L	"	7	7	8	4	6
	M	"	9	9	10	7	8
	N	"	6	6	11	6	7
	O	"	7	7	12	5	9
	P	"	8	8	11	7	8
	Q	"	10	10	10	6	7
	R	"	6	6	11	5	8
	S	"	15	15	10	13	7
1/18/43	C	71°48%	26	26	9	20	4
	D	"	73	68	7	19	6
	E	"	41	39	7	22	5

Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Si
130? (100% H)							
1/18/43	F	71°48%	34	34	7	8	
	●	"	58	56	7	16	
	H	"	63	63	8	37	
1/20/43	I	63°37%	12	12	9	8	
	J	"	18	18	7	7	
							IN.
1/26/43	A	67°15%	51	51	11	50	
	B	"	44	44	11	43	
	C	"	39	39	11	37	
	D	"	50	50	12	46	
2/1/43	J	73°25%	16	16	11	14	
	K	"	22	22	12	20	
	L	"	20	20	11	18	
	M	"	41	41	12	36	
	M	"	41	41	12	26	
2/2/43	L-2	71°21%	10	10	11	9	
	M	"	17	17	9	15	
	M	"	20	20	12	19	
2/3/43	M	72°31%	9	9	11	8	
	N	"	8	8	12	8	
	O	"	10	10	10	7	
2/8/43	X	62°36%	10	10	10	9	
	Y	"	9	9	12	7	
2/9/43	J	60°34%	29	29	10	23	
2/10/43	G	59°20%	22	22	10	11	
2/15/43	T	62°28%	9	9	10	7	
	U	"	9	9	11	8	
2/23/43	A	67°30%	22	22	10	17	
	B	"	19	19	10	15	
	C	"	18	18	11	16	
	D	"	21	21	10	19	
	W	"	6	6	10	5	
2/24/43	G	69°48%	15	15	12	14	
3/3/43	B	71°23%	20	20	11	17	
	H	"	43	43	11	38	
3/9/43	K	75°72%	24	24	13	23	
	N	"	10	10	12	10	
	O	"	8	8	12	8	
	R	"	10	10	11	10	
	S	"	9	9	12	9	
3/17/43	G	65°41%	10	10	10	10	
	H	"	9	9	12	9	
	I	"	10	10	12	10	
	J	"	9	9	11	8	
	O	"	9	9	9	7	
	P	"	10	10	10	9	
	Q	"	11	11	12	11	
	R	"	10	10	12	9	

UNCLASSIFIED -SECRET-

Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
130X (100% H)							
3/17/43	S	65°41%	7	7	13	5	10
	T	"	10	10	14	9	10
	U	"	10	10	13	7	9
	V	"	10	10	11	10	8
	W	"	10	10	12	10	7
	X	"	10	10	11	10	6
	Y	"	10	10	11	10	7
	Z	"	10	10	11	8	8
	EE	"	10	10	12	9	8
3/23/43	K	75°40%	25	25	12	21	9
	L	"	23	23	14	23	10
	M	"	30	30	12	30	8
	N	"	27	27	13	27	8
	O	"	26	26	14	26	10
3/30/43	Q	71° N.R.	16	16	13	14	10
4/6/43	C	76°28%	29	29	11	23	7
4/13/43	C	65°28%	20	20	12	19	8
	D	"	20	20	11	20	8
	E	"	18	18	10	14	7
	F	"	20	20	11	17	8
	G	"	19	19	11	18	8
	H	"	16	16	11	14	8
	I	"	20	20	11	20	8
	J	"	17	17	6	17	8
	K	"	20	20	12	20	8
	L	"	18	18	12	18	9
	M	"	35	35	11	33	8
	Z	"	10	10	12	10	8
4/27/43	C	67°62%	20	20	12	17	9
	O	"	20	20	10	17	9
	P	"	18	18	10	8	10
5/4/43	J	76°28%	9	9	12	5	8
	K	"	10	10	11	5	5
	L	"	10	10	12	4	9
	I	"	60	60	11	42	7
5/11/43	K	65°50%	39	39	13	36	9
	S	63°55%	15	15	11	15	8
5/18/43	FF	65°70%	24	24	14	23	10
5/25/43	AA	75°40%	20	17	12	11	9
	H	70°48%	9	9	11	9	7
11/[illegible]/43	H	64°38%	45	45	11	35	7
	I	"	5	5	11	5	7
11/9/43	A	66°34%	34	34	12	31	8
	B	"	33	33	13	29	7

Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
130X (100% H)							
11/16/43	A	65°47%	25	25	10	17	8
	B	"	24	24	10	20	8
	C	"	25	25	11	24	8
	D	"	29	29	11	24	8
	E	"	24	24	10	19	6
	F	"	25	25	10	25	8
	G	"	26	26	10	21	8
	H	"	16	16	11	16	9
11/22/43	G	60°63%	16	16	12	15	8
	H	"	20	20	11	14	7
	O	"	18	18	13	17	8
	P	"	19	19	13	19	8

CLOSED VESICATION TESTS

(for technique see page)

Rod No. 3 (3% D.P.E.) closed 5 minutes							
10/14/42	G	74°52% (8% D.P.E.)	9	7	5	0	-
	H	74°52%	10	10	5	0	-
Rod No. 3 (3% dioxane) closed 10 minutes							
2/6/43	K	62°36% (3% D.P.E.)	13	8	7	2	5
2/8/43	T	62°36%	15	0	-	0	-
	Q	"	14	0	-	0	-
	W	" (10% dioxane)	15	0	-	0	-
2/8/43	J	62°36% (10% D.P.E.)	15	14	7	7	4
2/8/43	M	62°36%	16	8	5	1	3
	N	"	15	10	5	1	3
	P	"	15	3	5	0	-
	S	"	11	8	6	1	4
	V	" (15% D.P.E.)	15	7	4	0	-
2/8/43	L	62°36% (30% dioxane)	14	13	6	3	4
2/8/43	I	62°36% (30% D.P.E.)	15	15	8	13	5
2/8/43	O	62°36%	15	15	9	2	5
	R	"	16	15	9	4	4
	U	"	15	13	6	2	5
Rod No. 3 (100% H) "closed"							
2/8/43	E	62°36%	15	14	12	14	8
	F	"	15	15	12	13	8
	G	"	15	15	10	13	6
	H	"	15	15	10	15	6

Vesicant Comparisons

Comparisons of Different Kinds of Mustard. The data show that redistilled Levinstein mustard (TL 528) and thiodiglycol mustard (TL 155), are equally vesicant, and are superior to plant-run Levinstein mustard (TL 5).

TL 744, obtained by condensing the gases produced in the candling of Levinstein mustard, is a slightly better vesicant than redistilled Levinstein mustard.

Comparison of Mustard and Mustard Sulfone. The sulfone is not as effective as mustard in producing irritations at low doses (Rod No. 3 of a 5% dioxane solution, closed 10').

Comparisons of Mustard and Sesquimustard, TL 153, TL 258, and TL 454. The data speak for themselves in each case. All four are superior to mustard, and except for TL 153, are very close to each other in vesicant action. These comparisons have been repeated with the Benesh microburette using undiluted compounds, and analogous results have been obtained (these will be discussed in a special report on the Benesh microburette).

Comparisons of Mustard with Other Vesicants. Bromoacetyl bromide was reported to be a powerful vesicant; however, we were unable to find any indication of strong blistering action.

TL 645, as stated before, was not actually tris(2-chloroethylmercapto)phosphine, but was largely sesquimustard.

Comparisons of Different Kinds of Mustard

Materials

TL 3 plant-run Levinstein H
TL 155 H prepared at UCTL from thiodiglycol
TL 328 plant-run Levinstein H, redistilled
TL 744 condensation of gases produced in candling Levinstein H

Series		TL No.	Dose	Concn. or Solvent	Temp. (°F.)	R.H. (%)	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
11/9/42	O	328	#3 Rod	100%	73	46	58	57	8	47	6
	O	3						58	6	39	4
9/29/42	A	328	#3 Rod	100%	74	42	11	11	6	7	4
	A	3						11	4	3	3
9/29/42	B	328	#3 Rod	50% D.P.E.	74	42	11	10	5	2	2
	B	3						11	6	4	3
9/29/42	C	328	#3 Rod	30 D.P.E.	74	42	10	10	4	0	-
	C	3						10	4	0	-
9/29/42	D	155	#3 Rod	100%	74	42	11	11	7	8	3
	D	328						11	7	8	3
9/29/42	E	155	#3 Rod	50%	74	42	10	10	6	0	-
	E	328						10	5	1	1
6/22/43	S	328	16 [illegible]	100%	69	66	24	21	5	8	3
	S	744						21	6	13	4
6/13/43	SS	328	65 [illegible]	100%	84	56	10	10	8	7	5
	SS	744						10	10	10	5
Comparison of Mustard and Mustard Sulfone (TL 4)											
2/8/43	I	328	#3 Rod*	30% Dioxane	62	36	15	15	8	13	5
	I	4						12	5	9	3
2/8/43	J	328	#3 Rod*	10% Dioxane	62	36	15	14	7	7	4
	J	4						10	3	2	3
2/8/43	K	328	#3 Rod*	3% Dioxane	62	36	13	8	7	2	5
	K	4						1	6	1	5
Comparison of Mustard and Sesquimustard (TL 86)											
9/14/42	P	328	#3 Rod	15% D.P.E.	76	72	15	0	-	0	-
	P	86						15	16	14	10
9/14/42	Q	328	#3 Rod	1% D.P.E.	76	72	15	1	5	0	-
	Q	86						15	11	14	8

(Table con't. on next page)

SECRET

* Closed 15 minutes

Series	TL No.	Dose	Concn. or Solvent	Temp. (°F)	R.H. (%)	No. Men	Erythemas No.	Erythemas Size	Blister No.	Blister Size
Comparison of Mustard and Sesquimustard (TL 86) (con't.)										
9/14/42 R	328	#3 Rod	3% D.P.E.	76	72	15	0	-	0	-
R	86						12	4	1	2
2/8/43 L	328	#3 Rod*	15% D.P.E.	62	36	14	13	6	3	4
L	86						14	10	11	7
2/8/43 M	328	#3 Rod*	10% D.P.E.	62	36	16	8	5	1	3
M	86						16	8	2	3
Comparison of Mustard and Propylene bis(2-chloroethyl sulfide) (TL 153)										
9/14/42 S	328	#3 Rod	30%	N.R.	N.R.	15	6	5	0	-
S	153						15	10	13	7
9/14/42 T	328	#3 Rod	10%	N.R.	N.R.	15	1	3	0	-
T	153						15	7	4	4
9/14/42 U	328	#3 Rod	3%	76	72	15	0	-	0	-
U	153						4	3	1	1
2/8/43 F	328	#3 Rod*	10%	62	36	15	15	12	13	8
F	153						15	12	12	8
2/8/43 O	328	#3 Rod*	10% D.P.E.	62	36	15	15	9	2	5
O	153						15	12	4	6
2/8/43 P	328	#3 Rod*	10% D.P.E.	62	36	15	5	5	0	-
P	153						10	6	0	-
2/8/43 Q	328	#3 Rod*	3% D.P.E.	62	36	14	0	-	0	-
Q	153						1	4	0	-
Comparison of Mustard and Propane, 2-chloro-1,3-bis(2-chloroethylthio)- (TL 258)										
9/14/42 V	328	#3 Rod	30% in D.P.E.	76	72	15	10	3	0	
V	258						15	10	15	6
9/14/42 W	328	#3 Rod	10% in D.P.E.	76	72	14	3	3	0	-
W	258						14	10	14	
9/14/42 X	328	#3 Rod	3% in D.P.E.	76	72	15	0	-	0	-
X	258						15	7	6	5
2/8/43 G	328	#3 Rod*	10%	62	36	15	15	10	13	6
G	258						15	13	9	5
2/8/43 R	328	#3 Rod*	30% D.P.E.	62	36	16	15	9	4	4
R	258						16	9	6	6
2/8/43 S	328	#3 Rod*	10% D.P.E.	62	36	11	8	6	1	4
S	258						11	7	1	7
2/8/43 T	328	#3 Rod*	3% D.P.E.	62	36	15	0	-	0	-
T	258						6	7	0	-

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* Closed 10 minutes

Date	Series	TL No.	Dose	Diluent and Solvent	Temp. (°F)	R.H. (%)	No. Men	Erythema No.	Erythema Size	Blisters No.	Blisters Size
Comparison of Mustard and Bis(2-chloroethylmercapto)ether (TL 454)											
2/3/43	H	323	#3 Rod*	10%	62	36	15	15	10	15	6
	B	454						15	13	14	8
2/3/43	U	323	#3 Rod*	3% D.P.E.	62	36	15	13	6	3	5
	U	454						15	11	12	7
2/3/43	V	323	#3 Rod*	1% D.P.E.	62	36	15	7	4	0	-
	V	454						15	8	5	4
2/3/43	W	323	#3 Rod*	3% D.P.E.	62	36	15	0	-	0	-
	W	454						5	5	0	-
Comparison of Mustard and Tris(2-chloroethylmercapto)phosphine (TL 645)											
5/4/43	M	328	65 ɣ	100%	76	28	24	24	6	7	4
	M	645	70 ɣ					24	12	24	7
5/4/43	N	323	32 ɣ	50% Dioxane	76	28	23	22	5	1	5
	N	645	35 ɣ					23	9	23	5
5/4/43	O	328	16 ɣ	25% Dioxane	76	28	22	18	4	0	-
	O	645	17 ɣ					22	7	20	4
5/4/43	P	323	7 ɣ	10% Dioxane	76	28	23	14	3	0	-
	P	645						23	6	5	3
5/4/43	Q	328	3 ɣ	5% Dioxane	76	28	21	0	-	0	-
	Q	645	4 ɣ					19	5	3	4
Comparison of Mustard with Acetyl bromide, bromo- (TL 632)											
4/6/43	AA	632	#3 Rod	25% D.P.E.	76	28	15	0	-	0	-
	AA	328						9	5	0	-
4/6/43	Z	632	#3 Rod	50% D.P.E.	76	28	15	0	-	0	-
	Z	328						15	7	4	1
4/6/43	Y	632	#3 Rod	100%	76	28	16	12	3	1	1
	Y	328						16	10	12	6
4/6/43	X	632	#5 Rod	100%	76	28	19	13	3	0	-
	X	328						19	10	9	7
4/13/43	M	632	115 ɣ	100%	65	28	35	0	-	0	-
	M	328	130 ɣ					35	11	33	8

* Closed 10 minutes

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Vesicant Mixtures

Mustard - PD Mixture - Our comparison of a 1:1 by weight mixture of mustard and phenyldichloroarsine with the components was done with the micrometer burette using small volumes (0.013 and 0.025 cu.mm.), and therefore is open to criticism. The results are not clear-cut, but it is apparent that the mixture is no better than either ingredient, and that the vesicant action is probably an average of those of its components.

Mustard - Lewisite Mixtures - Here again most of the work was done at low doses. The mixture, like the H-PD mixture, is of intermediate vesicant action.

Mustard - ED Mixtures - A 1:1 by weight mustard - ethyldichloroarsine mixture is less vesicant than 100% mustard or lewisite.

Mustard - Sesquimustard (and Homologues) Mixtures - Addition of 25% sesquimustard by volume increases the vesicant action of mustard to a considerable extent. Mixtures of TL 153 and mustard are also more vesicant than pure mustard. The data on TL 258 mixtures cannot be considered complete, because of the somewhat delayed action of TL 258 -- it does not produce maximum damage within 48 hours.

Aged Mixtures - Two mixtures of ED and mustard, 1:1 by volume which had been stored for 8 months at 60°C., were compared with freshly prepared mixtures. In two separate tests, both of the heated mixtures were superior to the unheated controls.

Seven other vesicant mixtures were tested later; only the sesquimustard -HN3 mixture was a better vesicant after aging.

Mustard (TL 155 or TL 328) - PD (TL 69) Mixture

Materials

TL 3 plant-run H
TL 155 UCTL thiodiglycol H
TL 328 plant-run Levinstein H, redistilled
TL 8 plant-run L
TL 327 " " L, redistilled

Series		TL NO.	Dose	Concn. or Mixture	Temp. (°F)	R.H. (%)	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
5/25/43	U	69 & 328	10%	1:1	70	48	66	16	5	8	4
	M,O	69	20%	100%	"	"	25	5	5	3	4
	M,Q	328	16%	100%	"	"	25	7	5	1	2
	O,Q	69 & 328	20%	1:1	"	"	28	9	5	6	3
6/1/43	O	69	16%	100%	78	73	17	11	4	5	3
		69 & 328	20%	1:1	"	"	17	12	4	2	3
6/29/43	N	328	16%	100%	69	53	48	40	6	12	2
		69	20%	100%	"	"	48	23	5	11	4
		328 & 69	20%	1:1	"	"	48	16	5	6	2
6/29/43	M	155	16%	100%	69	53	48	36	7	12	3
		69	20%	100%	"	"	48	28	6	18	4
		155 & 69	20%	1:1	"	"	48	22	4	6	3
5/25/43	N,R	328	32%	100%	70	48	34	22	5	3	4
	N,P	69	40%	100%	"	"	29	6	8	3	5
	P,R	69 & 328	35%	1:1	"	"	33	25	5	8	4
5/11/43	HH	69 & 328	75%	1:1	63	55	13	13	18	13	14
5/25/43	S	327 & 328	20%	1:1	70	48	22	13	5	0	-
		69 & 328	17%	1:1	"	"	22	10	5	1	5
	T	327	16%	100%	"	"	31	19	8	17	5
		69 & 328	17%	1:1	"	"	31	16	5	6	3
Lewisite - Mustard Mixture											
6/1/43	M	328 & 327	16%	1:1	78	73	25	22	5	7	4
6/29/43	K	3	20%	100%	69	53	43	34	5	6	2
		8	25%	100%	"	"	43	31	5	19	3
		3 & 8	25%	1:1	"	"	43	35	4	14	3
6/29/43	L	3	20%	100%	69	53	49	48	5	16	3
		327	25%	100%	"	"	49	34	6	28	5
		3 & 327	25%	1:1	"	"	49	43	5	27	3
7/6/43	TT	155	32%	100%	74	77	30	28	7	24	4
		327 & 155	35%	1:1	"	"	30	30	7	30	4
		327	40%	100%	"	"	30	25	7	26	4
7/6/43	WW	328	32%	100%	74	77	30	30	8	27	4
		327 & 328	35%	1:1	"	"	30	29	7	29	5
		327	40%	100%	"	"	30	30	8	29	5
7/7/42	A	327 & 328	43 Rod	100%	N.R.	N.R.	29	29	8	27	4

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Series		TL NO.	Dose	Concn.or Mixture	Temp. (°F)	R.H. (%)	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Mustard - ED Mixture											
7/6/43	UU	155	32γ	100%	74	77	28	26	9	24	5
		155 & ED	35	1:1	"	"	28	28	7	18	4
		327	40γ	100%	"	"	28	28	9	27	5
7/6/43	VV	328	32γ	100%	74	77	28	27	8	25	5
		328 & ED	35γ	1:1	"	"	28	28	7	21	5
		327	40γ	100%	"	"	28	27	8	27	5
HQ Mixture											
6/1/43	J	328	16γ	100%	78	73	29	26	7	12	4
		328 & 86	16γ	3:1*	"	"	29	29	11	29	5
5/4/43	W	328	65γ	100%	73	27	12	12	9	9	5
		328 & 86	70γ	3:1	"	"	12	12	12	12	7
Mixtures of Mustard and TL 153 1,2-Bis(2-chloroethylmercapto)propane											
5/1/43	J	328	16γ	100%	78	73	12	12	9	9	5
	K	328 & 153	16γ	3:1*	"	"	27	25	10	21	6
	L	328 & 153	16γ	1:1	"	"	32	32	8	32	4
	N	153	16γ	100%	"	"	20	20	9	18	6
5/4/43	U	328	65γ	100%	73	27	15	15	7	10	5
		153	65γ	100%	"	"	15	15	11	13	7
5/4/43	X	328	65γ	100%	73	27	14	13	7	9	4
		328 & 153	65γ	3:1	"	"	14	14	12	14	7
	Y	328	65γ	100%	73	27	14	14	7	7	4
		328 & 153	65γ	1:1	"	"	14	14	9	9	6
Mixtures of Mustard and TL 258 2-chloro-1,3-bis-(2-chloroethylmercapto)propane											
6/1/43	J	328	16γ	100%	78	73	12	12	9	9	5
	K	328 & 258	16γ	3:1*	"	"	27	27	8	21	4
	L	328 & 258	16γ	1:1	"	"	32	32	8	29	4
	M	328 & 258	16γ	1:3	"	"	25	25	8	17	5
	N	258	16γ	100%	"	"	20	20	11	19	7
5/4/43	V	328	65γ	100%	73	27	13	13	8	11	5
		258	65γ	100%	"	"	13	13	13	9	8
5/4/43	Z	328	65γ	100%	73	27	15	15	8	9	3
		328 & 258	65γ	3:1	"	"	15	15	11	7	5
5/4/43	AA	328	65γ	100%	73	27	15	15	7	12	4
		328 & 258	65γ	1:1	"	"	15	15	10	7	8
5/4/43	BB	328	65γ	100%	73	27	12	12	9	9	6
		328 & 258	65γ	1:3	"	"	12	12	8	6	7

* (By volume)

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Dose: 0.025 cu. mm. (micrometer burette)

Series	TL NO.	Mixture	Time Stored at 60°C.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
9/14/43 R	934	H (thiodiglycol) & ED (pure), equal parts by volume	0 mo.	33	32	6	18	3
Temp. 65°	155-214	Control	Fresh		22	4	0	-
R. H. 80% S	935	H (plant-run) & ED (pure), equal parts by volume	8 mo.	36	32	6	20	4
	3-214	Control	Fresh		31	5	3	5
9/21/43 G	934	H (thiodiglycol) & ED (pure), equal parts by volume	8 mo.	17	17	10	16	6
	155-214	Control	Fresh		16	5	2	2
Temp. 64° R. H. 60%	935	H (plant-run) & ED (pure), equal parts by volume	8 mo.	17	17	8	16	4
	3-214	Control	Fresh		17	5	0	-

Dose: 0.05 cu. mm. (micrometer burette) Indoor Temp.: 57°F. Indoor R. H.: 40% Outdoor Temp.: 60°F.

Series	TL NO.	Mixture	Days Stored at 60°C.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
12/14/43	1041	PD(pure) & H (pure) equal parts by volume	97	25	15	12	11	8
	1097	Control	Fresh		15	8	10	6
12/14/43 M	1042	PD(pure) & H (crude Levinstein), equal parts by volume	97	17	17	10	14	7
	1099	Control	Fresh		17	10	13	7

Dose: 0.05 cu. mm. (micrometer burette) Indoor Temp.: 72°F. Indoor R. H.: 21% Indoor Temp.: 11°F.

Series	TI NO.	Mixture	Days Stored at 60°C.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
12/14/43 N	1043	PD (pure) & H (steam distilled), equal parts by volume	97	15	15	11	11	8
	1100	Control	Fresh		15	11	13	7
O	1044	L (crude) & sesqui-mustard (pure), 75-25% by weight	98	15	15	8	13	5
	1101	Control	Fresh		15	10	15	6
P	1045	HN3 (pure) & H (crude Levinstein), equal parts by volume	96	15	15	9	9	5
	1102	Control	Fresh		15	11	10	7
Q	1046	HN3 (pure) & H (steam distilled), equal parts by volume	80	13	12	7	2	8
	1103	Control	Fresh		12	6	1	3
R	1047	HN3 (pure) & sesqui-mustard (pure), 75%-25% by weight	77	15	15	11	14	7
	1104	Control	Fresh		15	9	8	7

Part of the reason for the increase in the vesicant action of the aged H-ED mixture was learned as a result of heating mustard alone for 2 days at 132°C. A similar "rapid-aging" process was carried out with H and ED, equal parts by volume, and with Q-ED, equal parts by weight.

Like the H-ED mixtures stored at 60° for 8 months, this mixture was more vesicant than the fresh control. However, the increased vesicant action of H alone was more striking.

Dose: 0.05 cu. mm. (micrometer burette) Indoor Temp.: 58°F. Indoor R. H.: 58% Outdoor Temp.: 34°F.

Series	Vesicant	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
11/9/43 K	H (thiodiglycol) heated 2 days at 132°C.	20	20	12	20	8
	H, unheated		19	10	15	7
L	H-ED, heated (1:1 by volume)	21	21	9	15	6
	H-ED, unheated (1:1 by volume)		21	9	11	5
M	H-Q, heated (1:1 by weight)	21	21	9	14	6
	H-ED, heated (1:1 by volume)		21	10	18	6

Vesicant "Potentiators"

A few preparations have been dissolved in mustard in attempts to increase the rate of skin penetration to enhance the wetting power and hence to increase the contamination skin area, or to thicken mustard in order to cut down loss by evaporation.

Of the six substances tested on January 6, 1943, none had a positive effect, and the dodecylamines had a slight negative effect by diminishing the number of blisters.

Cellulose acetate butyrate tested as a thickener on April 27, 1943, caused mustard to blister 17/18 men, but the lesion sizes were extremely small. The thickened sample was very viscous. Golva #7 had a doubtful positive effect in increasing mustard vesicancy.

Triton NE, tested as a wetting agent on September 7, 1943 produced a decrease in the number of blisters.

Series	TL No.	Vesicant	Dose (γ)	Temp. and R. H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
1/6/43 A	328	100%	65	69°F. 24%	20	20	8	12	4
	328	5% tetradodecylamine acetate added				20	7	9	3
B	328	100%	65	69°F. 24%	20	20	8	16	6
	328	5% Aerosol OT added				20	8	14	6
C	328	100%	65	69°F. 24%	19	19	7	13	4
	328	5% didodecylamine added				19	8	8	5
D	328	100%	65	69°F. 24%	20	20	7	11	5
	328	5% Lecithin added				19	7	11	6
E	328	100%	65	69°F. 24%	20	20	8	7	5
	328	5% Duponol C added				20	7	8	4
F	328	100%	65	69°F. 24%	20	13	7	11	6
	328	5% Lanolin added				13	7	11	5
4/27/43 O	328	100%	130	67°F. 62%	20	20	10	17	9
	328	5% Golva #7 added				20	11	20	7
P	328	100%	130	67°F. 62%	18	18	10	8	10
	328	5% Cellulose acetate butyrate added				18	5	17	3
9/7/43 OO	328	100%	32	74°F.	24	23	7	10	3
	328	1% Triton NE added				24	5	5	4

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An observation that when HN3 on the skin is treated with triethanolamine there is an increase in size and percentage of blisters led us to attempt to increase the vesicant action of HN3 by dissolving it in triethanolamine (1:1).

The test was not as striking as the decontamination tests had been; although the lesions were considerably larger, there was no increase in blister percentage (both of these observations could be attributed to solvent effect).

A similar experiment with HN3 and pyridine showed no increased vesicant action over undiluted HN3.

Outdoor Temp. - 70°F.
Indoor " - 75°F.
Indoor R. H. - 65%

Series	Dose (γ)	Solvent	No. Men	48-Hour Readings			
				Erythema No.	Erythema Size	Blisters No.	Blisters Size
8/3/43 I	120	100%	16	13	11	7	11
		50% in triethanolamine		16	14	7	15
8/3/43 J	120	100%	16	16	11	10	8
		50% in pyridine		15	9	8	7

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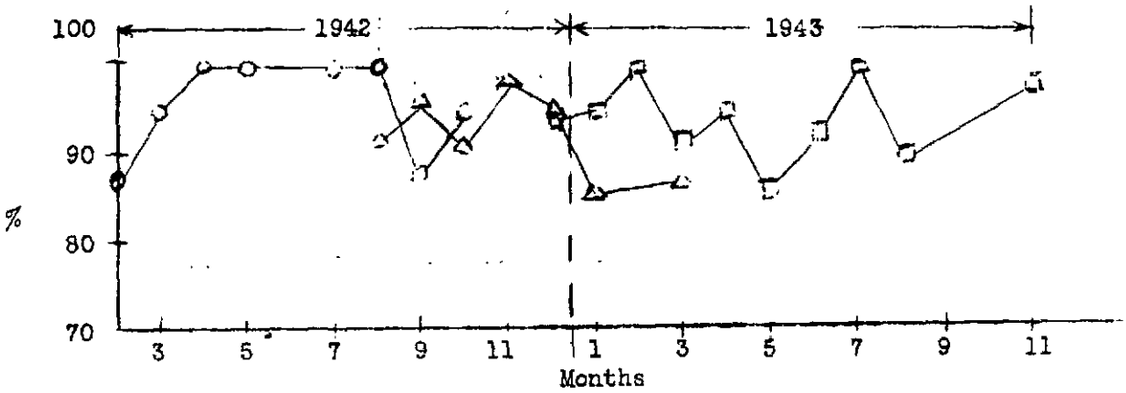
III. LEWISITE

As in the case with mustard, monthly summaries have been made of the lewisite data. Fewer men have been run with L, and the graph (Figure 4) is even less revealing than the graphs of H (Figures 2 and 3).

In no month did the percentage of blisters fall below 85%, and in most cases it was above 90%. While daily deviations from this average might be explained on the basis of an insufficient number of experimental subjects, no explanation is available for the failure of lewisite to produce more than 57% of blisters on 114 men used in a test on September 21, 1942.

Figure 5 shows a month-by-month comparison of mustard and lewisite from December, 1942 through May, 1943. Except for March, when they were equal, lewisite was a better vesicant than mustard. It should be pointed out that lewisite was applied to considerably fewer men.



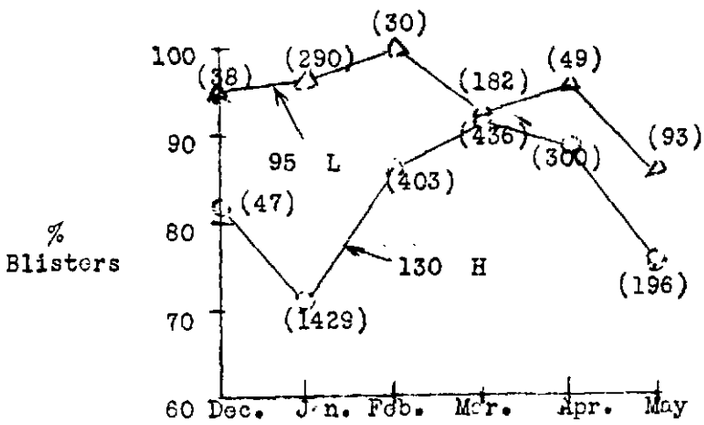


Figure 5

Comparison of H and L

Dec. '42 - May '43

(Number of experimental subjects indicated within brackets)

Figure 4

Daily and Monthly Percentages of Blisters
in 48-Hour Tests With Lewisite

Dose: Rod #3

Date	Blisters (in 48 hours) No.	Av. Size (mm.)	%	In-door Temp. (°F.)	In-door R.H. (%)	Out-door Mean Temp. (°F.)
2/24/42	7/8	6	88	-	-	26
3/2/42	20/20	7	100	-	-	34
3/5/42	17/18	4	95	-	-	41
3/9/42	36/40	3	90	-	-	34
3/10/42	36/38	4	95	-	-	38
3/12/42	29/29	5	100	-	-	36
3/16/42	39/39	6	100	-	-	48
3/17/42	5/5	5	100	-	-	42
3/23/42	39/39	5	100	-	-	43
3/30/42	23/23	5	100	-	-	32
3/31/42	20/20	8	100	-	-	39
Totals for March '42	264/271	5	96			
4/6/42	298/298	5	100	-	-	54
4/7/42	34/34	6	100	-	-	38
Totals for April '42	332/332	5	100			
7/29/42	108/108	7	100	70	86	74
8/4/42	40/40	6	100	76	59	70
8/24/42	5/5	7	100	-	-	59
8/31/42	10/10	8	100	-	-	70
Totals for August '42	55/55	7	100			
9/2/42	10/10	9	100	82	64	76
9/16/42	244/244	7	100	74	78	76
9/21/42	42/114	5	37	66	48	54
9/23/42	199/206	7	97	62	52	50
Totals for September '42	585/664	7	88			
10/7/42	19/19	7	100	82	74	61
10/21/42	9/10	6	90	71	45	50
Totals for October '42	28/29	7	97			
3/23/43	30/30	7	100	75	40	38

(Table con't. on next page)

Dose: Rod #5

Date	Blisters (at 43 hours) No.	Av. Size (mm.)	%	Indoor Temp. (°F.)	Indoor R.H. (%)	Outdoor Mean Temp. (°F.)
8/4/42	55/60	5	92	76	59	70
9/7/42	18/20	13	90	74	76	68
9/8/42	10/10	8	100	73	78	71
9/9/42	20/20	10	100	76	87	71
9/28/42	18/20	7	90	72	42	42
Totals for September '42	68/70	9	97			
10/5/42	19/20	4	95	59	78	56
10/6/42	17/19	7	89	59	72	60
Totals for October '42	36/39	5	92			
11/10/42	168/170	5	99	73	57	38
12/2/42	312/337	6	93	49	51	6
12/7/42	202/204	7	99	-	-	16
12/9/42	148/159	6	93	55	54	25
12/15/42	389/395	6	98	-	-	22
12/16/42	185/195	4	95	60	-	13
Totals for December '42	1236/1290	6	96			
1/4/43	116/121	5	96	68	25	16
1/6/43	179/197	5	91	69	24	26
1/19/43	204/286	6	73	66	32	6
1/20/43	13/15	5	87	63	37	2
1/25/43	175/182	6	96	67	30	10
Totals for January '43	687/801	5	86			
3/2/43	30/36	5	83	69	18	6
3/17/43	37/40	6	93	65	41	30
Totals for March '43	67/76	6	87			

(Table con't. on next page)

Dose: 95 micrograms (micrometer burette)

Date	Blisters (at 48 hours) No.	Av. Size (mm.)	%	In-door Temp. (°F.)	In-door R.H. (%)	Out door-Mean Temp. (°F.
12/16/42	36/38	4	95	60	-	13
1/20/43	114/120	6	95	63	37	2
1/27/43	165/170	6	97	72	14	19
Totals for January /43	279/290	6	96			
2/3/43	30/30	7	100	72	31	33
3/9/43	168/182	7	92	75	72	41
4/6/43	37/38	5	97	76	28	38
4/27/43	10/11	6	89	67	62	60
Totals for April '43	47/49	5	96			
5/4/43	15/19	4	79	76	28	55
5/11/43	35/36	6	97	65	50	48
5/18/43	27/29	7	93	73	50	52
5/25/43	3/9	7	33	75	40	54
Totals for May '43	80/93	6	86			
6/1/43	34/37	10	92	80	59	78
7/20/43	67/67	7	100	86	50	80
8/17/43	18/20	8	90	69	59	64
11/9/43	44/45	8	98	66	34	32

Tabulation of Individual 48-Hour Tests With L

Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Rod No. 5 (25% D.P.E.)							
3/10/42	A	N.R.	51	48	N.R.	36	5
		(30% D.P.E.)					
3/4/42	B	N.R.	20	20	N.R.	20	6
3/11/42	A	N.R.	51	46	N.R.	44	6
2/16/42	A	N.R.	24	24	N.R.	24	N.R.
2/17/42	A	N.R.	20	20	N.R.	4	4
		(35% D.P.E.)					
2/23/42	A	N.R.	49	46	N.R.	40	5
2/24/42	D	N.R.	6	6	6	6	6
2/25/42	A	N.R.	24	21	N.R.	18	6
	B	N.R.	22	19	N.R.	19	5
3/3/42	A	N.R.	18	17	N.R.	15	5
		(40% D.P.E.)					
	A	N.R.	18	17	N.R.	16	5
		(45% D.P.E.)					
	A	N.R.	18	17	N.R.	17	7
Rod No. 3 (100% L)							
2/19/42	A	N.R.	20	14	N.R.	13	4
	A	N.R.	20	11	N.R.	10	3
	B	N.R.	33	26	N.R.	24	3
	B	N.R.	33	33	N.R.	29	3
2/24/42	A	N.R.	8	8	N.R.	7	6
3/2/42	B	N.R.	20	20	N.R.	20	7
3/5/42	B	N.R.	9	9	N.R.	8	5
	C	N.R.	9	9	N.R.	9	4
3/9/42	A	N.R.	10	10	N.R.	10	5
	B	N.R.	10	10	N.R.	8	3
	C	N.R.	10	10	N.R.	9	3
	D	N.R.	10	10	N.R.	9	3
3/10/42	A	N.R.	9	9	N.R.	9	4
	B	N.R.	10	10	N.R.	9	4
	C	N.R.	10	10	N.R.	10	6
	D	N.R.	9	9	N.R.	8	3
3/12/42	A	N.R.	19	19	N.R.	19	5
	B	N.R.	10	10	N.R.	10	6
3/16/42	A	N.R.	10	10	N.R.	10	6
	B	N.R.	10	10	N.R.	10	6
	C	N.R.	9	9	N.R.	9	6
	D	N.R.	10	10	N.R.	10	6
3/17/42	A	N.R.	5	5	N.R.	5	5
3/23/42	A	N.R.	10	10	N.R.	10	4
	B	N.R.	10	10	N.R.	10	5
	C	N.R.	9	8	N.R.	6	5
	D	N.R.	10	10	N.R.	10	6
3/30/42	A	N.R.	10	10	N.R.	10	6
	B	N.R.	9	9	N.R.	9	5
	C	N.R.	4	4	N.R.	4	3

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Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Rod No. 2 (100% L)							
3/31/42	A	N.R.	10	10	N.R.	10	6
	B	N.R.	10	10	N.R.	10	10
4/6/42	A	N.R.	100	100	N.R.	100	5
	B	N.R.	101	101	N.R.	101	5
	C	N.R.	97	97	N.R.	97	4
4/7/42	A	N.R.	10	10	N.R.	10	7
	B	N.R.	9	9	N.R.	9	6
	B	N.R.	9	4	N.R.	3	3
	C	N.R.	15	15	N.R.	15	6
7/29/42	H	70°86%	14	14	9	14	7
	I	"	15	15	9	15	8
	J	"	15	15	7	15	5
	K	"	15	15	8	15	7
	L	"	15	15	9	15	7
	M	"	15	15	8	15	7
	N	"	15	15	7	15	6
	O	"	4	4	6	4	5
	P	"	9	9	7	9	5
8/4/42	O	76°59%	20	20	9	20	7
	P	"	20	20	9	20	7
	Q	"	20	20	8	20	6
8/24/42	M	N.R.	5	5	8	5	7
8/31/42	J	N.R.	10	10	13	10	8
9/2/42	I	82°64%	10	10	16	10	9
9/16/42	A	74°78%	17	17	11	17	8
	B	"	19	19	10	19	7
	C	"	20	20	9	20	6
	D	"	20	20	10	20	7
	E	"	19	19	10	19	7
	F	"	20	20	9	20	7
	G	"	20	20	8	20	6
	H	"	20	20	9	20	7
	I	"	19	19	10	19	8
	J	"	20	20	9	20	7
	M	"	20	20	9	20	5
	T	"	20	20	10	20	8
	W	"	10	10	12	10	8
9/21/42	A	66°48%	18	15	4	12	2
	B	"	19	1	4	1	2
	C	"	20	0	-	0	-
	D	"	19	7	3	1	3
	F	"	20	18	9	14	5
	O	"	8	8	9	7	6
	P	"	10	9	8	7	7
9/23/42	A	62°52%	18	18	10	17	5
	B	"	19	19	9	18	6
	C	"	15	15	8	14	6

(Tabulation continues on next page)

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Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Rod No. 3 (100% L)							
8/25/42	D	83°52%	15	15	6	14	5
	E	"	20	20	9	17	7
	F	"	20	20	9	20	7
	G	"	15	15	9	15	6
	H	"	15	15	10	15	7
	I	"	19	19	10	19	7
	J	"	21	21	10	20	8
	K	"	15	15	12	15	8
	L	"	14	14	10	14	8
10/1/42	H	62°74%	19	19	9	19	7
10/21/42	V	71°45%	10	9	6	9	6
1/23/43	S	75°40%	30	30	9	30	7
Rod No. 5 (100% L)							
8/4/42	L	75°59%	20	19	6	17	5
	M	"	20	20	6	19	5
	N	"	20	20	6	19	5
9/1/42	C	74°78%	10	10	17	10	13
	F	"	10	9	17	8	12
9/3/42	A	73°73%	10	10	11	10	8
9/9/42	I	76°87%	10	10	14	10	11
	J	"	10	10	14	10	11
9/28/42	F	72°42%	10	10	10	10	9
	G	"	10	10	5	8	5
10/1/42	A	59°78%	20	20	9	19	4
10/6/42	F	59°72%	19	18	9	17	7
11/10/42	I	73°57%	23	23	9	22	6
	J	"	20	20	7	20	5
	K	"	20	20	6	20	4
	L	"	20	20	7	20	6
	M	"	26	26	8	26	5
	N	"	18	18	7	18	5
	O	"	22	22	6	21	5
	Q	"	21	21	8	21	5
12/2/42	B	49°51%	21	20	7	19	6
	C	"	19	19	6	18	5
	D	"	20	20	5	16	6
	E	"	20	19	4	15	4
	F	"	20	20	10	10	8
	G	"	20	20	8	20	6
	H	"	19	19	8	19	6
	I	"	21	21	7	21	5
	J	"	20	20	7	20	7
	K	"	20	20	10	20	8
	L	"	20	20	6	18	6
	M	"	20	20	7	19	5
	N	"	20	20	7	20	5
	O	"	20	20	8	20	6
	P	"	20	20	7	19	6
	Q	"	19	19	8	19	6
	R	"	18	18	8	18	6
12/7/42	A	N.R.	20	20	10	20	7
	B	"	20	20	10	20	7
	C	"	15	15	12	15	6

Series		Temp. F. R.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
Rod No. 5 (100% L)							
12/7/42	D	N.R.	20	20	9	20	7
	E	"	21	21	9	21	7
	F	"	19	19	10	19	7
	G	"	20	20	12	20	8
	H	"	20	20	10	20	7
	I	"	20	19	10	18	6
	J	"	19	19	8	19	6
	K	"	10	10	11	10	8
12/9/42	A	55°54%	20	20	8	17	6
	B	"	20	20	7	19	6
	C	"	18	18	7	15	5
	D	"	20	20	9	19	7
	E	"	20	20	7	20	6
	F	"	21	21	9	21	7
	G	"	20	20	8	20	6
	H	"	20	19	8	16	6
12/15/42	A	N.R.	20	19	9	18	7
	B	"	20	20	10	20	8
	C	"	20	20	9	20	7
	D	"	20	20	10	20	8
	E	"	19	19	10	19	7
	F	"	17	17	8	17	6
	G	"	17	17	10	16	7
	H	"	19	19	8	19	6
	I	"	19	19	8	19	6
	J	"	18	18	8	17	6
	K	"	19	19	10	19	7
	L	"	21	21	8	21	6
	M	"	20	20	8	20	6
	N	"	21	21	9	21	7
	O	"	20	20	10	20	8
	P	"	21	21	7	21	5
	Q	"	18	18	7	17	5
	R	"	14	14	8	14	6
	S	"	17	17	8	16	6
	T	"	17	17	5	17	5
	U	"	18	18	7	18	6
12/16/42	A	60°est.	18	18	6	18	6
	B	"	16	16	6	15	5
	C	"	17	17	5	15	5
	D	"	12	12	5	10	4
	E	"	15	15	6	14	5
	F	"	20	20	6	18	6
	G	"	18	18	5	18	6
	H	"	19	19	4	18	5
	I	"	7	7	4	7	4
	J	"	14	14	6	14	5
	O	"	38	38	7	38	6
1/4/43	A	68°25%	20	20	6	18	6
	B	"	20	19	7	19	6
	C	"	20	20	7	20	6
	D	"	21	21	9	21	7
	E	"	20	19	9	19	7
	F	"	20	20	7	19	6

SECRET

Tabl cont'd. from preceding page

Series		Temp. F. P.H.	No. Men	Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
ked No. ... (100% L)							
1/5/43	G-I	69°24%	39	39	7	35	5
	H-J	"	37	37	7	34	5
	K	"	13	15	6	14	4
	L	"	21	21	7	21	5
	M	"	20	20	6	18	5
	N	"	20	20	6	20	5
	O	"	20	17	5	17	3
	P	"	22	20	5	20	3
1/12/43	A	66°32%	78	78	8	70	5
	B	"	48	48	9	36	6
	C	"	68	68	10	43	6
	D	"	37	36	10	25	7
	E	"	55	53	8	27	5
1/20/43	V	73°37%	15	15	7	13	5
1/25/43	A	67°30%	36	36	9	36	6
	B	"	38	38	7	37	5
	C	"	43	43	9	42	6
	D	"	34	33	8	32	5
	E	"	25	25	6	23	6
	F	"	6	5	6	5	5
3/2/43	A	69°28%	10	9	6	9	4
	B	"	9	9	6	8	5
	C	"	8	8	5	8	3
	D	"	9	9	5	8	4
3/1[illegible]'43	K	65°41%	10	10	8	9	5
	L	"	10	10	9	9	6
	M	"	10	10	7	10	4
	N	"	10	10	9	9	6
15% (100% L)							
5/25/43	T	70°48%	31	19	8	17	5
	LL	75°40%	9	4	5	9	-
20% (100% L)							
6/29/43	L	69°53%	49	34	6	28	5
30% (100% L)							
5/25/43	MM	75°40%	8	7	5	4	4
45% (100% L)							
5/11/43	L	65°50%	23	22	5	18	4
		"	23	21	6	19	5
	M	"	26	23	7	19	6
7/6/43	TT	74°77%	30	26	7	26	4
	UU	"	26	23	9	27	5
	VV	"	28	27	8	27	5
	WW	"	30	30	8	29	5
64% (100% L)							
5/25/43	MM	75°40%	8	8	7	8	4
95% (100% L)							
12/13/42	O		38	38	6	36	4
1/20/43	A	63°37%	14	14	9	14	7
	B	"	17	17	8	17	6
	C	"	18	18	8	18	6
	D	"	19	18	10	13	8
	E	"	19	18	9	18	6
	F	"	18	18	7	18	5
	V	"	15	13	8	11	6
1/27/43	A	72°34%	29	29	7	27	7
	B	"	29	29	9	29	8
	C	"	39	36	10	36	9
	D	"	34	34	7	32	5
	E	"	39	39	9	39	8
2/3/43	J	62°51%	11	11	7	11	6
	K	"	19	19	10	19	7
3/9/43	L	75°72%	10	10	9	10	7
	M	"	8	7	7	6	5
	P	"	9	9	8	7	7
	Q	"	9	8	7	7	6
	AA	"	10	10	9	10	7
	BB	"	8	8	7	8	6
	CC	"	10	10	9	10	8
	DD	"	9	8	9	8	6
	EE	"	7	7	11	7	8
	FF	"	9	9	10	9	7
	GG	"	10	10	10	10	8
	HH	"	8	8	10	8	6
	II	"	9	8	8	6	6
	JJ	"	9	9	6	7	6
	KK	"	5	5	8	4	6
	LL	"	10	10	9	10	7
	MM	"	8	8	12	7	11
	NN	"	10	10	9	8	8
	OO	"	9	9	11	9	8
	PP	"	11	11	8	11	6
	QQ	"	4	4	10	4	8
4/6/43	P	76°28%	10	10	7	10	5
	Q	"	10	10	9	10	6
	R	"	9	9	7	8	5
	S	"	9	9	7	9	5
4/27/43	H	67°62%	11	11	7	10	6
5/4/43	A	76°28%	19	19	6	15	4
5/11/43	M	65°50%	26	25	9	25	6
	V	63°55%	10	10	7	10	6
5/18/43	K	73°50%	10	10	12	10	11
	F	"	10	10	10	9	8
	G	"	9	9	10	8	7
5/25/43	LL	75°40%	9	8	8	3	7
6/1/43	T	80°59%	19	19	10	16	10
	U	"	18	18	12	18	10
7/20/43	EE	86°50%	13	13	9	13	8
	FF	"	12	12	9	12	7
	GG	"	14	14	8	14	6
	HH	"	14	14	8	14	6
	II	"	13	13	8	13	7
	QQ	"	15	15	12	15	10
8/17/43	CC	69°59%	20	20	10	18	8
11/9/43	H	66°34%	11	11	10	11	7
	I	"	10	10	10	10	7
	N	"	24	24	10	23	8
125% (100% L)							
5/25/43	NN	75°40%	10	9	10	8	8

[redacted]

UNCLASSIFIED

IV. SCREENING TESTS OF COMPOUNDS FOR VESICANT ACTION ON HUMAN SKIN

In the following tables will be found the results of tests for vesicant action on human skin of over 400 compounds which were submitted to the University of Chicago Toxicity Laboratory between August 1941 and December 1943. We are indebted to Dr. C. E. Redemann for aid in the preparation of many of the vesicants.

The arrangement of the compounds is as follows:

- Arsenic Compounds
  - Primary Arsines
  - Secondary Arsines
  - Tertiary Arsines
  - Arsenoxides & Arsonic Acids
- Nitrogen Compounds
  - Amides
  - Amines
  - Amines Containing Sulfur
  - Ammonium Compounds
  - Carbamates
  - Heterocylic Nitrogen Compounds
  - Nitriles
  - Nitro Compounds
  - Oximes
  - Phenylenediamines
  - Miscellaneous
- Phosphorus Compounds
  - Phosphorus Compounds
  - Phosphonium Compounds
  - Phosphorus Compounds Containing Sulfur
- Sulfur Compounds
  - Thiols
  - Sulfides
  - Sulfoxides
  - Sulfones
- Organometallics
- Acetylene Derivatives
- Esters
  - 2-Chloroethyl Esters
  - Miscellaneous
- Acid Halides
- Ethers
- Catechols
- Miscellaneous

The following abbreviations are used in the tables:

D.P.E. - Diphenyl ether
E.- - Compound irritant to one man in a group at 0.2 mg.
E. - Compound which produces erythemas but not blisters at 0.2 mg.
K. - Micro Kahn pipettes
N.V. - Compound which is non-irritant at 0.2 mg.
T.P. - Thermometer pipette
V. - Vesicant - compound which produces blisters at 0.2 mg. or less

When compounds were delivered by Edgewood Rod, no dose is given. Unless otherwise specified, all compounds for which a dose is given were delivered by micrometer burette. Exceptions are thermometer pipettes (T.P.) and micro Kahn pipettes (K.). The dose is calculated from the density of the compound (or solution) and the volume expelled in delivery.

The indoor temperatures and relative humidities are given in the tables. The outdoor temperatures will be found in Appendix II.

Sizes of erythemas and blisters are the average diameters of lesions on those men who reacted positively. Zeros are not included in the average lesion sizes.

The status of a compound is given with the first entry of the compound in the table. If a compound irritates one man at a low dose and is inactive at a higher dose, it is classed as non-irritant, since the erythema observed in the first series may have been an error in observation.

Arsenic Compounds

A large number of the arsenicals are good vesicants; among the primary arsines, $RAsX_2$, the most active compounds are those in which X is chlorine and R is butyl, n-amyl, n-hexyl, 2-chlorovinyl, 4-pentenyl, 2-chloro-1-pentenyl, or phenyl.

The lower molecular weight alkyl derivatives (ethyl and propyl) are of higher volatility and do not produce as many or as severe lesions as the others. Replacement of the chlorine by bromine or CN decreases the vesicant action. Ring substitution diminishes the vesicancy of phenyldichloroarsine.

There are relatively few good vesicants among the R_2AsX compounds - allylphenylchloroarsine and chloromethyl(n-nitrophenyl)arsine are the two most powerful.

No active vesicants were found among the R_2As compounds in which R represents a hydrocarbon radical. Among the other tertiary arsines, 2-chlorovinyldiethoxyarsine is outstanding.

Theoxides of L and ED are moderately good vesicants.

PRIMARY ARSINES

Series	TL No.		Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/1/43 GG	625	Arsine, phenyl-	75 γ	100%	80°F. 50%	30	13	5	11	4	V
6/1/43 CC		$C_6H_5AsH_2$	150 γ	100%	80°F. 59%	20	17	8	11	6	V
4/27/43 Q	624	Arsine, p-tolyl-	130 γ	100%	67°F. 62%	14	12	5	9	2	V
		$CH_3C_6H_4AsH_2$									
7/29/42 A	214	Arsine, dichloroethyl- ED	No. 3 Rod	100%	70°F. 86%	17	0	-	0	-	V
8/5/42 D		$CH_3CH_2AsCl_2$	No. 3 Rod	100%	N.R.	20	0	-	0	-	
9/14/42 Y			No. 3 Rod	100%	76°F. 72%	9	0	-	0	-	
9/14/42 Y			No. 3 Rod (closed 5')	100%	76°F. 72%	9	9	9	9	5	
10/7/42 G			No. 3 Rod (closed 5')	100%	62°F. 74%	18	12	5	10	4	
9/1/42 D			No. 5 Rod	50%	78°F. 69%	20	2	2	1	2	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
10/14/42	214	Arsine, dichlorcethyl-	400 γ T.P.	100%	74°F. 52%	10	0	-	0	-	V
		Arsine, dichloroethyl-	Information from other sources:								
			A 5% solution in alcohol applied to the skin had no action: 10% solution gave vesication in 1/2 cases after 24 hours (P.R. 964). 0.005 cc. of 12.4% solution produced vesication (P.R.). Vesicant power through clothing is considerably less than that of lewisite I and mustard gas (Porton not reported) ....British NRB (1940).								
			A vesicant of fairly rapid action....Porton Memo No. 15 (1941)								
			Non-vesicant compared to H....V.19514 (B-1427)								
			Vesicant action on man is 1/6th that of mustard ....EmTR 525								
			Skin irritant data obtained by different procedures are rather conflicting, but exposure of men to concentrations of 0.48-12.2 mg./l. for 5-minutes gave negative results in most cases and produced nothing more than a slight burn in any case.... EmTR 550 (1942)								
For additional data on TL 214, see sections on Vesicant Mixtures and on Closed Vesication Tests											
12/7/42 Q	485	Arsine, dibromoethyl-	No. 5 Rod	100%	N.R.	9	6	2	0	-	V
		$CH_3CH_2AsBr_2$									
12/16/42 R			200 γ T.P.	100%	N.R.	10	5	S	1	10	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/14/42 M	214	Arsine, dichloroethyl- (cont'd)	No. 5 Rod	80% in nitro benzene	76°F. 72%	20	3	5	2	3	V
9/14/42 M			No. 5 Rod	100%	76°F. 72%	20	5	5	4	3	
8/19/42 C			No. 5 Rod	100%	67°F. 80%	20	7	2	4	2	
9/14/42 N			No. 5 Rod	100%	76°F. 72%	20	2	5	1	2	
12/2/42 S			No. 5 Rod	100%	49°F. 51%	18	1	2	0	-	
12/2/42 S		Thickened with cellulose acetate butyrate (5%)	No. 5 Rod	100%	49°F. 51%	18	1	1	0	-	
9/14/42 N		Arsine, dichloroethyl-	No. 5 Rod (closed 5')	100%	76°F 72%	20	11	8	8	7	
6/8/43 H-J			85 Y	100%	62°F 75%	36	0	-	0	-	
9/7/42 O			100 Y T.P.	100%	74°F. 78%	20	0	-	0	-	
10/7/42 F			200 Y T.P.	100%	62°F. 74%	10	0	-	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	Len	48-hour Readings Erythemas No.	Size	Blisters No.	Size	Status
12/14/43 D-2	963	Arsine, dichloroethoxy-	80 γ	100%	57°F. 40%	10	1	6	0	-	N.V.
12/21/43 L-1		$CH_3CH_2OAsCl_2$	240 γ	100%	64°F. 43%	9	0	-	0	-	
2/23/42 A	54	Arsine, dichloro(2-chloroethyl-	No. 5 Rod	30% D.P.E.	N.R.	49	1	N.R.	0	0	N.V.
2/25/42 B		$ClCH_2CH_2AsCl_2$	No. 5 Rod	60% D.P.E.	N.R.	22	0	0	0	0	
2/24/42 B			No. 3 Rod	100%	N.R.	8	0	0	0	0	
3/2/42 B			No. 3 Rod	100%	N.R.	20	0	0	0	0	
		Information from other sources:	The undiluted compound does not redden the skin.... Porton Memo No. 15 (1941). Alcoholic solutions, 5-10% produced irritation but no blisters on man....BA&RD 26 (1924).								
2/23/42 A	55	Arsine, dichloro(2-methoxy- ethyl)-	No. 5 Rod	30% D.P.E.	N.R.	49	5	N.R.	5	5	
2/25/42 B		$CH_3OCH_2CH_2AsCl_2$	No. 5 Rod	40% D.P.E.	N.R.	22	6	N.R.	5	6	
2/25/42 B			No. 3 Rod	100%	N.R.	8	2	N.R.	0	0	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/2/42 B	55	Arsine, dichloro(2-methoxyethyl)- (cont'd.)	No. 3 Rod	100%	N.R.	26	16	N.R.	18	4	
3/24/42 A			No. 3 Rod	100%	N.R.	26	9	N.R.	6	3	
2/25/42 B	56	Arsine, dichloro(2-ethoxyethyl)-	No. 5 Rod	40% D.P.E.	N.R.	22	8	N.R.	4	5	
2/24/42 B		$CH_3CH_2OCH_2CH_2AsCl_2$	No. 3 Rod	100%	N.R.	8	5	N.R.	2	4	
3/2/42 B			No. 3 Rod	100%	N.R.	20	20	N.R.	19	4	
3/24/42 A			No. 3 Rod	100%	N.R.	26	23	N.R.	15	3	
6/29/43 K	8	Arsine, dichloro(2-chlorovinyl)- (Lewisite, plant-run) L $ClCH=CHAsCl_2$	25	100%	69°F. 53%	43	31	5	19	3	V
3/18/42 A	9	Arsine, dichloro(2-chlorovinyl)- L Lewisite, Isomer I	No. 5 Rod	20% D.P.E.	N.R.	51	46	N.R.	35	5	V
3/18/42 A		$ClCH=CHAsCl_2$	No. 5 Rod	25% D.P.E.	N.R.	51	50	N.R.	48	7	
2/17/42 A			No. 5 Rod	30% D.P.E.	N.R.	26	18	N.R.	12	5	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/11/42 A	9	Arsine, dichloro(2-chloro-vinyl)- Lewisite, Isomer I (cont'd.)	No. 5 Rod	30% D.P.E.	N.R.	51	49	N.R.	46	7	V.
2/24/42 D			No. 5 Rod	35% D.P.E.	N.R.	9	9	N.R.	6	6	
3/4/42 B			No. 5 Rod	40% D.P.E.	N.R.	20	20	N.R.	20	6	
3/4/42 A			No. 5 Rod	45% D.P.E.	N.R.	19	18	N.R.	17	5	
2/17/42 A	10	Arsine, dichloro(2-chloro-vinyl)- Lewisite, Isomer II L $ClCH_2=CHAsCl_2$	No. 5 Rod	30% D.P.E.	N.R.	20	12	N.R.	4	6	V
2/24/42 D			No. 5 Rod	35% D.P.E.	N.R.	9	5	N.R.	3	6	
2/24/42 D			No. 5 Rod	50% D.P.E.	N.R.	9	9	N.R.	5	6	
3/4/42 A			No. 5 Rod	50% D.P.E.	N.R.	19	15	N.R.	12	4	
3/4/42 A			No. 5 Rod	60% D.P.E.	N.R.	19	15	N.R.	14	4	
3/11/42 A			No. 5 Rod	65% D.P.E.	N.R.	51	47	N.R.	36	4	
3/18/42 A			No. 5 Rod	70% D.P.E.	N.R.	51	50	N.R.	47	5	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/18/42 A	10	Lewisite, Isomer II (cont'd.)	No. 5 Rod	75% D.P.E.	N.R.	51	50	N.R.	46	8	V

For additional data on L see page 35 and Section III, page 51

8/5/42 G	295	Arsine, dichloropropyl-	No. 5 Rod	100%	N.R.	20	16	5	7	4	V
9/1/42 E		$CH_3CH_2CH_2AsCl_2$	No. 5 Rod	100%	78°F. 69%	20	3	2	0	-	
10/5/42 CC			200 γ T.P.	100%	59°F. 78%	10	0	-	0	-	
11/11/42 H			200 γ T.P.	100%	73°F. 31%	9	5	3	2	1	
		Information from other sources:	The undiluted compound reddened the skin....Porton Memo No. 15 (1941).								
9/15/42 O	361	Arsine, dicyanopropyl-	75 γ T.P.	20% D.P.E.	75°F. 78%	20	2	5	0	-	V
		$CH_3CH_2CH_2As(CN)_2$									
2/25/42 B	57	Arsine, dichloro(3-chloro-methoxypropyl)-	No. 5 Rod	60% D.P.E.	N.R.	22	0	0	0	0	N.V.
2/24/42 C		$ClCH_2OCH_2CH_2CH_2AsCl_2$	No. 5 Rod	100%	N.R.	7	1	N.R.	0	0	
3/2/42 B			No. 5 Rod	100%	N.R.	20	0	0	0	0	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Size	Blisters No.	Size	Status
8/5/42 H	296	Arsine, allyldichloro- $CH_2=CHCH_2AsCl_2$	No. 3 Rod	100%	N.R.	20	0	-	0	-	V
8/17/42 M	"	"	No. 5 Rod	100%	63°F. 79%	19	0	-	0	-	
10/5/42 BB	"	"	200 l T.P.	100%	59°F. 78%	10	2	6	2	5	
		Information from other sources:	Man, no irritation at 0.05 mg./l., in a closed chamber in 5 minutes....see EaCD 107								
6/4/42 A	209	Arsine, butyldichloro- $CH_3CH_2CH_2CH_2AsCl_2$	No. 3 Rod	100%	N.R.	84	83	N.R.	78	5	
		Information from other sources:	The undiluted compound produces marked reddening of the skin....Porton Memo No. 15 (1941). 50/50 mixture with mustard is quite effective vesicant (M.P. 9°C.). Less effective in large drops.... EaTDS 27 (1941).								
3/23/43 JJ	613	Arsine, butyldicyano- $CH_3CH_2CH_2CH_2As(CN)_2$	100 ✗	40% dioxane	75°F. 40%	9	4	6	2	5	V
3/2/42 A	67	Arsine, sec-butyldichloro- $CH_3CH_2CH(CH_3)AsCl_2$	No. 3 Rod	100%	N.R.	19	1	N.R.	0	0	-
		Information from other sources:	The undiluted compound does not redden the skin..... Porton Memo No. 15 (1941).								

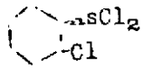
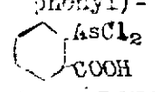
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
4/14/42 B	164	Arsine, amyldichloro-	No. 5 Rod	100%	N.R.	9	9	N.R.	8	4	V
		$CH_3(CH_2)_4AsCl_2$									
9/7/42 I			No. 5 Rod	100%	74°F. 78%	8	8	13	8	8	
9/7/42 N			No. 5 Rod	100%	74°F. 78%	21	20	15	16	12	
		Information from other sources:	The undiluted compound causes marked reddening of the skin just short of vesication....Porton Memo No. 15 (1941). As a vesicant < potent than M-1. 0.025 mg. delivered by capillary apparatus to arms of each of 14 men, 10 blistered. Produced smaller vesicles than did equal quantities of lewisite....TDMR 452 (1942).								
9/21/42 G	368	Arsine, amyldibromo-	No. 5 Rod	100%	66°F. 48%	19	16	4	4	2	V
		$CH_3(CH_2)_4AsBr_2$									
10/21/42 Q	428	Arsine, amyldicyano-	60 γ T.P.	27% abs. alc.	71°F. 45%	10	0	-	0	-	N.V.
		$CH_3(CH_2)_4As(CN)_2$									
11/11/42 V			150 γ T.P.	27% abs. alc.	72.5°F. 31%	10	0	-	0	-	
2/24/42 A	62	Arsine, dichloroisoamyl-	No. 5 Rod	100%	N.R.	26	12	N.R.	4	3	V
		$(CH_3)_2CHCH_2CH_2AsCl_2$									

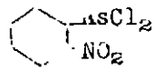
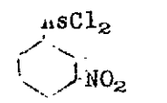
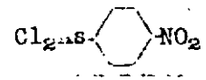
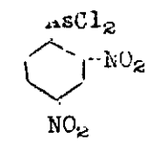
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Blisters Status
5/2/42 A	62	Arsine, dichloroisoamyl- (cont'd)	No. 3 Rod	100%	N.R.	19	14	N.R.	9	4	V
		Information from other sources:	On men (14) minute quantities of the undiluted liquid produced smaller vesicles than did equal quantitities of lewisite....TDMR 452 (1942).								
8/4/42 E	129	Arsine, dichloro(4-pentenyl)- $CH_2=CHCH_2CH_2CH_2AsCl_2$	No. 3 Rod	100%	76°F. 59%	20	15	4	4	4	V
9/1/42 A			No. 5 Rod	100%	78°F. 69%	19	19	7	18	5	
9/21/42 I	382	Arsine, dichloro(2-chloro-1-pentenyl)- $CH_3CH_2CH_2CCl=CHAsCl_2$	No. 5 Rod	100%	66°F. 48%	18	15	3	14	2	V
10/5/42 H			No. 5 Rod	100%	59°F. 78%	10	10	7	8	3	
6/2/42 A	231	Arsine, dichlorohexyl- $CH_3(CH_2)_5AsCl_2$	No. 3 Rod	100%	N.R.	100	99	N.R.	88	3	V
10/5/42 GG	229	Arsine, dichloroheptyl- $CH_3(CH_2)_6AsCl_2$	No. 5 Rod	100%	59°F. 78%	10	7	6	1	4	V
10/19/42 R			No. 6 Rod	100%	68°F. 41%	10	10	5	4	2	
2/24/42 A	69	Arsine, dichlorophenyl- PD $C_6H_5AsCl_2$	No. 3 Rod	100%	N.R.	8	8	N.R.	7	6	V

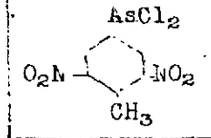
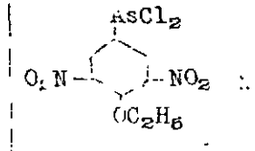
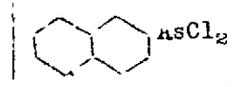
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/2/42 A	69	Arsine, dichlorophenyl- (cont'd)	No. 3 Rod	100%	N.R.	19	19	N.R.	19	6	V
3/31/42 C			No. 3 Rod	100%	N.R.	14	14	N.R.	14	6	
4/13/42 A			No. 3 Rod	100%	N.R.	356	354	N.R.	349	5	
3/16/42 A			No. 5 Rod	20% D.P.E.	N.R.	51	35	N.R.	15	5	
2/16/42 A			No. 5 Rod	25% D.P.E.	N.R.	24	24	N.R.	21	2	
3/18/42 A			No. 5 Rod	25% D.P.E.	N.R.	51	33	N.R.	15	5	
2/16/42 A			No. 5 Rod	30% D.P.E.	N.R.	24	24	N.R.	20	N.R.	
3/18/42 A			No. 5 Rod	30% D.P.E.	N.R.	51	45	N.R.	31	4	
2/17/42 A			No. 5 Rod	40% D.P.E.	N.R.	20	20	N.R.	9	5	
2/25/42 A			No. 5 Rod	45% D.P.E.	N.R.	24	23	N.R.	16	7	
3/4/42 B			No. 5 Rod	55% D.P.E.	N.R.	20	20	N.R.	20	6	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.d.	No. men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
10/14/42 X	69	Arsine, dichlorophenyl- (cont'd)	No. 5 Rod	100%	74°F. 52%	13	13	6	12	5	V
6/1/43 O			20"	100%	78°F. 73%	17	11	4	5	5	
5/25/42 M,O			20"	100%	70°F. 48%	25	5	5	3	4	
6/29/43 M			20"	100%	69°F.	48	28	6	16	4	
6/29/43 N			21"	100%	69°F. 53%	48	23	5	11	4	
5/25/43 P			35"	100%	70°F. 48%	14	3	11	2	11	
		Information from other sources: Produced local necrosis and intense oedema when applied to the skin....W.10260, CD 1096, W.142-8									

For additional data on TL 69, see Vesicant Mixtures, page 43.

7/20/43 AA	807	Arsine, dichloro(o-chlorophenyl)-  Information from other sources:	100"	64% dioxane	80°F. 62%	7	4	4	3	1	V
		This compound is not a vesicant....Porton Memo No. 15 (1941).									
7/13/43 GG	800	Arsine, dichloro(o-carboxyphenyl)- 	100"	28% dioxane	87°F. 51%	12	2	6	2	4	V

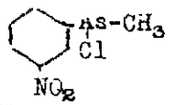
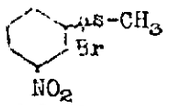
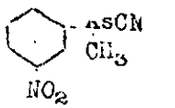
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
10/21/42 P	427	Arsine, dichloro(o-nitrophenyl)- 	60 γ T.P.	48% dioxane	71°F. 45%	10	0	-	0	-	N.V.
11/10/42 T			100 γ T.P.	48% dioxane	73°F. 57%	10	0	-	0	-	
11/11/42 U			200 γ T.P.	48% dioxane	73°F. 31%	10	0	-	0	-	
		Information from other sources:	Application of 0.005 cc. of a solution stronger than 1% produces a lesion on the skin of man....FR (see FRR, 1940)								
2/23/42 A	66	Arsine, dichloro(m-nitrophenyl)- 	No. 5 Rod	50% D.P.E.	N.R.	49	7	N.R.	2	S	V
2/23/42 A	68	Arsine, dichloro(p-nitrophenyl)- 	No. 5 Rod	50% D.P.E.	N.R.	49	48	N.R.	0	0	N.
10/21/42 X	440	Arsine, dichloro(2,4-dinitrophenyl)- 	60 γ T.P.	44% dioxane	71°F. 45%	10	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
11/10/42 A	440	Arsine, dichloro(2,4-dinitrophenyl)- (cont'd.)	100 T.P.	44% dioxane	73°F. 57%	10	0	-	0	-	N.V.
11/11/42 Z			200 T.P.	44% dioxane	73°F. 31%	10	2	5	0	-	
3/3/43 N	557	Arsine, dichloro(4-methyl-3,5-dinitrophenyl)- 	115	26% chloroform	71°F. 23%	10	4	5	0	-	E
3/9/43 BBB			200	26% chloroform	75°F. 72%	7	1	3	0	-	
3/17/43 WW	489	Arsine, dichloro(4-ethoxy-3,5-dinitrophenyl)- 	100	90% dioxane	65°F. 41%	10	0	-	0	-	V
3/5/43 K			200	90% dioxane	71°F. 23%	10	2	6	1	4	
3/23/43 A			200	90% dioxane	75°F. 40%	10	6	5	0	-	
8/31/43 L	673	Arsine, dichloro-2-naphthyl- 	50	26% dioxane	81°F. 75%	15	10	5-	4	3	V

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/8/43 MM	733	Arsine, p-phenylene bis[dichloro- Information from other sources:	200γ	31% cello-solve	76°F. 47%	19	0	-	0	-	V
		Not a vesicant....Porton Memo No. 16 (1941) 1.1 mm. drop of 20% solution has no effect on the skin ....NRB (1940) 10% solution gave no effect on man....EATR 50 (1931)									
6/15/43	769	Arsine, 2-nitro-p-phenylene-	200γ	24%	84°F.	10	0	-	0	-	N.V.

SECONDARY ARSINES

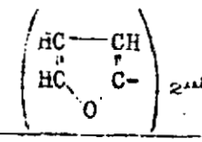
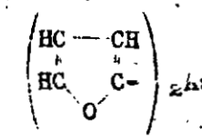
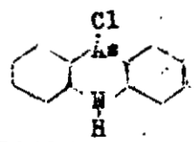
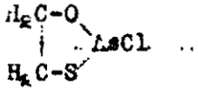
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/15/43 GG	746	Cacodyl cyanide $(CH_3)_2AsCN$	200 γ	45% dioxane	84°F. 56%	14	0	-	0	-	N.V.
		A rather weak and variable skin irritant....CWS Vol. 49 (1919)									
8/31/43 Q	899	Arsine, dimethylthiocyano- $(CH_3)_2AsSCN$	220 γ	100%	81°F. 75%	11	2	9	0	-	L-
3/11/42 A	114	Arsine, chlorobis(chloromethyl)- $(ClCH_2)_2AsCl$	No. 3 Roi	100%	N.R.	51	30	N.R.	11	2	V
10/6/42 D			No. 5 Roi	100%	59°F. 72%	10	7	2	2	2	
6/3/43 Q	806	Arsine, chloromethylphenyl- $C_6H_5-As-CH_3$ Cl	75 γ	100%	78°F. 65%	14	9	3	0	-	E
8/17/43 EE			225 γ	100%	69°F. 59%	9	9	9	0	-	
6/3/43 R	808	Arsine, cyanomethylphenyl- C_6H_5AsCN CH_3	200 γ	100%	78°F. 65%	14	13	7	1	7	V
7/20/43 CC	810	Arsine, methylphenylthiocyano- C_6H_5AsSCN CH_3	75 γ	100%	80°F. 62%	9	9	4	0	-	E
8/17/43 EE			210 γ	100%	69°F. 59%	9	9	8	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/31/43 J	871	Arsine, chloromethyl-(m-nitrophenyl)- 	.80Y	100%	81°F. 75%	16	16	10	14	7	V
8/31/43 K	872	Arsine, bromomethyl-(m-nitrophenyl)- 	80Y	100%	81°F. 75%	15	15	10	9	7	V
9/7/43 JJ	889	Arsine, cyanomethyl-(m-nitrophenyl)- 	50Y	7% methyl cellosolve	74°F. 65%	7	7	12	2	10	V
8/31/43 O	889		200Y	7% methyl cellosolve	81°F. 75%	15	11	19	6	15	
11/11/42 I	574	Arsine, chlorodiethyl- $(CH_3CH_2)_2AsCl$	No. 5 Rod	100%	75°F. 31%	10	0	-	0	-	N.V.
3/9/43 ZZ	552	Arsine, cyanodiethyl- $(CH_3CH_2)_2AsCN$	100Y	100%	75°F. 72%	10	0	-	0	-	N.V.
3/17/43 FFF			200Y	100%	65°F. 41%	10	0	-	0	-	

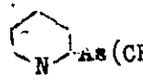
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/3/43 Z	860	Arsine, chlorodiethoxy- $(CH_3CH_2O)_2AsCl$	200 γ	100%	78°F. 65%	12	1	3	0	-	--
10/21/42 N	426	Arsine, chloroethylpropyl- $C_2H_5-As-C_3H_7$ Cl	No. 5 Rod	100%	71°F. 45%	10	0	-	0	-	E
11/9/42 V			100 γ T.P.	100%	73°F. 46%	4	3	4	0	-	
11/11/42 T			200 γ	100%	73°F. 51%	10	2	1	0	-	
4/27/43 R	635	Arsine, cyanoethylpropyl- C_2H_5AsCN C_3H_7	120 γ	100%	67°F. 62%	13	0	-	0	-	N.T.
5/4/43 MM			240 γ	100%	75°F. 27%	14	0	-	0	-	
8/31/43 R	900	Arsine, ethylpropylthiocyano- C_2H_5AsSCN C_3H_7	65 γ	100%	81°F. 75%	9	0	-	0	-	E
9/7/43 LL			200 γ	100%	74°F. 65%	10	3	5	0	-	
12/7/42 R	486	Arsine, butylchloroethyl- $C_2H_5AsC_4H_9$ Cl	No. 5 Rod	100%	N.R.	9	1	1	0	-	E
12/16/42 S			200 γ T.P.	100%	N.R.	10	3	5	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Mon	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
12/7/42 S	487	Arsine, butylcyanoethyl-	No. 5 Rod	100%	N.R.	10	0	-	0	-	N.V.
12/8/42 W		C_2H_5AsCN C_4H_9	200 K T.P.	100%	N.R.	14	0	-	0	-	
2/24/42 C	59	Arsine, chloro(2-chlorovinyl)-phenyl-	No. 3 Rod	100%	N.R.	7	4	N.R.	0	0	V
3/2/42 A		$C_6H_5AsCH=CHCl$ Cl	No. 3 Rod	100%	N.R.	19	13	N.R.	7	3.4	
3/24/42 A			No. 3 Rod	100%	N.R.	26	21	N.R.	0	0	
	-	Information from other sources:	Undiluted compound causes marked reddening of the skin ...Porton Memo No. 15 (1941). Sample prepared in 1918 reported to be a severe skin irritant and vesicant....MTDS 90 (1941).								
2/25/42 B	58	Arsine, allylchlorophenyl-	No. 5 Rod	40% D.P.E.	N.R.	22	15	N.R.	9	5	V
2/24/42 C		$C_6H_5AsCH_2CH=CH_2$ Cl	No. 3 Rod	100%	N.R.	7	6	N.R.	6	5	
3/2/42 A			No. 3 Rod	100%	N.R.	19	18	N.R.	15	4.1	
3/24/42 A			No. 3 Rod	100%	N.R.	26	24	N.R.	21	5	
8/18/42 D	131	Arsine, dibutyliodo-	No. 5 Rod	100%	72°F. 64%	20	15	4	7	2	V
		$(CH_3CH_2CH_2CH_2)_2AsI$									

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
4/13/43 W	652	Arsine, chlorodiphenyl- $(C_6H_5)_2AsCl$	130 γ	100%	65°F. 28%	12	4	6	0	-	V
4/13/43 X			260 γ	100%	65°F. 28%	17	8	8	1	7	
		Information from other sources:	0.005 cc. of 8.16% solution produces a lesion on the skin....(FR) A 30% solution of crude DA in CCl_4 produces a few small vesicles on the skin in 36 hours....CCP 5582 ....see NRB (1940)								
5/11/43	684	Arsine, diphenylthiocyano- $(C_6H_5)_2AsSCN$	140 γ	100%	63°F. 55%	14	1	6	0	-	N.V.
5/18/43 R			210 γ	100%	73°F. 50%	15	0	-	0	-	
3/17/43 XX	490	Arsine, chlorobis(m-nitrophenyl)- $(O_2N\text{-}C_6H_4)_2AsCl$	200 γ	78% dioxane	65°F. 41%	11	0	-	0	-	N.V.
3/17/43 YY	491	Arsine, cyanobis(m-nitrophenyl)- $(O_2N\text{-}C_6H_4)_2AsCN$	200 γ K.	7% dioxane	65°F. 41%	10	0	-	0	-	N.V.
3/23/43 Y	492	Arsine, thiocyanobis- (m-nitrophenyl)- $(O_2N\text{-}C_6H_4)_2AsSCN$	100 γ	32% dioxane	75°F. 40%	10	0	-	0	-	N.V.
3/30/43 S			200 γ	32% dioxane	71°F. N.R.	10	0	-	0	-	

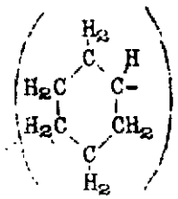
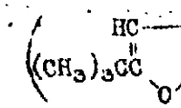
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/18/42 O	289	Arsine, chlorodi-2-furyl- 	No. 5 Rod	100%	72°F. 64%	19	17	4	8	2	V
10/5/42 W	376	Arsine, cyanodi-2-furyl- 	200 γ T.P.	100%	59°F. 78%	10	9	17	0	-	L
			The undiluted compound produces marked reddening and inflammation of the skin just short of vesication.... Porton Memo No. 15 (1941)								
4/27/43 T	644	Phenarsazine, 10-chloro-5,10-dihydro- adamsite 	200 γ	13% methyl cellesolve	67°F. 62%	14	0	-	0	-	N.V.
8/31/43 X	911	1,3,2-Oxathiarsenolane, 2-chloro-	100 γ	100%	81°F. 75%	16	2	7	0	-	D
9/7/43 NN			200 γ	100%	74°F. 65%	25	13	7	0	-	

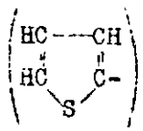
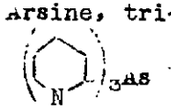
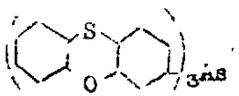
TERTIARY ARSINES

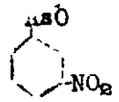
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
12/21/43 E-1	1105	Acetylene, bis(dimethylarsino)- $(CH_3)_2As-C\equiv C-As(CH_3)_2$	220	100%	64°F. 43%	10	0	-	0	-	N.V.
8/3/43 S	839	Arsine, dimethyl-2-pyridyl-  $As(CH_3)_2$	190	100%	79°F. 65%	15	1	8	0	-	E
8/31/43	909	Arsine, (2-chloroethyl-mercapto)dimethyl- $ClCH_2CH_2S-As(CH_3)_2$	210	100%	81°F. 75%	30	0	-	0	-	N.V.
8/3/43 T	840	Arsine, p-phenylene-bis[dimethyl- $(CH_3)_2As-C_6H_4-As(CH_3)_2$	210	100%	78°F. 65%	14	0	-	0	-	N.V.
4/27/43 S	636	Arsine, bis(2-chlorovinyl)-methyl- $CH_3As(CH=CHCl)_2$	220	100%	67°F. 62%	15	0	-	0	-	N.V.
7/20/43 BB	809	Arsine, methoxymethylphenyl- $C_6H_5-As(OCH_3)-CH_3$	65	100%	80°F. 62%	10	9	5	2	2	V

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
12/7/42 T	488	Arsine, bis(2-ethoxyethyl)-methyl-	No. 5 Red	100%	N.R.	10	0	-	0	-	N.V.
12/8/42 X		$(C_2H_5OCH_2CH_2)_2AsCH_3$	200 γ T.P.	100%	N.R.	16	0	-	0	-	
7/20/43 DD	611	Arsine, acetoxymethylphenyl- $C_6H_5AsCH_3$ $OCOCH_3$	135 γ	100%	80°F. 62%	10	10	7	2	9	V
5/18/43 W	714	Arsine, triethyl- $(CH_3CH_2)_3As$	60 γ	100%	73°F. 50%	13	0	-	0	-	N.V.
5/18/43 W			115 γ	100%	73°F. 50%	13	0	-	0	-	
5/25/43 L			230 γ	100%	70°F. 48%	10	0	-	0	-	
12/7/42 P	482	Arsine, ethyldipropoxy- $C_2H_5As(OCH_2CH_2CH_3)_2$	No. 5 Rod	100%	N.R.	10	10	7	6	6	V
10/5/42 F	405	Arsine, (2-chlorovinyl)-dimethoxy- $(CH_3O)_2AsCH=CHCl$	No. 5 Rod	100%	59°F. 73%	10	10	5	4	4	V
			Vesicant power equals that of H....EATR 50 (1931). A 1% solution is about as vesicant as H....EATR 332 (1942)								

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/9/42 S	178	Arsine, (2-chlorovinyl)-diethoxy-	No. 5 Rod	30% D.P.E.	76°F. 87%	40	4	9	13	5	V
9/2/42 R		$(CH_3CH_2O)_2AsCH=CHCl$	No. 5 Rod	40% D.P.E.	82°F. 64%	40	39	11	38	6	
9/2/42 S			No. 5 Rod	60% D.P.E.	82°F. 64%	33	33	10	33	8	
8/18/42 E			No. 5 Rod	75% D.P.E.	N.R.	19	7	5	2	4	
8/4/42 G			No. 5 Rod	100%	76°F. 59%	19	19	6	19	5	
9/7/42 L			No. 5 Rod	100%	74°F. 78%	10	9	10	9	7	
		Information from other sources:	A vesicant as potent as lewisite when applied under the same conditions....Porton Memo No. 15 (1941).								
9/7/42 U	339	Arsine, 2-chlorovinylbis-methylmercapto)- $(CH_3S)_2AsCH=CHCl$	No. 5 Rod	100%	74°F. 78%	41	39	10	27	f	V
9/9/42 T	338	Arsine, bis(2-chloroethyl-mercapto)(2-chlorovinyl)-	No. 5 Rod	75% D.P.E.	76°F. 87%	20	0	-	0	-	E-
9/9/42 U		$(ClCH_2CH_2S)_2AsCH=CHCl$	No. 5 Rod	100%	76°F. 87%	19	1	2	0	-	
		Information from other sources:	A vesicant but less potent than H....Porton Memo No. 15 (1941)								

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/9/43	553	Arsine, diacetoxypropyl- $CH_3CH_2CH_2As(OCOCH_3)_2$	100 γ	100%	75°F. 72%	8	2	6	2	5	V
8/17/42 F	130	Arsine, tricyclohexyl- 	No. 5 Rod	23% dioxane	63°F. 79%	20	0	0	0	0	N.V.
10/5/42 R			100 γ T.P.	23% dioxane	59°F. 78%	10	0	0	0	0	
10/19/42 Q			200 γ T.P.	23% dioxane	68°F. 41%	10	0	0	0	0	
8/5/42	113	Arsine, trioctyl- $[CH_3(CH_2)_7]_3As$	No. 3 Rod	100%	N.R.	20	0	0	0	0	N.V.
8/18/42 C			No. 5 Rod	100%	72°F. 64%	20	0	0	0	0	
10/5/42 II			200 γ T.P.	100%	59°F. 78%	10	0	0	0	0	
8/3/42 N	302	Arsine, tris(5-tert-butyl-2-furyl)- 	No. 5 Rod	20% dioxane	N.R.	20	0	-	0	-	N.V.
10/5/42 O			200 γ T.P.	20% dioxane	59°F. 78%	8	0	-	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/5/42 C	213	Arsine, tri-2-thienyl- 	No. 3 Rod	100%	N.R.	20	0	-	0	-	E-
8/17/42 I			No. 5 Rod	100%	N.R.	19	1	5	0	-	
			Undiluted compound causes some reddening of the skin....Porton Memo No. 15 (1941)								
10/6/42 T	362	Arsine, tri-2-pyridyl- 	100 γ	28% dioxane	50°F. 72%	7	0	-	0	-	N.V.
5/4/43 FF	600	Arsine, tri-4-phenoxathiin- 	200 γ	8% chloroform	73°F. 27%	14	0	-	0	-	N.V.
		ARSENOXIDES									
9/7/42 X	369	Arsine, ethyl- oxide $C_2H_5CH_2AsO$	No. 5 Rod	75% D.P.E.	74°F. 78%	19	9	7	0	-	V
8/19/42 H			No. 5 Rod	100%	67°F. 80%	19	1	1	0	-	
9/2/42 U			No. 5 Rod	100%	82°F. 64%	19	10	5	6	2	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/7/42 W	369	Arsine, ethyl- oxide (cont'd.)	100γ T.P.	100%	74°F. 78%	21	11	4.4	5	5	V
		0.005 cc. of 3.7% solution produces a lesion on human skin (FR)....NRB (1940).									
12/14/43 D-1	88	Arsine, 2-chlorovinyl- oxide I Lewisite oxide ClCH=CHAsO	50γ	25% in diethylene glycol	57°F. 40%	10	10	8	3	10	V
		Information from other sources:	a vesicant equal to lewisite....Porton Memo No. 15 (1941) Is capable of producing burns and blisters on the skin upon prolonged contact, but it is very ineffective as a vesicant agent when compared with L....TRLR No. 8 (1943) A 2 mm. drop on the skin was used throughout. 4.6% solution in alcohol produced 3 cases of vesication and 1 of erythema. 3.4% solution in water produced vesication in 2/2 cases. 2.5% solution in xylene produced erythema in 2/2 cases, the variation being comparable with a solution of L at the same concentration....PDRS 0.005 cc. of 0.1-0.2% solution produces a lesion on the skin....FR									
4/6/43 KK	614	Arsine, m-nitrophenyl- oxide 	200γ	12% aqueous $NaHCO_3$	75°F. 28%	13	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/5/42 I	297	Cacodyl oxide	No. 5 Rod	100%	N.R.	20	0	-	0	-	N.V.
8/18/42 Q		$(CH_3)_2As\text{-}O\text{-}As(CH_3)_2$	No. 5 Rod	100%	72°F. 64%	20	0	-	0	-	
		MISCELLANEOUS									
3/3/43 J	483	Arsenimide, ethyl-N-ethyl- $C_2H_5{=}NC_2H_5$	200	100%	71°F. 23%	10	5	6	2	7	V
		ARSONIC ACIDS									
3/23/43 nn	509	Ethylenearsonic acid, 2-chloro- $ClCH{=}CH\text{-}As(O)(OH)_2$	200	20% water	75°F. 40%	10	1	6	0	-	L-
		Not a vesicant....Porton Memo No. 15 (1941)									
3/23/43 GG	598	Benzenearsonic acid $C_6H_5As(O)(OH)_2$	200	10% water	75°F. 40%	9	1	2	0	-	L-

Nitrogen Compounds

Amides: None of the amides tested was vesicant. (The carbamates are not included under the amides).

Amines: Most of the vesicant amines were of the type $(Cl\text{-}CH_2\text{-}CH_2)_2$ N-R, either as free bases or as hydrochlorides where R was methyl, ethyl, 2-chloroethyl, 2-methoxyethyl, 2-cyanoethyl, 3-chlorobutyl, heptyl, benzyl, or furfuryl. The ethyl homologue (HN-1) was active at 0.2 mg. only as the hydrochloride. Two sulfide-amines were also vesicant.

Ammonium Compounds: None of these was vesicant.

Carbamates: A few of these compounds were irritant, but none produced blisters within 48 hours. TL 186 showed a delayed vesicant action after one week, and it is probable that several others would have had a similar effect had we been able to observe the men for longer periods.

Heterocyclic Nitrogen Compounds (Miscellaneous): None of these was of any effect as an irritant.

Nitriles: Benzylidenemalononitrile blistered 1/10 as a dry powder (exact dose unknown), and 1/20 in solution (Rod #5). The o- bromo derivative was irritant (19/19 erythemas with Rod #5 of a 36% dioxane solution). 1-Chlorofumaronitrile was a poor vesicant.

Nitro Compounds: Only nitroethylene and 2-chloro-6-nitro-α-bromotoluene, both mild irritants showed any action.

Oximes: TL 867, the monoxime of 1-chloro-2-methylglyoxal, was a good vesicant; the dioxime, TL 868, was much less active.

Phenylenediamines: None of these produced blisters, and only a few were irritant.

Miscellaneous: α-Triazobutyric acid was a compound which produced severe necroses on mice, but was relatively ineffective on man.

AMIDES

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/17/42 H	210	Formamide, N,N-bis(2-chloroethyl)-	No. 5 Rod	100%	N.R.	20	0	-	0	-	N.V.
8/5/42 B		$HC(=O)-N(CH_2CH_2Cl)_2$	No. 3 Rod	100%	N.R.	20	0	0	0	0	
8/19/42 G	334	Cyanamide, bis(2-chloroethyl)- $(ClCH_2CH_2)_2N-CN$	No. 5 Rod	100%	67°F. 80%	18	0	-	0	-	N.V.
2/23/43 S	459	Formamide, chloro-N,N-dibutyl- $ClC(=O)-N(CH_2CH_2CH_2CH_3)_2$	200 γ	100%	67°F 30%	10	0	-	0	-	N.V.
12/8/42 V	477	Urea, tetrakis(2-chloroethyl)- $(ClCH_2CH_2)_2N-C(=O)-N(CH_2CH_2Cl)_2$	200 γ T.P.	100%	N.R.	9	0	-	0	-	N.V.
11/11/42 HH			No. 5 Rod	100%	73°F 31%	10	0	-	0	-	N.V.
2/15/43 M	521	Acetamide, N-(2-chloroethyl)- N-nitroso- $CH_3C(=O)-N(CH_2CH_2Cl)_2$	200 γ	100%	62 F 28%	11	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/17/42 J	248	Acetamide, N,N-bis-(2-chloroethyl)-	No. 5 Rod	100%	63°F. 79%	20	0	-	0	-	N.V.
8/5/42 F		$CH_3C(=O)-N(CH_2CH_2Cl)_2$	No. 3 Rod	100%	N. R.	20	0	-	0	-	
3/17/43 AAA	502	Acetamide, trichloro-N,N-bis(2-chloroethyl)- $Cl_3CC(=O)-N(CH_2CH_2Cl)_2$	200γ	18% dioxane	65°F. 41%	10	0	-	0	-	N.V.
10/6/42 W	33	Acetamide, α-chloro-N,N-diethyl-	200γ T.P.	100%	59°F. 72%	10	0	0	0	0	N.V.
8/17/42 D		$ClCH_2-C(=O)-N(CH_2CH_3)_2$	No. 5 Rod	100%	N. R.	20	0	0	0	0	
8/4/42 C			No. 3 Rod	100%	76°F. 59%	21	0	0	0	0	
10/5/42 Q	160	Mandelamide, N-vanillyl-	200γ T.P. 24°	31% dioxane	59°F. 73%	10	0	0	0	0	N.V.
8/17/42 G		$C_6H_5-C(H)(OH)-C(=O)-N(H)-CH_2-C_6H_3(OCH_3)(OH)$	No. 5 Rod	31% dioxane	N. R.	20	0	2	0	0	
10/6/42 X	76	10-Hendecenamide, N-vanillyl-	200γ T.P. 32°	23% dioxane	59°F. 72%	10	0	0	0	0	N.V.
9/7/42 M		$CH_2=CH(CH_2)_8C(=O)-N(H)-CH_2-C_6H_3(OCH_3)(OH)$	50γ T.P. 3°	23% dioxane	74°F. 78%	20	0	0	0	0	
8/3/42 A			No. 5 Rod	23% dioxane	N. R.	20	0	0	0	0	

AMINES

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/23/43 M	449	Dimethylamine, N-(formoxy-ethyl)- $(CH_3)_2N \cdot CH_2CH_2OC(=O)-H$	200 γ	100%	67°F. 30%	10	0	-	0	-	N.V.
2/23/43 I	445	Dimethylamine, N-(2-acetoxy-ethyl)- $(CH_3)_2N \cdot CH_2CH_2OC(=O)-CH_3$	200 γ	100%	67°F. 30%	9	0	-	0	-	N.V.
11/11/42 S	424	Dimethylamine, N-(2-chloro-propyl)- $(CH_3)_2N \cdot CH_2CHClCH_3$	No. 5 Rod	100%	73°F. 31%	10	0	-	0	-	N.V.
12/8/42 S			200 T.P.	100%	N. R.	15	0	-	0	-	
2/23/43 O	451	Triethylamine, 2-formoxy- $(C_2H_5)_2N \cdot CH_2CH_2OC(=O)-H$	200 γ	100%	67°F. 30%	10	0	-	0	-	N.V.
2/23/43 K	447	Triethylamine, 2-acetoxy- $(C_2H_5)_2N \cdot CH_2CH_2OC(=O)-CH_3$	200 γ	100%	67°F. 30%	9	0	-	0	-	N.V.
2/23/43 N	450	Diethylamine, 2-formoxy-N-methyl- $CH_3 \diagdown N \cdot CH_2CH_2OC(=O)-H$ $C_2H_5 \diagup$	200 γ	100%	67°F. 30%	9	0	-	0	-	N.V.

-SECRET-

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/23/43 Q	453	Diethylamine, 2,2'-diformoxy-N-methyl- $CH_3N(CH_2CH_2OC(=O)-H)_2$	200 γ	100%	67°F. 30%	6	0	-	0	-	N.V.
2/23/43 P	452	Diethylamine, 2-formoxy-2'-hydroxy-N-methyl- $CH_3N(CH_2CH_2OH)(CH_2CH_2OCH(=O))$	200 γ	100%	67°F. 30%	10	0	-	0	-	N.V.
2/23/43 J	446	Diethylamine, 2-acetoxy-N-methyl- $CH_3(C_2H_5)N-CH_2CH_2OC(=O)-CH_3$	200 γ	100%	67°F. 30%	8	0	-	0	-	N.V.
2/23/43 L	448	Diethylamine, 2,2'-acetoxy-N-methyl- $CH_3N(CH_2CH_2OC(=O)-CH_3)_2$	200 γ	100%	67°F. 30%	9	0	-	0	-	N.V.
10/6/42 S	385	Diethylamine, 2,2'-dithiocyano-N-methyl- HCl $CH_3N(CH_2CH_2SCN)_2 \cdot HCl$	200 γ T.P.	48% water	59°F. 72%	10	0	-	0	-	N.V.
2/15/43 P	526	Diethylamine, 2-chloro- $ClCH_2CH_2(CH_3CH_2)NH$	200 γ	100%	62°F. 28%	10	0	-	0	-	N.V.

-SECRET-

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings				Status
							Erythemas		Blisters		
							No.	Size	No.	Size	
7/13/43 II	649	Diethylamine, 2-chloro-2'-hydroxy-N-methyl-	50 γ	50% water	87°F. 51%	12	0	-	0	-	E.
8/3/43 P		$HOCH_2CH_2$, NCH_3, $ClCH_2CH_2$	200 γ	50% water	78°F. 65%	13	3	4	0	-	
7/29/42 F	309	Aniline, N-(2-chloroethyl)-N-ethyl	No. 3 Rod	100%	70°F. 86%	17	0	-	0	-	N.V.
8/19/42 F		C_6H_5N, CH_2CH_2Cl, CH_2CH_3	No. 5 Rod	100%	67°F. 83%	20	0	-	0	-	
3/11/42 A	118	Diethylamine, dichloro-N-nitroso- $(ClC_2H_4)_2N-N=O$	No. 3 Rod	100%	N. R.	51	1	N.R.	0	0	E.-
3/11/42 A	146 HSA	Diethylamine, 2,2'-dichloro-N-methyl- $(ClCH_2CH_2)_2NCH_3$ HN2	No. 3 Rod	100%	N. R.	51	18	N.R.	3	3	T.
3/19/42 A	146 Coleman		No. 3 Rod	100%	N. R.	19	16	N.R.	1	3	
3/19/42 A	146 Kharasch		No. 3 Rod	100%	N.R.	19	16	N.R.	1	2	
4/14/42 A	146		No. 3 Rod	100%	N.R.	8	8	-	8	3	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
4/1/42 B	146	Diethylamine, 2,2'-dichloro-N-methyl- (cont'd.)	No. 3 Rod	10% in 88% Formic acid	N.R.	8	8	N.R.	8	3	V
4/2/42 A			No. 3 Rod	"	N.R.	7	7	-	7	3	
6/11/42 A	146 (unheated)		No. 3 Rod	10% Formic acid	N.R.	12	12	N.R.	12	4	
6/11/42 A	146 (K-2)		No. 3 Rod	10% in 88% Formic acid	N.R.	12	1	N.R.	11	1	
6/11/42 A	146 (unheated)		No. 3 Rod	10% Glacial acetic	N.R.	12	12	N.R.	12	3	
6/11/42 A	146 (K-1)		No. 3 Rod	"	N.R.	12	3	N.R.	3	2	
4/1/42 B	146		No. 3 Rod	50% in 88% Formic acid	N.R.	8	8	N.R.	7	3	
4/2/42 A			No. 3 Rod	50% in 88% Formic acid	N.R.	7	7	-	7	3	
4/2/42 B			No. 5 Rod	100%	N.R.	10	10	1	4	6	
1/12/43 C,D			No. 5 Rod	100%	64°F. 33%	73	68	5	7	4	
9/23/42			No. 6 Rod		62°F. 52%	212	164	4	21	3	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/8/43 A-D	146	Diethylamine, 2,2'-dichloro- N-methyl- (cont.)	110 γ	100%	62°F. 36%	91	53	5	1	3	V.
2/15/43 T		(right arm)	110 γ	100%	62°F. 28%	9	6	5	0	-	
2/24/43 A-C			110 γ	100%	69°F. 48%	58	52	7	5	4	
5/25/43 DD			110 γ	100%	75°F. 40%	17	13	6	0	-	
2/8/43 Z			170 γ	100%	62°F. 36%	9	2	7	1	4	
2/15/43 U		(right arm)	220 γ	100%	62°F. 28%	9	9	11	8	3	
3/23/43 R			165 γ	100%	75°F. 40%	35	26 (whites	6	6	3	
3/23/43 U			165 γ	100%	75°F. 40%	30	8 (Negroes)	4	0	-	
3/30/43 G-I			165 γ	100%	71°F. N. R.	52	48	7	6	3	
5/25/43 NN			165 γ	100%	75°F. 40%	10	6	6	2	4	
2/8/43 AA			220 γ	100%	62°F. 36%	13	9	7	1	5	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/17/43 A-H	146	Diethylamine, 2,2'-dichloro-N-methyl- (cont.)	220 γ	100%	69°F. 51%	162	161	9	52	4	V.
3/30/43 D-F	146		230 γ	100%	71°F. N. R.	74	71	10	10	5	
5/18/43 II-JJ	146		220 γ	100%	65°F. 70%	28	24	9	5	8	
3/25/43 EE	146		220 γ	100%	75°F. 40%	15	12	3	0	-	
5/11/43 II	146		220 γ	100%	63°F. 55%	17	9	4	0	-	
4/1/42 B	146 HCl	Diethylamine, 2,2'-dichloro-N-methyl- hydrochloride $(ClCH_2CH_2)_2NCH_3 \cdot HCl$	No. 3 Rod	10% 88% Formic acid	N. R.	8	8	N.R.	8	3	V.
4/2/42 A			No. 3 Rod	10% 88% Formic acid	N. R.	7	7	N.R.	7	2	
4/1/42 B			No. 3 Rod	50% 88% Formic acid	N. R.	8	8	N.R.	8	4	
4/2/42 A			No. 3 Rod	50% 88% Formic acid	N. R.	7	7	N.R.	7	3	
12/28/42 E			40 γ	2% water	68°F.	10	10	6	2	3	

Sereis	TL No.		Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Size	Blisters No.	Size	Status
12/28/42 F	146 HCl	Diethylamine, 2,2'-dichloro- N-methyl- hydrochloride	60γ	3% water	68°F.	10	10	6	1	5	V
12/28/42 G		$(ClCH_2CH_2)_2NCH_3 \cdot HCl$	100γ	5% water	68°F.	10	9	5	3	3	
1/4/43 L			200γ	10% water	68°F. 25%	16	14	6	2	4	
See also "Toxicity Data on the Nitrogen Mustards" by Renshaw, NDRC, Division 9 Report (1944)											
12/14/43 H-Q	1081 HCl	Diethylamine, 2,2'-dichloro- N-tris(chloroemthyl)methyl- $(ClCH_2)_3C\text{-}N(CH_2CH_2Cl)_2$	200γ	13% in ethyl cellosolve	57°F. 40%	10	0	-	0	-	N.V.
12/28/42 K	329 HCl	Triethylamine, 2,2'-dichloro- $(ClCH_2CH_2)_2NC_2H_5$ HNl	40γ	2% water	68°F.	11	3	7	0	-	
12/28/42 L			60γ	3% water	68°F.	9	3	9	0	-	
12/28/42 M			100γ	5% water	68°F.	10	1	9	0	-	
1/4/43 O			100γ	5% water	68°F. 25%	19	5	6	1	3	
1/4/43 P			200γ	10% water	68°F. 25%	20	14	6	4	4	
See also, "Toxicity Data on the Nitrogen Mustards" by Renshaw, NDRC Division 9 Report (1944)											
7/13/43 II	801	Triethylamine, 2-chloro- 2-hydroxy- picryl sulfonate $HOCH_2CH_2\text{-}N\text{-}C_2H_5(NO_2)_3C_6H_2SO_3H$	200γ	16% water	87°F. 51%	12	0	-	0	-	V

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/17/42 C	145	Triethylamine, 2,2',2"-trichloro-	No. 3 Rod	100%	N. R.	10	9	N.R.	4	4	V.
3/17/42	145 (Old Sample)	$(ClCH_2CH_2)_3N$; HN3	No. 3 Rod	100%	N. R.	10	10	N.R.	3	5	
4/14/42 B	145		No. 3 Rod	100%	N. R.	9	9	N.R.	9	2	
4/1/42 A	145		No. 3 Rod	10% 88% Formic acid	N. R.	20	20	N.R.	17	3	
4/8/42 A	145		No. 3 Rod	10% 88% Formic acid	N. R.	10	10	N.R.	10	3	
6/11/42 B	145 (unheated)		No. 3 Rod	10% 88% Formic acid	N. R.	8	8	N.R.	8	4	V.
6/11/42 B	145 K-3 (heated)		No. 3 Rod	10% 88% Formic acid	N. R.	8	1	N.R.	1	1	
6/11/42 B	145 (unheated)		No. 3 Rod	10% glacial acetic acid	N. R.	8	8	N.R.	8	3.8	
6/11/42 B	145 K-4 (heated)		No. 3 Rod	10% glacial acetic acid	N. R.	8	2	N.R.	2	2	
4/1/42 A	145		No. 3 Rod	50% 88% Formic acid	N. R.	20	20	N.R.	15	3	V.

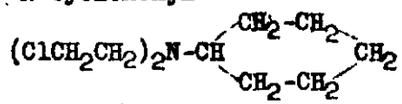
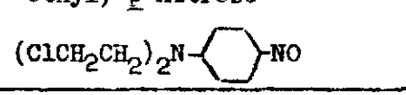
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
4/2/42 B	145	Triethylamine, 2,2',2"-trichloro (cont.)	No. 5 Rod	100%	N. R.	10	10	N.R.	2	7.5	V.
5/25/43 FF			15γ	100%	75°F. 40%	16	4	5	0	-	
5/25/43 GG			30γ	100%	75°F. 40%	18	17	4	0	-	
5/25/43 HH			50γ	100%	75°F. 40%	15	13	7	1	4	
5/25/43 HH			90γ	100%	75°F. 40%	15	13	8	2	5	
5/25/43 GG			125γ	100%	75°F. 40%	18	18	10	2	4	
7/20/43 VV-WW			125γ	100%	80°F. 32%	19	19	13	15	9	
5/25/43 OO			190γ	N. R.	75°F. 40%	17	17	11	4	9	
6/8/43 V-JJ			100γ	100%	77°F. 47%	147	145	10	34	8	
7/20/43 XX-YY			180γ	100%	80°F. 100%	20	20	12	14	9	
5/25/43 FF			250γ	100%	75°F. 40%	16	13	11	0	-	

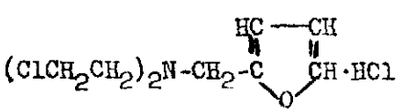
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings				Status
							Erythemas		Blisters		
							No.	Size	No.	Size	
11/22/43 J-N	145	Triethylamine, 2,2',2"-trichloro- (cont.)	180γ	100%	60°F. 63%	46	46	12	13	8	V.
12/21/43 A-B-C	145		180γ	100%	64°F. 43%	44	41	11	14	7	
4/1/42 A	145 HCl	Triethylamine, 2,2',2"-trichloro- HCl	No. 3 Rod	10% 88% Formic acid	N. R.	20	20	N.R.	18	3	V.
4/8/42 A	145 HCl		No. 3 Rod	10% 88% Formic acid	N. R.	10	10	N.R.	10	3	
6/11/42 C	145 (unheated) HCl		No. 3 Rod	10% 88% Formic acid	N. R.	7	7	1	7	2.8	
6/11/42 C	145 (heated) HCl		No. 3 Rod	10% 88% Formic acid	N. R.	7	0	0	0	0	
4/1/42 A	145 HCl		No. 3 Rod	10% 88% Formic acid	N. R.	20	20	N.R.	17	3	
12/28/42 B	145 HCl		40γ	2% water	68°F.	10	10	5	2	4	
12/28/42 C	145 HCl		60γ	3% water	68°F.	10	10	5	0	-	
12/28/42 D	145 HCl		100γ	5% water	68°F.	10	10	9	1	4	

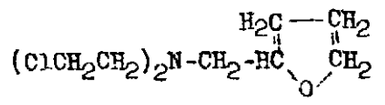
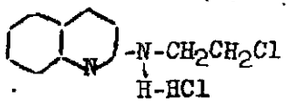
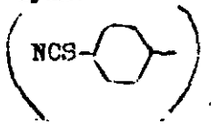
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
1/4/42 I	145 HCl	Triethylamine, 2,2',2"-trichloro- HCl (cont.)	100γ	5% water	68°F. 25%	17	14	8	4	1	V.
1/4/42 J-K			200γ	10% water	68°F. 25%	35	35	6	5	4	
For a summary of data from other sources see 'Toxicity Data on the Nitrogen Mustards' by Renshaw, NDRC, Div. 9 Report (1944)											
7/20/43 W	785 HCl	Triethylamine, 2,2'-dichloro-2'-methoxy- HCl $(ClCH_2CH_2)_2NCH_2CH_2OCH_3$	100γ	20% Propylene glycol	80°F. 62%	15	11	10	2	5	V.
7/13/43 DD			200γ	20% Propylene glycol	87°F. 51%	14	12	14	8	11	
10/5/43 O	958	Propionitrile, 3,3'-bis-(2-chloroethylamino) - $(ClCH_2CH_2)_2NCH_2CH_2CN$	120γ	100%	67°F. 55%	20	18	9	6	5	V.
9/28/43 K-1	953 HCl		100γ	17% water	79°F. 57%	11	11	8	10	5	
10/12/43 W-2	966 HCl	Ethylenediamine, N,N,N'N'-tetrakis-(2-chloroethyl)· 2HCl $H_2C\text{-}N(CH_2CH_2Cl)_2$ $H_2C\text{-}N(CH_2CH_2Cl)_2$ $\cdot 2HCl$	100γ	56% water	80°F. 54%	12	2	6	0	-	E.
10/19/43 E			200γ	56% water	77°F. 48%	15	1	5	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/3/43 M	481	Diethylamine, 2,2'-dichloro-N-propyl- $(ClCH_2CH_2)_2N\cdot CH_2CH_2CH_3$	200 γ	100%	72°F. 31%	9	4	3	0	-	V.
		Less vesicant than HN2 on the bare skin; considerably less vesicant than S through clothing .... W. 5913 (C.D.R.1095, 1942)									
8/4/42	301	Diethylamine, 2,2'-dichloro-N-isopropyl- $(ClCH_2CH_2)_2N\cdot CH(CH_3)_2$	No. 3 Rod	100%	76°F. 59%	20	0	-	0	-	E.
8/18/42 R			No. 5 Rod	100%	72°F. 64%	20	10	4	0	-	
9/15/42 F	301		100 γ T.P.	100%	75°F. 78%	12	0	-	0	-	
10/5/42 AA	301		100 γ T.P.	100%	59°F. 78%	10	0	-	0	-	
12/28/42 H	301 HCl	Diethylamine, 2,2'-dichloro-N-isopropyl- HCl $(ClCH_2CH_2)_2N\cdot CH(CH_3)_2\cdot HCl$	40 γ	2% water	68°F.	9	2	2	0	-	
12/28/42 I			60 γ	3% water	68°F.	12	0	-	0	-	
12/28/42 J			100 γ	5% water	68°F.	7	2	6	0	-	
1/4/43 M			100 γ	5% water	68°F. 25%	16	2	7	0	-	
1/4/43 N			200 γ	10% water	68°F. 25%	18	4	3	0	-	
		Information from other sources:	Dilute acetone sol. or satd. vapor, skin irritant effect slightly less than H. Much less than H when applied undiluted with No. 7 Rod (ca. 0.15 mg.) on 11 men. .... TDMR 438 (1942)								

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/3/43 O	513	Diethylamine, N-butyl-2,2'-dichloro- $(ClCH_2CH_2)_2N\cdot CH_2CH_2CH_2CH_3$	200γ	100%	72°F. 31%	10	1	11	0	-	E.
		Produced about same degree of erythema as HN2 but EN2 gave greater degree of vesication. .... Suffield Tech. Minute No. 16 (1943)									
2/15/43 O	525	Diethylamine, N-isobutyl-2,2'-dichloro- $(ClCH_2CH_2)_2N\cdot CH_2C(CH_3)_2$ (H)	200γ	100%	62°F. 28%	11	2	4	0	-	E.
2/15/43 N	524	Diethylamine, N-sec·butyl-2,2'-dichloro- $(ClCH_2CH_2)_2N\cdot CH(CH_3)CH_2CH_3$	200γ	100%	62°F. 28%	8	0	-	0	-	N.V.
3/3/43 O	568	Diethylamine, N-tert-butyl-2,2'-dichloro- $(ClCH_2CH_2)_2N\cdot C(CH_3)_3$	100γ	100%	71°F. 23%	17	8	5	0	-	E.
3/17/43 III			200γ	100%	65°F. 41%	9	3	6	0	-	
11/9/43 Q-2	1014 HCl	Diethylamine, 2,2'-dichloro-N-(3-chlorobutyl)- HCl $ClCH_2CH_2)_2N\cdot CH_2CH_2CH(Cl)CH_3\cdot HCl$	100γ	20% dioxane	58°F. 58%	15	7	5	1	4	V.
9/15/42 I	340 HCl	Diethylamine, 2,2'-dichloro-N-heptyl-, HCl $(ClCH_2CH_2)_2N\cdot(CH_2)_6CH_3.HCl$	75γ T.P.	20% dioxane	75°F. 78%	20	16	4	4	5	V.
10/6/42 U			200γ	20% dioxane	59°F. 72%	10	0	-	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/3/43 N	512	Diethylamine, 2,2'-dichloro-N-cyclohexyl- 	200 Y	100%	72°F. 31%	8	2	9	0	-	E.
11/11/42 GG	476	Aniline, N,N-bis(2-chloroethyl)- $(ClCH_2CH_2)_2N\cdot C_6H_5$	60 Y	40% dioxane	73°F. 31%	10	0	-	0	-	N.V.
12/8/42 U			200 Y	40% dioxane	N. R.	15	0	-	0	-	
3/17/43 BBB	507	Aniline, N,N-bis(2-chloroethyl)-p-nitroso- 	100 Y	65% dioxane	65°F. 41%	10	8	5	0	-	E.
3/23/43 Z			200 S	65% dioxane	75°F. 40%	13	13	7	0	-	
6/8/43 NN	695	Benzylamine, N,N-bis-(2-chloroethyl)- $(ClCH_2CH_2)_2N\text{-}CH_2C_6H_5$	No. 3 Rod	100%	77°F. 47%	30	15	5	0	-	V.
6/8/43 OO			No. 5 Rod	100%	77°F. 47%	26	16	5	0	-	
6/8/43 PP			15 S	100%	77°F. 47%	25	2	5	0	-	
6/8/43 RR			15 S	100%	77°F. 47%	23	6	5	0	-	
6/8/43 NN			30 Y	100%		30	13	5	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/8/43 SS	695	Benzylamine, N,N-bis-(2-chloroethyl)- (cont.)	30 γ	100%	77°F. 47%	23	8	6	0	-	V.
6/8/43 QQ			45 γ	100%	77°F. 47%	19	3	7	0	-	
6/8/43 OO			55 γ			26	15	7	0	-	
6/8/43 PP			85 γ			23	9	9	0	-	
6/8/43 QQ			115 γ			19	10	7	0	-	
6/8/43 RR			140 γ			23	19	9	0	-	
6/1/43 DD			115 γ		80°F. 59%	20	18	10	6	9	
5/18/43 T	695 HCl	Benzylamine, N,N-bis(2-chloroethyl)- HCl (cont.)	100 γ	13% methyl cellosolve	73°F. 50%	8	5	10	0	-	D.
5/25/43 J	695 HCl		200 γ	13% methyl cellosolve	70°F. 48%	10	3	12	0	-	
12/14/43 F-2	1055 HCl	Diethylamine, 2,2'-dichloro-N-furfuryl- HCl 	100 γ	35% water	57°F. 40%	10	10	7	5	7	V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
11/9/43 O-2	995 HCl	Diethylamine, 2,2'-dichloro-N-tetrahydrofurfuryl- 	50 γ	16% water	58°F. 58%	15	5	4	1	4	V.
12/21/43 F-1	1120 HCl	Quinoline, 2-(2-chloroethyl-amino)- HCl 	200 γ	50% water	64°F. 43%	10	0	-	0	-	N.V.
11/11/42 P	421	Dipropylamine, 2,2'-dichloro-N-methyl-, $(CH_3CHClCH_2)_2N\cdot CH_3$	No. 5 Rod	100%	73°F. 31%	10	0	-	0	-	N.V.
12/8/42 Q			200 γ T.P.	100%	N. R.	14	0	-	0	-	
		A 2 mm. drop just produces erythema. B-2487 (1942)									
9/22/42 F	377	Diphenylamine, 4,4'-dithiocyano- 	No. 7 Rod	22% dioxane	59°F. 47%	18	0	-	0	-	N.V.
10/5/42 I			200 γ T.P.	22% dioxane	59°F. 78%	7	0	-	0	-	

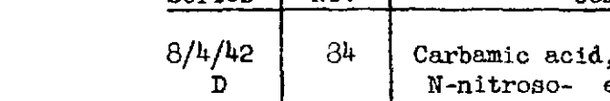
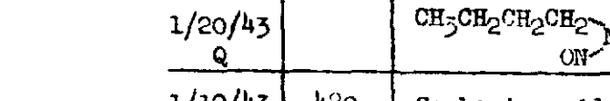
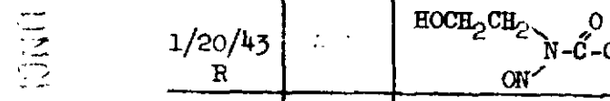
AMINES CONTAINING SULFUR (AS SULFIDE)

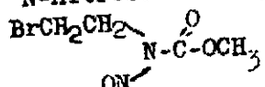
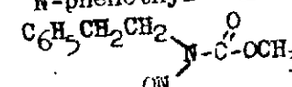
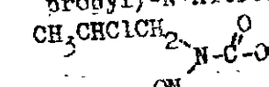
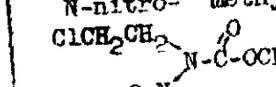
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
7/13/43 HH	803	Bis(ethylmercapto)amine, 2,2',N-trichloro- $(ClCH_2CH_2S)_2NCl$	75γ	100%	87°F. 51%	13	1	5	0	-	E.
7/20/43 Z			225γ	100%	80°F. 62%	12	3	4	0	-	
11/9/43 Q-1	1002 HCl	Diethylamine, 2,2'-bis-(2-chloroethylmercapto)-N-methyl- HCl $(ClCH_2CH_2SCH_2CH_2)_2NCH_3 \cdot HCl$	100γ	22% dioxane	58°F. 58%	15	15	10	4	8	V.
11/9/43 P-2	1001 HCl	Aniline, N,N-bis [2-(2-chloroethylmercapto)ethyl] - HCl $(ClCH_2CH_2SCH_2CH_2)_2NC_6H_5 \cdot HCl$	100γ	48% dioxane	58°F. 58%	15	0	0	0	-	N.V.
11/22/43 Q-1			200γ	48% dioxane	64°F. 32%	10	0	-	0	-	
12/21/43 E-2	1109 HCl	Sulfide, bis(2-[bis(2-chloroethyl)amino] ethyl)- 2HCl $[(ClC_2H_4)_2NC_2H_4]_2S \cdot 2HCl$	200γ	33% water	64°F. 43%	10	8	5	3	3	V.

AMMONIUM COMPOUNDS

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/22/42 C	379	Ammonium compound, bis(2-chloroethyl)dimethyl chloride $(ClCH_2CH_2)_2\overset{+}{N}(CH_3)_2\ \bar{Cl}$	No. 7 Rod	54% water	59°F.	20	0	-	0	-	N.V.
11/22/43 T-2	1032	Carbamic acid, 2-[bis(2-chloroethyl)amino] ethyl ester ethochloride $H_2N-\overset{O}{\overset{\|}{C}}-OCH_2CH_2\overset{+}{N}(CH_2CH_2Cl)_2\ C_2H_5\ \bar{Cl}$	200 ℥	25% water	64°F. 32%	8	1	2	0	-	E.-
9/22/42 D	381	Carbamic acid, N-methyl-2-(dimethylamino)ethyl ester methochloride $CH_3(H)N-\overset{O}{\overset{\|}{C}}-O-CH_2CH_2\overset{+}{N}(CH_3)_3\bar{Cl}$	No. 7 Rod	45% water	59°F. 47%	19	0	-	0	-	N.V.

CARBAMATES

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/4/42 D	84	Carbamic acid, N-methyl- N-nitroso- ethyl ester	No. 3 Rod	100%	76°F. 59%	19	0	0	0	0	N.V.
8/17/42 E			No. 5 Rod	100%	63°F. 79%	20	0	0	0	0	
		1 mm. and 2 mm. drops cause erythema and vesication of human skin. .... V. 20841, C.D.R. 1087 (1942) (B. 1203(X))									
1/12/43 V	478.	Carbamic acid, N-butyl- N-nitroso- methyl ester	No. 5 Rod	100%	64°F. 33%	8	0	-	0	-	N.V.
1/20/43 Q			200γ	100%	63°F. 31%	10	0	-	0	-	
1/12/43 W	480	Carbamic acid, N-(2-hydroxyethyl) N-nitroso- methyl ester	No. 5 Rod	100%	64°F. 33%	10	0	-	0	-	N.V.
1/20/43 R			200γ	100%	63°F. 37%	7	0	-	0	-	
6/4/42 B	186	Carbamic acid, N-(2-chloroethyl)- N-nitroso- methyl ester KB-16  (closed vesication)	No. 3 Rod	100%	N. R.	10	4	1	0	0	E.
12/28/42 A			No. 5 Rod (closed 5')	100%	68°F.	15	4	4	0	-	
1/4/43 R			200γ	100%	68°F. 25%	19	7	4	0	0	
1/20/43 N			200γ	100%	63°F. 37%	9	0 (48-hour Reading) 7 (7-day Reading)	0	0 1	0 2	(delayed V.
		Vesicant action about 1/4 that of H. ... Ptn. Memo. No. 24 (19									

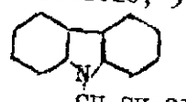
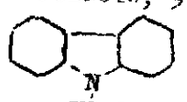
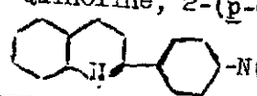
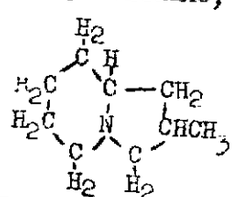
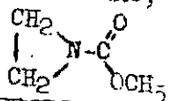
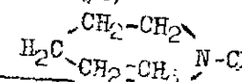
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/1/43 EE	700	Carbamic acid, N-(2-bromoethyl)-N-nitroso- methyl ester 	235 γ	100%	80°F. 59%	20	0	-	0	-	N.V.
5/18/43 R	704	Carbamic acid, N-nitroso-N-phenethyl- methyl ester 	240 γ	100%	73°F. 50%	15	0	-	0	-	N.V.
1/20/43 P	415	Carbamic acid, N-(2-chloropropyl)-N-nitroso- methyl ester 	200 γ	100%	63°F. 37%	3	0	-	0	-	N.V.
9/21/42 J	387	Carbamic acid, N-2-chloroethyl-N-nitro- methyl ester 	No. 5 Rod	100%	66°F. 48%	18	1	5	0	-	N.V.
11/11/42 J			150 γ T.P.	100%	63°F. 31%	10	0	-	0	-	
10/5/42 U			200 γ T.P.	100%	59°F. 78%	10	0	-	0	-	
12/8/42 K			200 γ T.P.	100%	N. R.	15	0	-	0	-	
1/12/43 Y	528	Carbamic acid, N-ethyl-N-nitroso- ethyl ester 	No. 5 Rod	100%	64°F. 33%	9	0	-	0	-	N.V.
1/20/43 T			200 γ	100%	63°F. 37%	7	0	-	0	-	

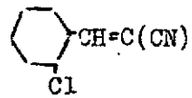
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
1/12/43 T	154	Carbamic acid, N-(2-chloroethyl)-N-nitroso- ethyl ester	No. 5 Rod	100%	64°F. 33%	3	0	-	0	-	E.-
1/20/43 M	'	$ClCH_2CH_2(ON)N-C(=O)-OC_2H_5$	200γ	100%	63°F. 37%	10	1	7	0	0	
1/12/43 U	220	Carbamic acid, N,N-bis-(2-chloroethyl)- ethyl ester	No. 5 Rod	100%	64°F. 33%	4	0	-	0	-	N.V.
1/20/43 O	'	$(ClCH_2CH_2)_2N-C(=O)-OC_2H_5$	200γ	100%	63°F. 37%	10	0	-	0	-	
1/12/43 X	514	Carbamic acid, N-methoxy- ethyl ester	No. 5 Rod	100%	64°F. 33%	10	0	-	0	-	N.V.
1/20/43 S		$CH_3O(H)N-C(=O)-OC_2H_5$	200γ	100%	63°F. 37%	7	0	-	0	-	
3/17/43 HHH	563	Carbamic acid, N,N-dichloro- ethyl ester	100γ	100%	65°F. 41%	10	0	-	0	-	N.V.
3/23/43 DD		$Cl_2N-C(=O)-OC_2H_5$	200γ	100%	75°F. 40%	10	0	-	0	-	
7/13/43 EE	790	Carbamic acid, N-methyl-N-nitroso- 2-fluoroethyl ester $CH_3(ON)N-C(=O)-OCH_2CH_2F$	260γ	100%	87°F. 51%	15	5	5	0	-	E.

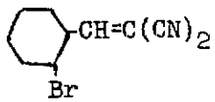
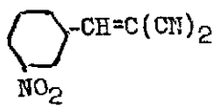
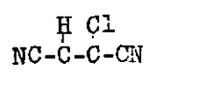
SECRET

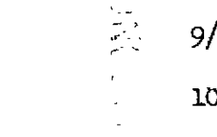
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size
10/5/42 G	397	Carbamic acid, N-(2-chloroethyl)-N-nitroso- isopropyl ester	No. 5 Rod	100%	59°F. 78%	10	0	-	0	-
10/19/42 W		$ClCH_2CH_2N(ON)-C(=O)-OCH(CH_3)_2$	No. 6 Rod	100%	68°F. 41%	10	0	-	0	-
10/21/42 G			No. 7 Rod	100%	71°F. 45%	10	0	-	0	-
11/11/42 K			100Y T.P.	100%	73°F. 31%	9	0	-	0	-
12/8/42 L			200Y T.P.	100%	N. R.	15	0	-	0	-
10/6/42 E	316	Carbamic acid, N-(2-chloroethyl)-N-nitroso- butyl ester	No. 5 Rod	100%	59°F. 72%	10	0	-	0	-
10/19/42 T		$ClCH_2CH_2N(ON)-C(=O)-OC_4H_9$	200Y T.P.	100%	68°F. 41%	10	2	4	0	-
6/15/43 II	748	Carbamic acid, N-ethylthiol-methyl ester	215Y	100%	84°F. 56%	14	0	-	0	-
		$C_2H_5N(H)-C(=O)-SCH_3$								

HETEROCYCLIC NITROGEN COMPOUNDS

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/3/42 E	188	Carbazole, 9-(β-chloroethyl)- 	No. 3 Rod	12% dioxane	N. R.	20	0	-	0	-	N.V.
6/18/42 F			No. 5 Rod	12% dioxane	N. R.	20	0	-	0	-	
6/8/43 LL	727	Carbazole, 9-vinyl- 	200	33% dioxane	77°F. 47%	15	0	-	0	-	N.V.
9/7/43 GG	679	Quinoline, 2-(p-dimethylamino-phenyl)- 	200 K.	2-1/2% in chloroform Chlorcosane 65%	74°F.	9	0	-	0	-	N.V.
12/28/42 Q	500	Piperolidine, 2-methyl- 	No. 5 Rod	100%	68°F.	10	0	-	0	-	N.V.
2/23/43 V	479	Aziridine, 1-carbomethoxy- 	200	100%	67°F. 30%	15	0	-	0	-	N.V.
8/18/42 S	330	Piperidine, 1-(β-chloro-ethyl)- 	No. 5 Rod	100%	72°F. 64%	20	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
7/29/42 B	236	Acrylonitrile, α,β-dichloro- $CHCl=CClCN$	No. 3 Rod	100%	70°F. 86%	16	0	-	0	-	N.V.
8/18/42 B			No. 5 Rod	100%	72°F. 64%	20	0	-	0	-	
10/5/42 X			200% T.P.	100%	59°F. 78%	10	0	-	0	-	
8/18/42 I	237	Malononitrile, benzylidene- $C_6H_5CH=C(CN)_2$	10 mg. (approx.)	Dry Powder	72°F. 64%	10	1	N.R.	1	10	V.
9/7/42 P			54% T.P.	27% dioxane	74°F. 78%	20	0	-	0	-	
8/3/42 H			No 5 Rod	27% dioxane	N. R.	20	1	3	1	1	
8/18/42 J	238	Malononitrile, o-chloro-benzylidene- 	10 mg. (approx.)	Dry Powder	72°F. 64%	10	0	-	0	-	N.V.
9/7/42 Q			55% T.P.	27% dioxane	74°F. 78%	19	0	-	0	-	
8/3/42 I			No. 3 Rod	27% dioxane	N. R.	20	0	-	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/18/42 T	239	Malonitrile, o-bromo-benzylidene-	10 mg. (approx.)	Dry Powder	72°F. 64%	10	0	-	0	-	E.
9/7/42 R	"		73% T.P.	36% dioxane	74°F. 78%	20	1	3	0	-	
8/3/42 J	"		No. 5 Rod	36% dioxane	N.R.	19	19	3	0	-	
8/18/42 K	240	Malonitrile, m-nitro-benzylidene-	10 mg. (approx.)	Dry Powder	72°F. 64%	10	0	-	0	-	N.V.
9/7/42 S	"		55% T.P.	28% dioxane	74°F. 78%	20	0	-	0	-	
8/3/42 K	"		No. 5 Rod	28% dioxane	N.R.	19	0	-	0	-	
8/3/43 [redacted]	644	Fumaronitrile, 1-chloro-	120%	100%	78°F. 65%	12	3	4	0	-	V.
8/17/43 FF	"		240%	100%	69°F. 59%	15	0	-	0	-	
8/31/43 G	"		240%	100%	81°F. 75%	15	2	7	1	9	

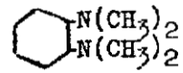
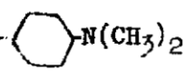
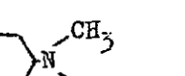
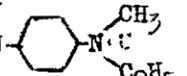
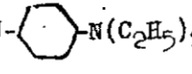
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
10/21/42 I	410	Methane, tris(chloromethyl)nitro-	60% T.P.	35% dioxane	71°F. 45%	9	0	-	0	-	N.V.
11/11/42 N		$(ClCH_2)_3C\text{-}NO_2$	150% T.P.	35% dioxane	73°F. 31%	10	0	-	0	-	
12/14/43 H-1	1066	Ethylene, nitro-	230%	100%	57°F. 40%	10	8	3	0	-	E.
12/21/43 F-2		$CH_2=CH\text{-}NO_2$	60% (closed 5')	100%	64°F. 43%	10	6	5	0	-	
9/15/42 M	347	Ethylene, 1-(2-furyl)-2-nitro- 	75% T.P.	29% dioxane	75°F. 73%	21	0	-	0	-	N.V.
10/5/42 N			200% T.P.	29% dioxane	59°F. 78%	8	0	-	0	-	
8/3/43 N	219	2-Propene, 1,1,1-trichloro- 3-nitro- $Cl_3CCH=CHNO_2$	225%	100%	78°F. 65%	12	0	-	0	-	N.V.
9/15/42 J	348	Propene, 1,(2-furyl)-2-nitro- 	75% T.P.	55% dioxane	75°F. 78%	20	0	-	0	-	N.V.
10/5/42 M			200% T.P.	55% dioxane	59°F. 78%	10	0	-	0	-	
9/15/42 K	349	Propene, 2-nitro-1-phenyl- 	75% T.P.	35% dioxane	75°F. 78%	17	0	-	0	-	N.V.
10/5/42 L			200% T.P.	34% dioxane	59°F. 78%	10	0	-	0	-	
9/15/42 L	351	Toluene, α-bromo-2-chloro-6-nitro- 	75% T.P.	41% dioxane	75°F. 78%	20	2	4	0	-	E.

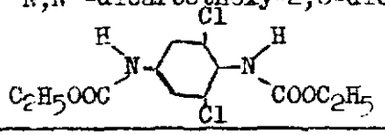
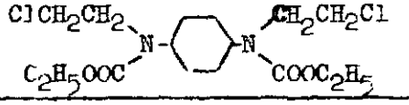
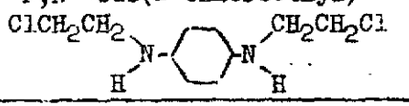
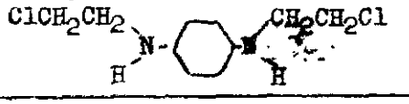
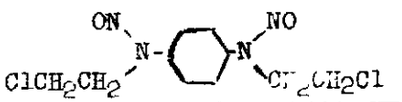
OXIMES

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/30/43 R	356	Chloral oxime Cl_3C-CH $\overset{\|}{N}OH$	100 γ	100%	71°F. N. R.	10	0	-	0	-	N.V.
4/6/43 BB			200 γ	100%	75°F. 28%	23	0	-	0	-	
		Reaction product of chloral and nitrosyl chloride shows mild vesicant properties. ... Ptn. Memo. No. 15, October, 1941.									
8/31/43 H	867	Acetone, 1-chloro-1-isonitroso- $CH_3-\overset{\overset{O}{\|}}{C}-\overset{Cl}{\overset{\|}{C}}=NOH$	200 γ	26% dioxane	81°F. 15%	13	13	3	10	6	V.
8/31/43 I	868	Glyoxime, 1-chloro-2-methyl- $CH_3C(=NOH)-\overset{Cl}{\overset{\|}{C}}=NOH$	200 γ	13% cello-solve	81°F. 75%	14	0	-	0	-	N.V.
6/8/43 KK	720	Formaldehyde, chloro-cyano- oxime $N\equiv CC\overset{\overset{N}{\|}}{Cl}$ NOH	200 γ	44% dioxane	76°F. 47%	14	10	6	1	4	V.

PHENYLENE DIAMINES

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/3/42 C	82	p-Phenylenediamine, N,N-dimethyl-	No. 3 Rod	19% D.P.E.	N. R.	19	0	0	0	0	N.V.
8/18/42 B	"	$(CH_3)_2N$-C$_6$H$_4$-NH_2	No. 5 Rod	19% D.P.E.	72°F. 64%	19	0	0	0	0	
3/17/43 DDD	548	p-Phenylenediamine, N,N'-dimethyl-	100γ	47% dioxane	65°F. 41%	10	9	6	0	-	E.
3/23/43 CC	"	H_3C-NH-C$_6$H$_4$-N(CH_3)-H	200γ	47% dioxane	75°F. 40%	10	10	9	0	-	
		Absolute alcohol solutions (1% to 5%) when applied to human subjects produced immediate marked smarting and redness. Application of the 5% solution was followed also by burning and soreness lasting 4 days. .... E.A.TDS 25 (1941)									
3/17/43 EEE	549	p-Phenylenediamine, N,N'-dimethyl-N,N'-dinitroso- H_3C-N(NO)-C$_6$H$_4$-N(CH_2)-NO	200γ K.	5% chloroform	65°F. 41%	4	0	-	0	-	N.V.
10/5/42 S	85	p-Phenylenediamine, N,N,N',N'-tetramethyl- $(CH_3)_2N$-C$_6$H$_4$-$N(CH_3)_2$	200γ T.P.	31% D.P.E.	59°F. 78%	10	0	0	0	0	N.V.
5/25/43 K	707	m-Phenylenediamine, N,N,N',N'-tetramethyl- $N(CH_3)_2$-C$_6$H$_4$-$N(CH_3)_2$	200γ	100%	70°F. 48%	10	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
5/18/43 V	108	o-Phenylenediamine, N,N,N',N'-tetramethyl- 	190 γ	100%	73°F. 50%	14	0	-	0	-	N.V.
4/6/43 CG	564	p-Phenylenediamine, N',N'-diethyl- 	100 γ	100%	75°F. 28%	15	1	2	0	-	N.V.
4/13/43 T			200 γ	100%	65°F. 28%	25	0	-	0	-	
4/6/43 EE	550	p-Phenylenediamine, N,N'-diethyl- N,N'-dimethyl- 	100 γ	100%	75°F. 28%	14	5	2	0	-	E.
4/13/43 R			200 γ	100%	65°F. 28%	16	1	9	0	-	
5/4/43 KK	623	p-Phenylenediamine, N,N,N'-triethyl-N'-methyl- 	190 γ	100%	73°F. 27%	14	3	-	0	-	N.V.
3/23/43 BB	547	p-Phenylenediamine, N,N,N',N'-tetraethyl- 	200 γ	10% dioxane	75°F. 40%	11	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/15/43 JJ	753	p-Phenylenediamine, N,N'-dicarbethoxy- Reaction product with HNO_2	100γ	9% dioxane	84°F. 56%	13	0	-	0	-	N.V.
6/29/43 W			200γ	9% dioxane	71°F. 41%	12	0	-	0	-	
6/15/43 KK	754	p-Phenylenediamine, N,N'-dicarbethoxy-2,6-dichloro- 	200γ	8% cello-solve	84°F. 56%	13	0	-	0	-	N.V.
6/15/43 LL	756	p-Phenylenediamine, N,N'-dicarbethoxy- N,N'-bis(2-chloroethyl)- 	200γ	21% dioxane	84°F. 56%	14	0	-	0	-	N.V.
5/18/43 U	706	p-Phenylenediamine, N,N'-bis(2-chloroethyl)- 	200γ	21% dioxane	73°F. 50%	12	11	7	0	-	E.
12/14/43 G-1	1061	p-Phenylenediamine, N,N'-bis(2-chloroethyl)- dihydrochloride  ·2HCl	200γ	11% water	57°F. 40%	10	10	6	0	-	E.
5/18/43 S	705	p-Phenylenediamine, N,N'-dinitroso- N,N'-bis(2-chloroethyl)- 	200γ	10% dioxane	73°F. 50%	14	0	-	0	-	N.V.

MISCELLANEOUS NITROGEN COMPOUNDS

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/22/42 E	388	Ethyl chloroacetimodoether HCl $ClCH_2-C(=NH\cdot HCl)-O-C_2H_5$	No. 7 Rod	26% water	59°F. 47%	20	0	-	0	-	N.V.
8/31/42 P	890	Butyric acid, α-triazo- $CH_3CH_2CHN_3COOH$	60 ¢	100%	81°F. 75%	12	1	2	0	-	E.
9/7/43 KK			180 ¢	100%	74°F. 65%	11	4	5	0	-	

Phosphorus Compounds

The phosphorus compounds are divided into three general groups: phosphonium compounds, phosphorus compounds containing sulfur, and others. Except for a few very mild irritants and one vesicant (triphenyl-2-bromoethylphosphonium bromide), all of the compounds of interest are in the sulfur-containing section.

The sample TL 645, tris(2-chloroethylmercapto)-phosphorus was the outstanding vesicant; it was discovered later, however, that the compound decomposed rapidly and that we had actually tested a mixture containing a large amount of Q. The bromine analogue of TL 645 appeared to be a fair vesicant, and two compounds of the $(ClCH_2CH_2)_2$ PR class, TL 1029 (R= ethyl), and TL 762 (R= phenyl) were vesicants.

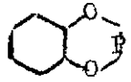
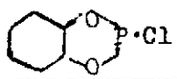
PHOSPHINES

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
4/6/43 DD	536	Phosphine, phenyl- $C_6H_5PH_2$	200 γ	100%	75°F. 28%	15	0	-	0	-	N.V.
2/15/43 Q	534	Phosphine, tris(chloromethyl)- $(ClCH_2)_3P$	200 γ	100%	62°F. 28%	10	0	-	0	-	N.V.
3/9/43 UU	540	Phosphine, diethylphenyl-	100 γ	100%	75°F. 72%	10	0	-	0	-	N.V.
3/17/43 CCC		$(C_2H_5)_2P \cdot C_6H_5$	200 γ	100%	65°F. 41%	10	0	-	0	-	
11/10/42 Z	464	Phosphine, dibutylphenyl-	No. 5 Rod	100%	73°F. 57%	11	0	-	0	-	N.V.
11/11/42 CC		$(CH_3CH_2CH_2CH_2)_2P \cdot C_6H_5$	200 γ T.P.	100%	73°F. 31%	10	0	-	0	-	
11/11/42 O	411	Phosphine, trioctyl-	60 γ T.P.	53% absolute alcohol	73°F. 31%	20	0	-	0	-	N.V.
12/8/42 O		$[CH_3(CH_2)_7]_3P$	200 γ T.P.	53% absolute alcohol	N. R.	15	0	-	0	-	
4/6/43 II	588	Phosphine, tridecyl- $[CH_3(CH_2)_9]_3P$	200 γ	40% dioxane	75°F. 28%	15	0	-	0	-	N.V.
4/13/43 U	604	Phosphine, tri-1-piperidyl-	200 γ	100%	65°F. 28%	24	0	-	0	-	N.V.
2/15/43 R	535	Phosphine, diethoxyphenyl- $(C_2H_5O)_2P \cdot C_6H_5$	200 γ	100%	62°F. 28%	12	0	-	0	-	N.V.
3/3/43 R	603	Phosphine, bis(o-chlorophenoxy)-phenyl- $(ClC_6H_4O)_2P \cdot C_6H_5$	200 γ	100%	71°F. 23%	14	0	-	0	-	N.V.

ESTERS OF PHOSPHOROUS ACID

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/23/43 FF	585	Phosphorous acid, dimethyl ester $(CH_3O)_2POH$	100 γ	100%	75°F. 40%	10	0	-	0	-	N.V.
3/30/43 T			200 γ	100%	71°F. N. R.	10	0	-	0	-	
3/3/43 P	586	Methyl phosphite $(CH_3O)_3P$	200 γ	100%	71°F. 23%	17	0	-	0	-	N.V.
2/23/43 T	463	Ethyl phosphite $(C_2H_5O)_3P$	200 γ	100%	67°F. 30%	12	0	-	0	-	N.V.
3/3/43 Q	587	Phosphorous acid, tris(2-chloroethyl) ester $(ClCH_2CH_2O)_3P$	200 γ	100%	71°F. 23%	16	0	-	0	-	N.V.
7/13/43 DD	787	Phosphorous acid, tris(2-bromoethyl) ester $(BrCH_2CH_2O)_3P$	180 γ	100%	87°F. 51%	12	1	4	0	-	E.-

PHOSPHINE HALIDES

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/23/43 KK	616	Phosphine, chloro-bis(2-chloroethoxy)- $(ClCH_2CH_2O)_2PCl$	200	100%	75°F. 40%	9	0	-	0	-	N.V.
3/17/43 KKK	584	Pyrocatechol phosphorus monofluoride	100	100%	65°F. 41%	8	0	-	0	-	N.V.
3/23/43 EE			200	100%	75°F. 40%	9	0	-	0	-	
3/9/43 TT	539	Pyrocatechol phosphorous monochloride 	200	100%	75°F. 72%	7	1	4	0	-	E.-
12/14/43 E-1	864	Phosphorus oxychloride, diphenyl- $(C_6H_5)_2P(=O)Cl$	190	100%	57°F. 40%	10	0	-	0	-	N.V.
7/13/43 CC	782	Phosphine, (2-chloroethoxy)-difluoro- $ClCH_2CH_2OPF_2$	200	100%	87°F. 51%	13	0	-	0	-	N.V.
9/28/43 H-1	952	Phosphine, dichloro(2-fluoro-ethoxy)- $FCH_2CH_2OPCl_2$	210	100%	79°F. 57%	9	0	-	0	-	N.V.
4/6/43 LL	615	Phosphine, dichloro-(2-chloroethoxy)- $ClCH_2CH_2OPCl_2$	200	100%	75°F. 28%	13	0	-	0	-	N.V.

PHOSPHINE CYANIDES

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
10/21/42 R	432	Phosphine, dicyanophenyl-	No. 5 Rod	100%	71°F. 45%	10	0	-	0	-	N.V.
11/10/42 U		$C_6H_5P(CN)_2$	100γ	100%	73°F. 57%	10	0	-	0	-	
11/11/42 X			200γ	100%	73°F. 31%	11	0	-	0	-	
2/22/43 Q	583	Phosphine, phenyl-dithiocyano- $C_6H_5P(CNS)_2$	200γ	100%	72°F. 31%	18	0	-	0	-	N.V.
4/13/43 V	646	Phosphine, (2-chloroethoxy)-dicyano- $ClCH_2CH_2OP(CN)_2$	270γ	100%	65°F. 28%	23	0	-	0	-	N.V.
			PHOSPHINE OXIDES								
5/4/43 JJ	618	Phosphine oxide, trimethyl- $(CH_3)_3PO$	200γ	58% water	73°F. 27%	15	0	-	0	-	N.V.
11/11/42 W	433	Phosphine oxide, triethyl- $(C_2H_5)_3PO$	No. 5	100%	73°F. 31%	9	0	-	0	-	N.V.
[illegible] R	1		200γ T.P.	100%	N.R.	15	0	-	0	-	
5/11/43 JJ	575	Phosphinimine, P,P,P,N-tetraphenyl- $(C_6H_5)_3P{=}NC_6H_5$	200γ	25% dioxane	63°F. 55%	15	0	-	0	-	N.V.

ESTERS OF PHOSPHONIC ACID

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/15/43 FF	743	Methylphosphonic acid, dimethyl ester $CH_3P(OCH_3)_2$ (O)	240 γ	100%	84°F. 56%	14	0	-	0	-	N.V.
6/1/43 FF	738	Methylphosphonic acid, bis(2-chloroethyl) ester $CH_3P(OCH_2CH_2Cl)_2$ (O)	205 γ	100%	80°F. 59%	16	0	-	0	-	N.V.
6/15/43 EE	742	Isopropylphosphonic acid, dimethyl ester $(CH_3)_2CH-P(OCH_3)_2$ (O)	200 γ	100%	84°F. 56%	14	0	-	0	-	N.V.
6/1/43 FF	739	Isopropylphosphonic acid, bis(2-chloroethyl) ester $(CH_3)_2CH-P(OCH_2CH_2Cl)_2$ (O)	210 γ	100%	80°F. 59%	16	0	-	0	-	N.V.
11/10/42 V	465	Acetic acid, diethyl-phosphono- ethyl ester	No. 5 Rod	100%	73°F. 57%	10	0	-	0	-	N.V.
11/11/42 DD		$(C_2H_5O)_2PCH_2COOC_2H_5$ (O)	200 γ T.P.	100%	73°F. 31%	10	0	-	0	-	

PHOSPHONYL HALIDES

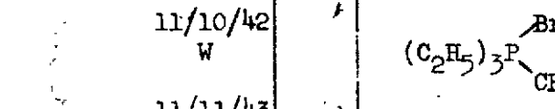
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
5/18/43 S	685	Phosphonyl chloride, N-(2-chloroethyl)-N-methyl-amino-	150 γ	100%	73°F. 50%	14	0	-	0	-	E.-
5/25/43 I		$ClCH_2CH_2$, CH_3, Cl, N-P=O, Cl	225 γ	100%	70°F. 48%	10	1	7	0	-	
5/11/43 MM	680	Phosphonyl chloride, N-(2-chloroethyl)-N-ethylamino-	210 γ	100%	63°F. 55%	15	0	-	0	-	N.V.
		$ClCH_2CH_2$, C_2H_5, Cl, N-P=O, Cl									
7/13/43 HH	802	Phosphonyl fluoride, bis(2-chloroethyl)amino-	185 γ	100%	87°F. 51%	13	0	-	0	-	N.V.
		$(ClCH_2CH_2)_2N$-P=O, F, F									
5/18/43 U	686	Phosphonyl chloride, bis(2-chloroethyl)amino-	200 γ	25% dioxane	73°F. 50%	12	0	-	0	-	N.V.
		$(ClCH_2CH_2)_2N$-P=O, Cl, Cl									

ESTERS OF SUBSTITUTED PHOSPHORIC ACIDS

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/21/42 L	345	Fluophosphoric acid, diethyl ester $(C_2H_5O)_2POF$	No. 7 Rod	100%	66°F. 48%	19	0	-	0	-	N.V.
6/1/43 CC	627	Fluophosphoric acid, 2-chloroethyl ester $(ClCH_2CH_2O)_2POF$	200γ	100%	80°F. 59%	20	0	-	0	-	N.V.
11/10/42 R	466	Fluophosphoric acid, diisopropyl ester	No. 5 Rod	100%	73°F. 57%	10	0	-	0	-	N.V.
11/11/42 EE		$\left[(CH_3)_2\overset{H}{C}O\right]_2POF$	200γ T.P.	100%	73°F. 31%	10	0	-	0	-	
3/9/43 VV	541	Chlorophosphoric acid, diethyl ester $(C_2H_5O)_2POCl$	200γ	100%	73°F. 72%	10	0	-	0	-	N.V.
5/18/43 V	699	Amidophosphoric acid, N,N-diethyl- diethyl ester $(C_2H_5O)_2\overset{O}{P}N(C_2H_5)_2$	200γ	100%	73°F. 50%	14	0	-	0	-	N.V.

PHOSPHONIUM COMPOUNDS

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/2/43 X	461	Phosphonium compound, tetrakis(chloromethyl)- chloride $(ClCH_2)_4PCl$	200 mg	40% water	69°F. 18%	10	0	-	0	-	N.V.
5/4/43 GG	610	Phosphonium compound, triallylphenyl- bromide $(CH_2{=}CHCH_2)_3P(Br)C_6H_5$	400 mg	34% water	73°F. 27%	11	0	-	0	-	N.V.
4/6/43 HH	581	Phosphonium compound, triethylphenyl- iodide $(C_2H_5)_3P(I)C_6H_5$	200 mg	66% water	75°F. 28%	15	0	-	0	-	N.V.
3/23/43 II	609	Phosphonium compound, triethyl-p-tolyl- iodide $(C_2H_5)_3P(I)C_6H_4CH_3$	200 mg	56% water	75°F. 40%	9	0	-	0	-	N.V.

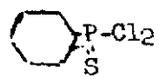
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
5/4/43 HH	607	Phosphonium compound, 3-chloroacetonyl-triphenyl-chloride 	180γ	15% Propylene glycol	73°F. 27%	15	0	-	0	-	N.V.
10/21/42 W	436	Phosphonium compound, 2-bromoethyltriethyl- bromide 	60γ T.P.	49% water	71°F. 45%	10	0	-	0	-	N.V.
11/10/42 W			100γ T.P.	49% water	73°F. 57%	10	0	-	0	-	
11/11/43 Y			200γ T.P.	49% water	73°F. 31%	10	0	-	0	-	
10/21/42 S	435	Phosphonium compound, 2-bromoethyltriphenyl- bromide 	60γ T.P.	35% water	71°F. 45%	10	2	5	1	2	V.
3/23/43 HH	606	1,2-Oxaphosphetane, 4-oxy-2-triphenyl- 	200γ	15% dioxane	75°F. 40%	8	0	-	0	-	N.V.

SULFUR CONTAINING PHOSPHORUS COMPOUNDS

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
11/22/43 Q-2	1020	Phosphine, chloro(2-chloroethylmercapto)ethyl- $ClCH_2CH_2S \cdot P(Cl)(C_2H_5)$	250γ	100%	64°F. 32%	10	0	-	0	-	N.V.
			About 1/5 as vesicant as H. ... P.R. 2580 (1944) (B-3969)								
8/31/43 W	910	Phosphine, (2-chloroethylmercapto)diphenyl- $ClCH_2CH_2S \cdot P(C_6H_5)_2$	250γ	100%	81°F. 75%	13	0	-	0	-	N.V.
7/13/43 CC	784	Phosphorus, dichloro-(2-chloroethylmercapto)- $ClCH_2CH_2S \cdot PCl_2$	160γ	100%	87°F. 51%	13	7	3	0	-	E.
7/20/43 V			240γ	100%	80°F. 62%	16	4	2	0	-	
2/15/43 S	578	Phosphine, bis(butylmercapto)-phenyl- $C_6H_5P(SC_4H_9)_2$	200γ	100%	62°F. 28%	3	0	-	0	-	N.V.
2/22/43 P	577	Phosphine, bis(methylmercapto)-phenyl- $C_6H_5P(SCH_3)_2$	200γ	100%	72°F. 31%	16	0	-	0	-	N.V.
11/22/43 R-2	1029	Phosphine, bis(2-chloroethylmercapto)ethyl- $C_2H_5P(SCH_2CH_2Cl)_2$	125γ	100%	64°F. 32%	11	11	12	6	7	V.
6/15/43 MM	762	Phosphine, bis(2-chloroethylmercapto)phenyl-	195γ	100%	84°F.	15	5	3	4	4	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/3/43 Y	859	Phosphine, bis(2-chloroethyl-mercapto)-(p-dimethylamino-phenyl)- monoethylate	100γ	38% dioxane	78°F. 65%	13	0	-	0	-	N.V.
8/17/43 FF	859	$(CH_3)_2N$-⬡-$P(SCH_2CH_2Cl)_2 \cdot C_2H_5OH$	200γ	38% dioxane	69°F. 59%	15	0	-	0	-	
5/18/43 X	645	Phosphine, tris(2-chloro-ethylmercapto)-	2γ	2% dioxane	73°F. 50%	13	6	4	0	-	V.
5/4/43 Q		$(ClCH_2CH_2S)_3P$	5γ	5% dioxane	76°F. 28%	21	19	5	3	4	
5/18/43 X			5γ	5% dioxane	73°F. 50%	13	12	6	0	-	
5/4/43 P			10γ	10% dioxane	76°F. 28%	23	23	6	5	3	
5/4/43 O			20γ	25% dioxane	76°F. 28%	22	22	7	20	4	
5/19/43 KK			20γ	100%	65°F. 70%	18	18	7	7	4	
5/4/43 N			35γ	50% dioxane	76°F. 28%	23	23	9	23	5	
5/11/43 N,O			35γ	100%	65°F. 50%	74	74	9	72	6	
4/27/43 U			70γ	100%	67°F. 62%	15	15	12	15	7	
5/4/43 M			70γ	100%	76°F. 28%	24	24	12	24	7	
5/11/43 O,X-GG			70γ	100%	63°F. 55%	116	115	10	109	6	
5/18/43 P			70γ	100%	73°F. 50%	40	40	11	39	6	

For additional data see Vesicant Comparisons, p.
Pure material is 1/2 as vesicant as H. High vesicancy of crude may be due to unremoved Q...P.P.2580(1944)(B-3969)

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/21/43 L-1	933	Phosphine, tris(2-bromoethyl-mercapto)- $(BrCH_2CH_2S)_3P$	90γ	100%	65°F. 60%	10	10	6	3	3	V.
4/6/43 JJ	602	Thiophosphoric acid, trimethyl ester $(CH_3O)_3PS$	200γ	100%	75°F. 28%	12	0	-	0	-	N.V.
3/9/43 RR	495	Thiofluophosphoric acid, diethyl ester $(C_2H_5O)_2PSF$	200γ	100%	75°F. 72%	7	0	-	0	-	N.V.
11/10/42 Y	462	Phosphine, dichlorophenylsulfo- 	No. 5 Rod	100%	73°F. 57%	9	0	-	0	-	N.V.
11/11/42 BB			200γ T.P.	100%	73°F. 31%	10	0	-	0	-	
3/9/43 WW	429	Thiophosphonyl chloride, ethoxy- $C_2H_5O\underset{Cl}{\overset{Cl}{P}}{=}S$	200γ	100%	75°F. 72%	10	0	-	0	-	N.V.
10/21/42 L	422	Thiophosphonyl chloride, (diethylamino)-	No. 5 Rod	100%	71°F. 45%	10	0	-	0	-	N.V.
11/9/42 T		$(C_2H_5)_2N\text{-}P{=}Cl_2$	100γ T.P.	100%	73°F. 49%	10	0	-	0	-	
11/11/42 Q		C_2H_5 S	200γ T.P.	100%	73°F. 31%	10	0	-	0	-	
9/21/43 K-2	932	Phosphine, [bis(2-chloroethyl)-amino]- bis(2-chloroethyl)-mercapto)- oxide $(ClC_2H_4)_2N\cdot P(SC_2H_4Cl)_2$ O	140γ	100%	65°F. 60%	12	8	7	0	-	E.

Sulfur Compounds

Thiols: There were no vesicants in this group, and only one irritant, 1,3-dichloro-2-mercaptopropane; however, TL 308, 2-chloroethanethiol, irritated one man with Rod #5, closed 5 minutes.

Sulfides: Included here are a large number of excellent vesicants, including H, Q and its homologues. None of the "one-armed" mustards was particularly effective, although TL 344, the methyl compound, blistered 14/20 with Rod #5 closed 5 minutes.

Replacement of the 2-chloroethyl radical by 2-chloropropyl, dichloroisopropyl, or 2-chlorobutyl diminishes the vesicant action of mustard.

Hydrocarbons with two 2-chloroethylmercapto substituents are, in general, excellent vesicants; for example, TL 905 (methane), TL 86 (ethane), TL 153 (1,2-propane), TL 843 (1,3-propane), etc. The only exception is TL 654 (2,2-propane).

Sulfoxides: Oxidation of sulfides to sulfoxides results in a total loss of vesicant action.

Sulfones: Three sulfones, divinyl, 2-chloroethylvinyl, and bis(2-chloroethyl), were good vesicants.

THIOLS

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
10/6/42 C	308	Ethanethiol, 2-chloro- $ClCH_2CH_2SH$	No. 5 Rod	100%	59°F. 72%	8	0	-	0	-	E.-
12/16/42 P			No. 5 Rod (closed 5')	100%	N. R.	20	1	3	0	-	
12/14/43 I-2	1094	Sulfenyl chloride, 2-chloroethyl- $ClCH_2CH_2SCl$	140 γ	100%	57°F. 40%	11	0	-	0	-	N.V.
12/21/43 D-2			210 γ	100%	64°F. 43%	9	0	-	0	-	
8/31/43 N	883	Propane, 1,3-dichloro- 2-mercapto- $ClCH_2-\underset{SH}{CH}-CH_2Cl$	200 γ	100%	81°F. 75%	8	6	7	0	-	E.
3/9/43 XX	545	Propane, 1-chloro- 2,3-dimercapto- $\underset{SH}{CH_2}\underset{SH}{CH}CH_2Cl$	200 γ	100%	75°F. 72%	8	0	-	0	-	N.V.
8/4/42 A	72	1,6-Hexanedithiol $HS(CH_2)_6SH$	No. 3 Rod	100%	76°F. 59%	20	0	0	0	0	N.V.
8/17/42 A			No. 5 Rod	100%	63°F. 79%	16	0	0	0	0	

SULFIDES

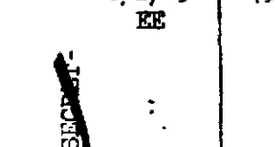
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
12/16/42 Q	344	Sulfide, (2-chloroethyl) methyl $ClCH_2CH_2S\text{-}CH_3$	No. 5 Rod (closed)	100%	N. R.	20	14	9	14	5	V.
9/21/42 K			No. 7 Rod	100%	66°F. 48%	20	0	-	0	-	
7/20/43 T			100 γ	100%	80°F. 62%	14	5	3	0	-	
8/3/43 C			200 γ	100%	78°F. 65%	13	10	5	1	5	
		Information from other sources:	On human skin 0.005 cc. of 0.13-0.29% solution produces lesion (FR). Vesicant power about 1/10 that of mustard. .... N.R.B. (1940) Vesicant action 0.2 that of mustard. .... EATR 50 (1931) Absolute vesicant action 6% that of mustard. .... Ptn.1753 (S. 2867), (1942) =H. .... Kirner, J. Am. Chem. Soc. 50, 2446 (1928) 1/10 H. .... Porton Memo. No. 16 OSRD 1377								
9/21/42 N	360	Sulfide, 3-chloropropylene-1,2- $Et_2C\text{-}CH\text{-}CH_2Cl$ (S)	No. 7 Rod	100%	66°F. 48%	18	1	4	0	-	E.-
			Non-vesicant when applied to humans. .... Porton Memo. No. 15 (1941)								
9/7/43 HH	862	Sulfide, 2-chloroethyl ethyl $ClCH_2CH_2S\ C_2H_5$	100 γ	100%	74°F. 65%	11	1	8	0	-	E.-
9/14/43 H-1			200 γ	100%	65°F. 80%	29	1	4	0	-	
		Information from other sources:	Negligible 'empirical' vesicancy relative to H; 'absolute' (cover glass over applied liquid) 6/100 that of mustard .... C.D.R. 1087, W-155-22, V.20841, (1942) (B-1663) Undiluted compound causes some reddening of the skin. .... Porton Memo. No. 15 (1941)								

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
11/22/43 R-1	1028	Sulfide, 2-chloroethyl cyclohexyl-	100γ	100%	64°F. 32%	11	0	-	0	-	N.V.
12/14/43 E-2		$ClCH_2CH_2S$-CH(cyclohexyl)	200γ	100%	57°F. 40%	10	0	-	0	-	
11/22/43 S-1	1030	Sulfide, (2-chloroethyl) (p nitrophenyl) $ClCH_2CH_2S$-C$_6$H$_4$-NO_2	200γ	37% dioxane	64°F. 32%	10	0	-	0	-	N.V.
11/22/43 S-2	1031	Sulfide, (2-chloroethyl) (o-nitrophenyl) $ClCH_2CH_2S$-C$_6$H$_4$-NO_2	200γ	22% dioxane	64°F. 32%	10	0	-	0	-	N.V.
8/17/43 DD	884	Sulfide, 2-chloroethyl 2-fluoroethyl	60γ	100%	69°F. 59%	12	1	2	0	-	V.
8/25/43 C		$ClCH_2CH_2$-S-CH_2CH_2F	240γ	100%	81°F. 70%	13	12	7	3	6	
6/29/43 K	3	Sulfide, bis(2-chloroethyl)- Plant run Levinstein	20γ	100%	69°F. 53%	92	32	5	22	2	V.
9/29/42 C		$(ClCH_2CH_2)_2S$	No. 3 Rod	30% D.P.E.	74°F. 42%	10	10	4	0	-	
9/29/42 B			No. 3 Rod	50% D.P.E.	74°F. 42%	11	11	6	4	3	
9/29/42 A			No. 3 Rod	100%	74°F. 42%	11	11	4	3	3	
11/9/42 O			No. 3 Rod	100%	73°F. 46%	58	58	6	39	4	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/29/43 M	155	Sulfide, bis(2-chloroethyl)- (Thiodiglycol process)	15γ	100%	69°F.	48	36	7	12	3	V.
7/6/43 TT,UU		$(ClCH_2CH_2)_2S$	30γ	100%	74°F.	58	56	8	48	4	
9/29/42 E			No. 3 Rod	50% D.P.E.	74°F. 42%	10	10	5	0	-	
9/29/42 D			No. 3 Rod	100%	74°F. 42%	11	11	7	8	3	
			For additional data on plant run Levinstein mustard and thiodiglycol mustard, see sections on Vesicant Comparisons and Vesicant Mixtures. For data on redistilled Levinstein mustard, see sections on Mustard, Vesicant Comparisons, and Vesicant Mixtures.								
10/6/42 B	393	Sulfide, bis(2-chloroethyl)- (Prepared by photochemical reaction of H_2S and vinyl chloride)	No. 3 Rod	50% D.P.E.	59°F. 72%	8	7	6	0	-	V.
10/6/42 A		$(ClCH_2CH_2)_2S$	No. 3 Rod	100%	59°F. 72%	10	10	8	5	3	
6/22/43 S	744	Sulfide, bis(2-chloroethyl)- (Obtained by condensing the gases produced in candling Levinstein mustard)	15γ	100%	79°F. 66%	24	21	6	13	4	V.
6/15/43 SS			65γ	100%	84°F. 56%	10	10	10	10	5	
6/15/43 RR		$(ClCH_2CH_2)_2S$	200γ	100%	84°F. 56%	10	10	12	10	8	
			For additional data on TL 744, see Vesicant Comparisons, page 40.								

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/28/43 J-2	957	Trisulfide, bis(2-chloroethyl) $ClCH_2CH_2-S_3-CH_2CH_2Cl$	140γ	100%	79°F. 57%	9	0	-	0	-	N.V.
10/5/43 N			210γ	100%	67°F. 55%	15	0	-	0	-	
			Not a vesicant. .... Porton Memo. No. 15 (1941)								
9/28/43 J-1	956	Pentasulfide, bis(2-chloroethyl) $ClCH_2CH_2-S_5-CH_2CH_2Cl$	150γ	100%	79°F. 57%	9	1	2	0	-	N.V.
10/5/43 M			225γ	100%	67°F. 55%	15	0	-	0	-	
8/31/43 S	903	Sulfide, bis(2-bromoethyl) $(BrCH_2CH_2)_2S$	90γ	100%	81°F. 75%	15	15	12	14	8	V.
			In man vesicant power roughly the same as H. .... British NRB 1940								
8/3/43 V	842	Sulfide, 2-chloroethyl 2-chloroisopropyl- $ClCH_2CH_2S-\underset{CH_3}{\overset{CH_2Cl}{CH}}$	120γ	100%	78°F. 65%	11	11	6	4	5	V.
			Vesicant properties are about one-half as potent as those of H. .... C.D.R. 1086, V.18194, W-93-18 (1941) (B-1142)								
2/8/43 W	454	Ether, bis[2-(2-chloroethyl-mercapto)ethyl] $(ClCH_2CH_2SCH_2CH_2)_2O$ T	No. 3 Rod (closed)	3% D.P.E.	62°F. 36%	15	5	5	0	-	V.
2/8/43 V			No. 3 Rod (closed)	10% D.P.E.	62°F. 36%	15	15	8	5	4	
2/8/43 U			No. 3 Rod (closed)	30% D.P.E.	62°F. 36%	15	15	11	12	7	
2/8/43 H			No. 3 Rod (closed)	100%	62°F. 36%	15	15	13	14	8	
			For a review of the work of other laboratories on the vesicant action of T on man see: CWS Field Lab. Memo. 1-4-5 page 344 (1944)								

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
11/9/43 P-1	1000	Ether, bis[2-(2-chloroethyl-mercapto)-1-methylethyl] $[ClCH_2CH_2SCH_2CH(CH_3)]_2O$	60	100%	58°F. 58%	15	15	9	2	2	V.
7/13/43 BB	780	Sulfide, bis(2-chloropropyl) $(CH_3CHClCH_2)_2S$	115	100%	87°F. 51%	15	14	8	7	6	V.
		1/7 as effective as mustard applied under the same conditions. .... Porton Memo. No. 15 (1941) Not nearly as powerful a skin irritant as mustard. .... C.W.M. Vol. 49, 1919									
7/29/42 D	293	Sulfide, bis(s-dichloro-isopropyl)- $ClCH_2CHCH_2Cl$ (S) $ClCH_2CHCH_2Cl$	No. 3 Rod	100%	70°F. 86%	17	9	3	0	-	E.
8/18/42 P			No. 5 Rod	100%	72°F. 64%	20	16	6	0	-	
8/19/42 E			No. 5 Rod	100%	67°F. 80%	19	12	4	0	-	
10/19/42 S			No. 6 Rod	100%	68°F. 41%	10	2	4	0	-	
11/10/42 S			200 T.P.	30% D.P.E.	73°F. 57%	10	0	-	0	-	
12/14/43 I-1	1093	Disulfide, bis(1,3-dichloro-isopropyl) $(ClCH_2)_2\overset{H}{C}-S-S-\overset{H}{C}(CH_2Cl)_2$	200	54% dioxane	57°F. 40%	11	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
6/1/43 EE	734	Sulfide, bis(2-chlorobutyl)-3- 	220 mg	100%	80°F. 59%	20	0	-	0	-	N.V.
		Non-vesicant. .... Porton Memo. No. 15 (1941)									
8/31/43 T	905	Methane, bis(2-chloroethyl-mercapto)- 	65 mg	100%	81°F. 75%	13	13	19	13	11	V.
		Man: 0.01 cc. drops of 5% solution in alcohol produced erythema in 3/6 cases. Drop of pure substance 0.3 mm. in diameter produced vesication in 4/4 cases. Burns thru clothing develop more slowly than those caused by mustard or HT 50/50. Skin lesions produced by 0.005 cc. of a 2.3% solution. .... British NRB (1940) Twice as powerful as H. .... Porton Memo. No. 15 (1941) Very dilute acetone solutions applied to animal or humans skin, twice as vesicant as mustard (erythema the criterion). .... (EATR 104) .. EATR 359 (1942)									
7/20/43 U	781	Thioorthoformic acid, tris-(2-chloroethyl) ester 	65 mg	100%	80°F. 62%	14	14	8	6	5	V.
7/13/43 BB			195 mg	100%	87°F. 51%	15	15	14	12	9	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
For additional data on TL 86, TL 153, and TL 258 see sections on Vesicant Comparisons and Vesicant Mixtures.											
9/14/42 R	86	Ethane, 1,2-bis(2-chloroethyl-mercapto)- Sesquimustard Q	No. 3 Rod	3% D.P.E.	76°F. 72%	15	12	4	1	2	V.
9/14/42 Q		H_2C-SCH_2CH_2Cl	No. 3 Rod	10% D.P.E.	76°F. 72%	15	15	11	14	8	
9/14/42 P		H_2C-SCH_2CH_2Cl	No. 3 Rod	15% D.P.E.	76°F. 72%	15	15	16	14	10	
2/8/43 N			No. 3 Rod (closed)	3% D.P.E.	62°F. 36%	15	7	5	0	-	
2/8/43 M			No. 3 Rod (closed)	10% D.P.E.	62°F. 36%	16	16	8	2	3	
2/8/43 L			No. 3 Rod (closed)	15% D.P.E.	62°F. 36%	14	14	10	11	6	
9/14/43 K			15 γ	2½% D.P.E.	65°F. 80%	31	31	23	30	16	
			For a summary of the work of other laboratories on the vesicant action of Q on human skin see CWS Field Lab. Memo. 1-4-5, page 327 (1944)								

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/14/43 I	904	Ethane, 1,2-bis(2-bromoethyl-mercapto)-	15 γ	2½% D.P.E.	65°F. 80%	31	19	14	0	-	E.-
9/7/43 MM		$BrCH_2CH_2SCH_2$ / $BrCH_2CH_2SCH_2$	50 γ	2½% D.P.E.	74°F. 65%	39	39	33	0	-	
9/21/43 M			100 γ	2½% D.P.E.	65°F. 60%	14	14	36	0	-	
10/12/43 X-2	985	Ethane, 1,1,2,2-tetrakis-(2-chloroethylmercapto)-	70 γ	100%	80°F. 54%	14	0	-	0	-	N.V.
10/19/43 F-2		$(ClCH_2CH_2S)_2CH$ / $(ClCH_2CH_2S)_2CH$	200 γ	100%	77°F. 54%	14	0	-	0	-	
9/14/42 U	153	Propane, 1,2-bis(2-chloro-ethylmercapto)-	No. 3 Rod	3% D.P.E.	76°F. 72%	15	4	3	1	1	V.
9/14/42 T		$H_3C-\overset{H}{\underset{H_2C}{C}}\cdot S\cdot CH_2CH_2Cl$ / $\cdot S\cdot CH_2CH_2Cl$	No. 3 Rod	10% D.P.E.	76°F. 72%	15	15	7	4	4	
9/14/42 S			No. 3 Rod	30% D.P.E.	76°F. 72%	15	15	10	13	7	
8/4/42 F			No. 3 Rod	100%	76°F. 59%	20	20	13	20	9	
2/8/43 Q			No. 3 Rod (closed)	3% D.P.E.	62°F. 36%	14	1	4	0	-	
2/8/43 P			No. 3 Rod (closed)	10% D.P.E.	62°F. 36%	15	10	6	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/8/43 C	153	Propane, 1,2-bis(2-chloroethylmercapto)-	No. 3 Rod (closed)	30% D.P.E.	62°F. 36%	15	15	12	4	6	V.
2/8/43 F			No. 3 Rod (closed)	100%	62°F. 36%	15	15	12	12	8	
9/1/42 A			No. 5 Rod	5% D.P.E.	78°F. 69%	48	48	18	40	12	
9/1/42 C			No. 5 Rod	15% D.P.E.	78°F. 69%	48	48	27	48	18	
8/19/42 A			No. 5 Rod	25% D.P.E.	67°F. 75%	19	19	14	18	8	
8/19/42 B			No. 5 Rod	65% D.P.E.	67°F. 80%	20	20	19	20	12	
6/1/43 N			15 ɣ	100%	78°F. 73%	20	20	9	18	6	
5/4/43 U			60 ɣ	100%	73°F. 27%	15	15	11	13	7	
8/3/43 W	843	Propane, 1,3-bis(2-chloroethylmercapto)-	60 ɣ	100%	78°F. 65%	11	11	20	11	14	V.
			Comparison of vesicant activity of benzene solns., mustard 100, this compd. 300, Q 500. .... ETF 550 E-274 (Porton) Vesicant power is about 4-5 times greater than H when applied in benzene soln. directly to skin of man. .... V. 18613, B-1275 (Ptn. 1/6/42)							

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings				Status
							Erythemas		Blisters		
							No.	Size	No.	Size	
4/27/43 V	654	Acetone mercaptol, bis(2-chloroethyl)-	120	100%	67°F. 62%	15	1	2	0	-	E.
5/4/43 NN		$(CH_3)_2C(SCH_2CH_2Cl)_2$	240	100%	73°F. 27%	15	8	10	0	-	
6/29/43 Y	768	1-Propanol, 2,3-bis(2-chloroethylmercapto)-	70	100%	71°F. 41%	21	21	9	16	4	V.
6/15/43 PP		$H_2C(OH)-HC(SCH_2CH_2Cl)-H_2C(SCH_2CH_2Cl)$	210	100%	84°F. 56%	10	10	19	10	10	
10/14/42 J	258	Propane, 2-chloro-1,3-bis(2-chloroethylmercapto)-	No. 3 Rod	3% D.P.E.	74°F. 52%	9	9	6	0	0	V.
9/14/42 X		$H_2C(SCH_2CH_2Cl)-HC(Cl)-H_2C(SCH_2CH_2Cl)$	No. 3 Rod	3% D.P.E.	76°F. 72%	15	15	7	6	5	
9/14/42 W			No. 3 Rod	10% D.P.E.	76°F. 72%	14	14	10	14	8	
9/14/42 V			No. 3 Rod	30% D.P.E.	76°F. 72%	15	15	10	15	8	
7/7/42 A			No. 3 Rod	100%	N. R.	29	29	9	28	4	
2/3/43 L			No. 3 Rod	100%	72°F. 31%	10	10	10	8	5	
2/8/43 T			No. 3 Rod (closed)	3% D.P.E.	62°F. 36%	15	6	7	0	-	
2/8/43 S			No. 3 Rod (closed)	10% D.P.E.	62°F. 36%	11	11	7	1	7	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/8/43 R	258	Propane, 2-chloro-1,3-bis(2-chloroethyl-mercapto)-	No. 3 Rod (closed)	30% D.P.E.	62°F. 36%	16	16	9	6	6	V.
2/8/43 G			No. 3 Rod (closed)	100%	62°F. 36%	15	15	13	9	5	
7/20/42 A			No. 5 Rod	1% D.P.E.	N. R.	21	21	10	0	-	
8/3/42 M			No. 5 Rod	2% D.P.E.	N. R.	21	21	7	0	-	
8/3/42 L			No. 5 Rod	3% D.P.E.	N. R.	19	19	9	6	4	
8/18/42 N			No. 5 Rod	3% D.P.E.	72°F. 64%	40	38	9	4	7	
8/18/42 M			No. 5 Rod	5% D.P.E.	72°F. 64%	38	38	13	19	8	
7/13/42 A	258 Site 3		No. 5 Rod	20% D.P.E.	81°F. 64%	27	27	10	26	6	
7/13/42 A	258 Site 2		No. 5 Rod	40% D.P.E.	81°F. 64%	27	27	11	26	7	
7/13/42 I	258		No. 5 Rod	60% D.P.E.	81°F. 64%	27	27	10	26	7	
6/1/43 N	258		16γ	100%	78°F. 73%	20	20	11	19	7	
5/4/43 V			70γ	100%	73°F. 27%	13	13	13	9	8	
		Information from other sources:	When applied undiluted to the forearm of men (10) by means of a capillary pipette, produced large blisters and a greater area of erythema than equal weights of pure mustard (0.05 mg.). Onset of erythema and blister formation occurred later than with H. Not an effective pain producer. .... TDMR 470 (1942) Vesicant 10 times as effective as H applied under same conditions. .... Porton Memo. No. 15 (1941) Area of erythema on skin greater than with H. Also vesicle formed was larger. Does not penetrate clothing. .... B-64 Suffield Experimental Station, April 12, 1943.								

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
7/6/43 YY	767	Butane, 2,3-bis(2-chloroethyl-mercapto)-	30	100%	74°F. 77%	33	33	9	32	4	V.
7/6/43 ZZ		H_3C-CH(S-CH_2CH_2Cl)-CH(S-CH_2CH_2Cl)-CH_3	60	100%	74°F. 77%	20	20	9	12	6	
6/29/43 X			115	100%	71°F. 41%	29	29	14	16	10	
6/15/43 CC			225	100%	84°F. 56%	10	10	19	10	12	
			Vesicant action about 1/3 that of mustard. .... Porton Memo. No. 15 (1941)								
8/3/43 U	241	Butane, 1,3-bis(2-chloroethyl-mercapto)- H_2C(-S-CH_2CH_2Cl)-H_2C-CH(S-CH_2CH_2Cl)-CH_3	120	100%	78°F. 65%	13	13	17	13	13	V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/21/43 I-2	907	Vinyl sulfoxide $(CH_2{=}CH)_2S{\rightarrow}O$	210γ	100%	65°F. 60%	8	0	-	0	-	N.V.
			Undiluted compound causes some reddening of the skin. .... Porton Memo. No. 15 (1941)								
9/21/43 I-1	905	Sulfoxide, 2-chloroethyl vinyl $CH_2{=}CH{-}S(\rightarrow O){-}CH_2CH_2Cl$	240γ	100%	65°F. 60%	8	0	-	0	-	N.V.
10/5/42 J	570	Sulfoxide, bis(2-hydroxyethyl) $(HOCH_2CH_2)_2S{\rightarrow}O$	200γ T.P.	7% 95% alcohol	59°F. 78%	7	0	-	0	-	N.V.
9/14/43 K	795	Ethane, 1,2-bis(2-chloroethyl-sulfinyl)- $CH_2(S(\rightarrow O)CH_2CH_2Cl)CH_2(S(\rightarrow O)CH_2CH_2Cl)$	210γ	3% thiodi-glycol	65°F. 80%	11	0	-	0	-	N.V.
9/14/43 J	794	Ethane 1,2-bis(2-chloroethyl-sulfinyl)- $CH_2(S(\rightarrow O)CH_2CH_2Cl)CH_2(S(\rightarrow O)CH_2CH_2Cl)$	190γ	4% thiodi-glycol	65°F. 80%	10	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
7/20/43 Y	797	Vinyl sulfone	60 γ	100%	80°F. 62%	15	10	4	3	4	V.
7/13/43 FF		$(CH_2{=}CH)_2SO_2$	115 γ	100%	87°F. 51%	16	14	9	13	7	V.
		Vesicant power roughly 1/40 that of H, but poisonous effect greater. Undiluted liquid applied to skin of man produced sharp erythema in 5/6 cases and vesication in 1/6. .... British NRB (1940)									
7/20/43 X	796	Sulfone, 2-chloroethyl vinyl	70 γ	100%	80°F. 62%	14	13	7	9	5	V.
7/13/43 EE		$ClCH_2CH_2SO_2CH{=}CH_2$	135 γ	100%	87°F. 51%	15	15	13	13	9	
12/14/43 F-1	1038	Sulfone, 2-chloroethyl p-nitrophenyl	200 γ	27% dioxane	57°F. 40%	10	0	-	0	-	N.V.
10/21/42 K	413	Sulfone, bis(2-hydroxyethyl)	60 γ	30% water	71°F. 45%	10	0	-	0	-	N.V.
12/8/42 P		$(HOCH_2CH_2)_2SO_2$	60 γ	30% water	N. R.	13	0	-	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R. H.	No. Men	48-Hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/8/43 J	4	Sulfone, bis(2-chloroethyl) $(ClCH_2CH_2)_2S(=O)_2$	No. 3 Rod (closed)	3% dioxane	62°F. 36%	13	1	6	1	5	V.
2/8/43 K			No. 3 Rod (closed)	10% dioxane	62°F. 36%	15	10	3	2	3	
2/8/43 I			No. 3 Rod (closed)	30% dioxane	62°F. 36%	15	12	5	9	3	
10/6/42 Z			200γ T.P.	45% dioxane	59°F. 72%	9	9	5	6	3	
1/4/43 Q			200γ	45% dioxane	68°F. 25%	19	13	6	11	3	
			In weak solution more vesicant than H. Man: 0.005 cc. of 0.09% solution produces skin lesion (F.R.), 2 mm. drop (0.005 cc.) of 0.1% solution in water produces a vesicle. .... British NRB (1940)								
7/13/43 FF	798	Sulfonium salt of thiodiglycol and bis(2-chloroethyl) sulfone $[(HOCH_2CH_2)_2SCH_2CH_2]_2S(=O)_2 \cdot Cl^-$	200γ	71% water	87°F. 51%	16	0	-	0	-	N.V.

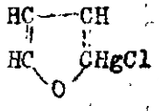
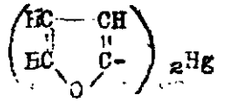
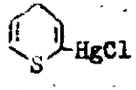
All four of the mercury compounds tested were vesicants, and TL 955, 2-furylmercuric chloride, was quite active. The tributyl tin halides were fair vesicants, and selenium oxychloride blistered 13/15 men. The selenium analogue of mustard was only mildly irritant. Compounds of antimony, lead, silicon, and thallium were non-irritant.

Antimony

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Size	Blisters No.	Size	Status
8/3/42 G	216	Stibine, tri-2-furyl-	No. 3 Rod	47% dioxane	N.R.	20	0	-	0	-	N.V.
10/5/42 P			200γ	47% dioxane	59°F. 78%	10	0	-	0	-	
9/22/42 A	365	Stibine, tri-2-pyridyl-	75γ	48% dioxane	59°F. 47%	20	0	-	0	-	N.V.
Lead											
8/5/42 E	246	Triethyl lead thiocyanate $(C_2H_5)_3PbSeCN$	No. 3 Rod	100%	N.R.	20	0	-	0	-	N.V.
8/19/42 D			No. 5 Rod	100%	67°F. 80%	20	0	-	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythema No.	Erythema Size	Blisters No.	Blisters Size	Status
7/20/43 SS-VV	747	Mercury, 2-thienyl- chloride (cont'd.)	160γ	20% dioxane	86°F. 50%	44	44	10	36	8	V
6/15/43 HH			200γ	20% dioxane	84°F. 56%	11	9	9	5	8	
Selenium											
11/9/43 O-1	992	Selenium oxychloride $SeOCl_2$	120γ	100%	58°F. 58%	15	14	5	13	4	V
			Corrosive action on skin, producing burns which are slow to heal, the selenium absorbed through the skin acts as a systemic poison....British NRB (1940).								
8/31/43 M	874	Selenide, bis(2-chloroethyl) $(ClCH_2CH_2)_2Se$	80γ	100%	81°F. 75%	19	0	-	0	-	E
9/7/43 II			240γ	100%	74°F. 65%	9	5	9	0	-	
Silicon											
7/29/42 C	245	Silicane, tetraethyl- $(C_2H_5)_4Si$	No. 3 Red	100%	70°F. 86%	20	0	-	0	-	N.V.
8/18/42 L			No. 3 Red	100%	72°F. 64%	20	0	-	0	-	

Mercury

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
5/4/43 II	617	Mercuric chloride-acetylene complex $C_2H_2HgCl_2$ or may be $C_2H_2 \cdot HgCl_2 \rightarrow ClCH{=}CHHgCl$	100γ	19% dioxane	75°F. 27%	15	13	8	5	5	V
9/28/43 I-2	955	Mercury, 2-furyl- chloride 	100γ	20% dioxane	79°F. 57%	10	10	8	9	7	V
		Undiluted compound causes some reddening of the skin. ....Porton Memo No. 15, 1941									
8/3/42 F	215	Mercury, di-2-furyl- 	No. 3 Rod	31% dioxane	N.R.	20	17	3	11	3	V
8/18/42 G			No. 5 Rod	31% dioxane	N.R.	20	20	4	12	3	
6/29/43 V	747	Mercury, 2-thienyl- chloride 	100γ	20% dioxane	71°F. 41%	15	10 (24-hour readings)	5	0	-	V
						15	2 (48-hour readings)	7	0	-	
7/6/43 XX			100γ	20% dioxane	74°F. 77%	16	14	6	3	4	
7/13/43 Y,Z			160γ	20% dioxane	87°F. 51%	21	18	9	15	5	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Size	Blisters No.	Size	Status
Thallium											
9/22/42 B	366	Thallium, (ethylthio)dimethyl- $(CH_3)_2TlSC_2H_5$	No. 7 Rod	54% dioxane	59°F. 47%	20	0	-	0	-	N.V.
3/3/43 L	531	Dithiocarbamic acid, N,N-diethyl-, dimethylthallium ester $(C_2H_5)_2NC(=S)-STl(CH_3)_2$	240 γ	42% chloroform	71°F. 25%	10	0	-	0	-	N.V.
3/3/43 M	532	Dithiocarbamic acid, N,N-diisopropyl-, dimethylthallium ester $[(CH_3)_2CH]_2NC(=S)-STl(CH_3)_2$	220 γ	22% chloroform	71°F. 23%	10	0	-	0	-	N.V.
9/15/42 N	364	2-Nonen-2-ol-4-one, 1,1,1-trifluoro-, dimethylthallium salt $(CH_3)_2TlOC(CF_3)CHCOC_5H_{11}$	75 γ T.P.	27% dioxane	75°F. 78%	20	0	-	0	-	N.V.
Tin											
3/24/42 A	23	Tin, bromotributyl- $(CH_3CH_2CH_2CH_2)_3SnBr$	No. 3 Rod	100%	N.R.	26	21	N.R.	8	2	V

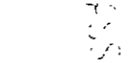
Tin (continued)

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/24/42 A	24	Tin, tributyliodo- $(CH_3CH_2CH_2CH_2)_3SnI$	No. 3 Rod	100%	N.R.	26	16	N.R.	4	2	V

ACETYLENE DERIVATIVES

Among the compounds in this group, iodopropargyl alcohol (TL 771) and bromopropiolic acid (TL 770), were good vesicants, and propiolic acid (TL 498) was a poor vesicant. All of the rest were non-vesicant.

4/27/43 X	661	2-Propynyl chloride $CH{\equiv}C\text{-}CH_2Cl$	215Y	100%	67°F. 62%	13	0	-	0	-	N.V.
4/27/43 Y	662	Formic acid, 2-propynyl ester Propargyl formate $HC(=O)\text{-}OCH_2C{\equiv}CH$	205Y	100%	67°F. 62%	13	0	-	0	-	N.V.
7/13/43 AA	771	2-Propyn-1-ol, 3-iodo- $I\text{-}C{\equiv}C\text{-}CH_2OH$	100Y	72% dioxane	67°F. 51%	13	15	7	11	6	V
3/9/43 SS	498	Propiolic acid $HC{\equiv}C\text{-}C(=O)\text{-}OH$	100Y	100%	75°F. 72%	9	6	4	0	-	V
3/17/43 ZZ			200Y	100%	65°F. 41%	10	5	4	±	2	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
7/13/43 AA	770	Propiolic acid, bromo-	100γ	55% water	87°F. 51%	15	14	7	14	6	V
1/4/43 U	497	Propiolic acid, methyl ester	200γ	100%	68°F. 25%	9	0	-	0	-	N.V.
12/28/42 P			No. 5 Rod	100%	68°F.	9	0	-	0	-	
12/28/42 O	496	Propiolic acid, ethyl ester	No. 5 Rod	100%	68°F.	10	0	-	0	-	N.V.
1/4/43 T			200γ	100%	68°F. 25%	10	1	1	0	-	
3/17/43 JJJ	570	Propiolic acid, 2-chloro-ethyl ester 	200γ	100%	65°F. 41%	12	0	-	0	-	N.V.
9/21/43 K-1	930	Tetrolic acid, methoxy-	210γ	100%	65°F. 60%	12	0	-	0	-	N.V.
9/21/43 J-2	929	Tetrolic acid, methoxy-methyl ester	200γ	100%	65°F. 60%	9	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
5/4/43 LL	631	Acetylenedicarboxylic acid, dimethyl ester	115 γ	100%	73°F. 27%	19	0	-	0	-	N.V.
5/11/43 KK		$CH_3O-C(=O)-C\equiv C-C(=O)-OCH_3$	230 γ	100%	63°F. 55%	13	0	-	0	-	
		Vesicant action to man when applied undiluted or in 0.1-50% weight volume solutions in acetone is less than 1/10 that of mustard....EATR 284 (1942)									
8/31/43 Y	912	Acetylenedicarboxylic acid, diethyl ester	200 γ	100%	81°F. 75%	17	0	-	0	-	N.V.
		$CH_3CH_2O-C(=O)-C\equiv C-C(=O)-OCH_2CH_3$									
		Report of an accident occurring durings its preparation (1936) indicated the compound to be a severe vesicant. ....EATDS 56 (1941)									
		Vesicant action to man when applied undiluted or in 0.1-50% weight volume solutions in acetone is less than 1/10 that of mustard....EATR 284 (1942)									
12/28/42 N	493	Carbinol, ethinyl-	No. 5 Rod	100%	68°F.	10	0	-	0	-	N.V.
1/4/43 S		$(CH_2)_2C=CH-\underset{CH}{\overset{H}{C}}-C\equiv CH$	200 γ	100%	68°F. 25%	10	0	-	0	-	
8/31/43 Z	913	2-Pentyne-4-one, 1-methoxy-	200 γ	100%	81°F. 75%	15	0	-	0	--	N.V.
		$CH_3O-CH_2-C\equiv C-C(=O)-CH_3$									

2-Chloroethyl esters: Three vesicants, bis(2-chloroethyl) trithiocarbonate (TL 960), an unidentified reaction product (TL 959) isolated in the preparation of TL 960, and 2-chloroethyl nitrite (TL 824), are in this classification. Of the others, bis(2-chloroethyl) thiooxalate (TL 954) was the only irritant.

Esters of Fatty Acids and Halogenated Derivatives: None was irritant or vesicant.

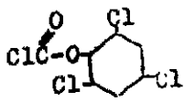
2-Chloroethyl Esters

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Size	Blisters No.	Size	Status
5/11/43 LL	677	Formic acid, azo- bis(2-chloroethyl) ester $ClCH_2CH_2O-\overset{\overset{O}{\|}}{C}-N$ $ClCH_2CH_2O-\underset{\underset{O}{\|}}{C}-N$	210γ	100%	63°F. 55%	12	0	-	0	-	N.V.
5/4/43 OO	671	Acetic acid, fluoro-2-chloroethyl ester $FCH_2\overset{\overset{O}{\|}}{C}-OCH_2CH_2Cl$	195γ	100%	73°F. 27%	15	0	-	0	-	N.V.
8/4/42 K	333	Acetic acid, thiol-2-chloroethyl ester	No. 5 Rod	100%	76°F. 59%	19	0	-	0	-	N.V.
8/17/42 N		$CH_3\overset{\overset{O}{\|}}{C}-SCH_2CH_2Cl$	No. 5 Rod	100%	65°F. 79%	19	0	-	0	-	

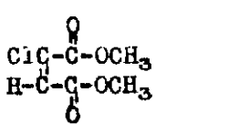
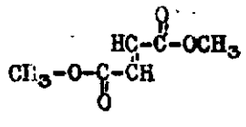
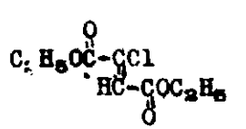
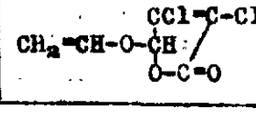
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/22/42 I 10/6/42 V	333	Acetic acid, thiol-2-chloroethyl ester (cont'd.)	No. 7 Rod	100%	59°F. 47%	21	0	-	0	-	N.V.
			200γ T.P.	100%	59°F. 72%	10	0	-	0	-	
			1/100 as effective as H applied under the same condition ....British								
9/28/43 I-1 10/5/43 L	954	Oxalic acid, dithiol-bis(2-chloroethyl) ester O C-SCH2CH2Cl C-SCH2CH2Cl O	100γ	44% dioxane	79° 57%	10	9	10	0	-	E
			100γ	44% dioxane	67° 55%	14	13	15	0	-	
4/6/43 FF 4/15/43 S	555	Carbonic acid, 2-chloroethyl methyl ester CH3O-C(=O)-OCH2CH2Cl	100γ	100%	74°F. 28%	15	0	-	0	-	N.V.
			200γ	100%	65°F. 28%	24	0	-	0	-	
9/28/43 L-2	960	Carbonic acid, trithio-bis(2-chloroethyl) ester S=C(SCH2CH2Cl)2	70γ	100%	79° 57%	17	17	7	7	3	V

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/28/43 K-2	959	Reaction product of thiophosgene and 2-chloroethyl mercaptan Reaction product of $CSCl_2$ and $ClCH_2CH_2SH$	70 γ	100%	79° 57%	11	11	6	10	3	V
9/21/42 H	380	Isocyanide, 2-chloroethyl-dichloride	No. 5 Rod	100%	66°F. 48%	20	0	-	0	-	N.V.
10/5/42 V		$ClCH_2CH_2N{=}CCl_2$	200 γ T.P.	100%	59°F. 78%	10	0	-	0	-	
2/15/45 K	515	Isocyanic acid, 2-chloroethyl ester $ClCH_2CH_2N{=}C{=}O$	200 γ	100%	62°F. 28%	10	0	-	0	-	N.V.
8/5/42 L	355	Thiocyanic acid, 2-chloroethyl ester	No. 3 Rod	100%	N.R.	20	0	-	0	-	N.V.
8/17/42 O		$ClCH_2CH_2SCN$	No. 5 Rod	100%	63°F. 79%	20	0	-	0	-	
10/5/42 Y			200 γ	100%	59°F. 78%	10	0	-	0	-	
9/2/42 T	324	Nitrous acid, 2-chloroethyl ester	No. 5 Rod	100%	82°F. 64%	19	1	2	0	-	V
9/15/42 B		$ClCH_2CH_2ONO$	100 γ T.P.	100%	75°F. 78%	20	18	2	15	2	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
9/7/42 T	325	Sulfurous acid, 2-chloroethyl ester	No. 5 Rod	100%	74°F. 78%	20	1	4	0	-	N.V.
9/22/42 H		$(ClCH_2CH_2O)_2SO$	No. 7 Rod	100%	59°F. 47%	21	0	-	0	-	
9/15/42 H			100γ T.P.	100%	75°F. 78%	20	0	-	0	-	
10/5/42 Z			200γ T.P.	100%	59°F. 78%	10	0	-	0	-	
			Not a vesicant....Porton Memo no. 15 (1941)								
9/21/43 J-1	917	Bis(2-fluoroethyl) sulfate $(FCH_2CH_2O)_2SO_2$	260γ	100%	65° 60%	9	0	-	0	-	N.V.
7/29/42 E	303	Silicic acid, 2-chloroethyl ester $(ClCH_2CH_2O)_4Si$	No. 3 Rod	100%	70°F. 86%	15	0	-	0	-	N.V.
8/5/42 J			No. 3 Rod	100%	N.R.	20	0	-	0	-	
			Not a vesicant....Porton Memo No. 15 (1941)								
Esters of Fatty Acids and Halogenated Derivatives											
10/21/43 M	423	Formic acid, chloroethyl ester $ClC(=O)-OC_2H_5$	No. 5 Rod	100%	71°F. 45%	10	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
11/9/42 U	425	Formic acid, chloroethyl ester (cont'd.)	100 γ T.P.	100%	73°F. 46%	10	0	-	0	-	N.V.
11/11/42 R			200 γ T.P.	100%	75°F. 31%	10	0	-	0	-	
11/11/42 L	398	Formic acid, chlorophenyl ester	No. 5 Rod	100%	75°F. 31%	11	0	-	0	-	N.V.
12/8/42 M		$ClC(=O)-OC_6H_5$	200 γ T.P.	100%	N.R.	14	0	-	0	-	
11/11/42 M	399	Formic acid, chloro-2,4,6-trichlorophenyl ester	No. 5 Rod	100%	75°F. 31%	9	0	-	0	-	N.V.
12/8/42 N			200 γ T.P.	100%	N.R.	14	0	-	0	-	
4/6/43 CC	529	Acetic acid, 1,2-dichloroethyl ester	200 γ	100%	75°F. 28%	13	0	-	0	-	N.V.
		$CH_3C(=O)-OCHClCH_2Cl$									
3/3/43 S	620	Acetic acid, dichlorofluoroethyl ester	200 γ	100%	71°F. 23%	17	0	-	0	-	N.V.
		$Cl_2CFC(=O)-OC_2H_5$									

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/15/43 L	516	Acetic acid, trifluoro-methyl ester	200γ	100%	62°F. 28%	7	0	-	0	-	N.V.
6/15/43 NN	763	Acetic acid, iodo-ethyl ester	250γ	100%	84°F. 46%	12	1	3	0	-	E-
			Renders skin abrasions very liable to infection.... NAB British (1940)								
3/9/43 YY	621	Butyric acid, α-fluoro-ethyl ester	200γ	100%	75°F. 72%	7	0	-	0	-	N.V.
3/23/43 LL	619	Butyric acid, γ-fluoro-ethyl ester	200γ	100%	75°F. 40%	6	0	-	0	-	N.V.
9/7/42 V	354	Maleic acid, dimethyl ester	No. 5 Rod	100%	74°F. 78%	22	0	-	0	-	N.V.
9/21/42 M			No. 7 Rod	100%	66°F. 48%	20	0	-	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythema No.	Erythema Size	Blisters No.	Blisters Size	Status
10/14/42 K	407	Maleic acid, chloro-dimethyl ester	No. 3 Rod	100%	74°F. 52%	10	0	-	0	-	N.V.
10/19/42 X			No. 5 Rod	100%	68°F. 41%	9	0	-	0	-	
10/21/42 H			200γ T.P.	100%	71°F. 45%	9	0	-	0	-	
9/15/42 P	[illegible]	Fumaric acid, dimethyl ester	No. 5	9% ethyl acetate	75°F. 78%	20	0	-	0	-	N.V.
10/5/42 K			200γ T.P.	9% ethyl acetate	59°F. 78%	8	0	-	0	-	
12/28/42 R	501	Fumaric acid, chloro-ethyl ester	No. 5 Rod	100%	68°F.	10	0	-	0	-	N.V.
1/4/43 V			200γ	100%	68°F. 25%	10	0	-	0	-	
4/13/43 Y	655	Vinyl mucochlorate	100γ	100%	65°F. 28%	53	0	-	0	-	N.V.
4/27/43 W			200γ	100%	67°F. 62%	15	0	-	0	-	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
2/23/43 R	455	ε-Dichloroisopropyl chlorosulfinate $ClCH_2$ $ClCH_2$ >CH-OSOCl	200γ	100%	67°F. 50%	11	0	-	0	-	N.V.
8/4/42 B	78	1,6-Hexanediol diisocyanate $OCN(CH_2)_6NCO$	No. 3 Rod	100%	76°F. 59%	19	0	0	0	0	N.V.
8/17/42 C			No. 5 Rod	100%	65°F. 79%	20	0	0	0	0	
10/5/42 HH			200γ T.P.	100%	59°F. 78%	10	0	0	0	0	

ACID HALIDES

Bromoacetyl bromide blistered one man out of 16 with a No. 3 Rod, and irritated 13/19 with No. 5 Rod. In all other tests it was non-irritant. The other compounds of the group were inactive.

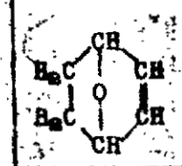
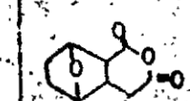
4/6/43 AA	632	Acetyl bromide, bromo- $BrCH_2C(=O)-Br$	No. 3 Rod	25% D.P.E.	76°F. 28%	15	0	-	0	-	V
4/6/43 Z			No. 5 Rod	50% D.P.E.	76°F. 28%	15	0	-	0	-	
4/6/43 Y			No. 3 Rod	100%	76°F. 28%	16	12	3	1	1	

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
4/6/43 X	632	Acetyl bromide, bromo- (cont'd.)	No. 5 Rod	100%	76°F. 28%	19	16	3	0	-	V
4/13/43 M			115 γ	100%	65°F. 28%	35	0	-	0	-	
1/4/43 W	508	Oxalyl chloride ClOCCOCl	200 γ	100%	68°F. 25%	3	0	-	0	-	N.V.
6/1/43 DD	691	Butanesulfonyl fluoride $C_4H_9SO_2F$	230 γ	100%	80°F. 59%	20	0	-	0	-	N.V.
10/21/42 Y	443	Sulfamyl chloride, dimethyl- $(CH_3)_2NSO_2Cl$	No. 5 Rod	100%	71°F. 45%	10	0	-	0	-	N.V.
11/9/42 W			100 γ T.P.	100%	73°F. 46%	10	0	-	0	-	
11/11/42 AA			200 γ T.P.	100%	73°F. 31%	9	0	-	0	-	

ETHERS

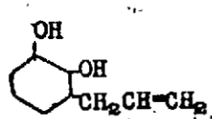
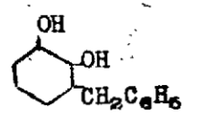
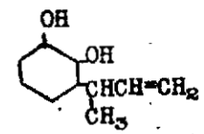
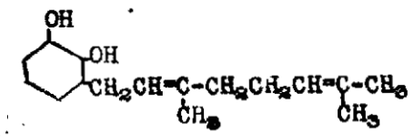
Bis(isothiocyanomethyl) ether (TL 273) was irritant with No. 3 Rod and vesicant (2/7) at 0.2 mg. The other ethers (including epoxy compounds) were non-irritant.

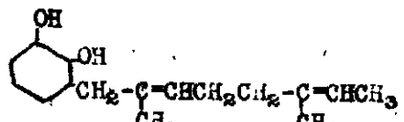
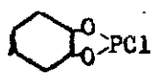
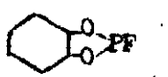
8/4/42 H	273	Ether, bis(isothiocyanomethyl) $(S{=}C{=}NCH_2)_2O$	No. 3 Rod	100%	76°F. 59%	20	3	3	0	-	V

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/17/42 K	273	Ether, bis(isothiocyanomethyl) (cont'd.)	No. 5 Rod	100%	63°F. 79%	20	6	6	0	-	V
10/5/42 FF			200γ T.P.	100%	59°F. 78%	9	0	-	0	-	
11/11/42 G			200γ T.P.	100%	75°F. 31%	7	6	6	2	2	
3/9/43 CCC	658	Ether, bis(2-chloroethyl) $(ClCH_2CH_2)_2O$	100γ	100%	75°F. 72%	6	0	-	0	-	N.V.
3/17/43 GGG			200γ	100%	65°F. 41%	10	0	-	0	-	
2/23/43 U	469	3,6-Epoxycyclohexene 	200γ	100%	67°F. 30%	11	0	-	0	-	N.V.
8/17/42 B	74	4,7-Epoxy-1,3-isobenzofurandione 	No. 5 Rod	6% dioxane	63°F. 79%	18	0	0	0	0	N.V.
10/6/42 Y			200γ K.	6% dioxane	59°F. 72%	8	0	0	0	0	

CATECHOLS

3-Allyl catechol, the two geranyl catechols, and pyrocatecholphosphorus monochloride were irritant but not vesicant.

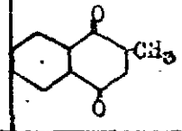
Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/19/42 A	142	Pyrocatechol, 3-allyl- 	No. 3 Rod	100%	N.R.	19	6	N.R.	0	0	E
		Some skin irritancy....Hawai, Sci. Papers Inst. Phys. Chem. Tokyo 3 263 (1925)									
6/16/42 A	223	Pyrocatechol, 3-benzyl- 	No. 3 Rod	100%	N.R.	15	0	-	0	-	N.V.
6/16/42 A	224	Pyrocatechol, 3-(1-vinylethyl)- 	No. 3 Rod	100%	N.R.	15	0	-	0	-	N.V.
6/16/42 A	225	Pyrocatechol, 3-geranyl- 	No. 3 Rod	100%	N.R.	15	1	N.R.	0	-	E-
		Marked vesicant action....Hawai, Sci. Papers Inst. Phys. Chem. Tokyo, 3 263 (1925)									

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/19/42 A	144	Pyrocatechol, 3-geranyl- 	No. 3 Rod	100%	N.R.	19	4	N.R.	0	0	E
3/17/43 KKK	584	Pyrocatechol phosphorus monofluoride	100γ	100%	65°F. 41%	8	0	-	0	-	N.V.
3/23/43 EE			200γ	100%	75°F. 40%	9	0	-	0	-	
3/9/43 TT	539	Pyrocatechol phosphorus monochloride 	200γ	100%	75°F. 72%	7	1	4	0	-	E-

MISCELLANEOUS

One of the five compounds not elsewhere classified, chloroallyl alcohol, was an irritant. The others were non-irritant.

Alcohol											
8/4/42 I	292	2-Propen-1-ol, 3-chloro- $ClCH{=}CHCH_2OH$	No. 3 Rod	100%	76°F. 59%	20	1	3	0	-	E

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings: Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
8/17/42 L	292	2-Propen-1-ol, 3-chloro- (cont'd.)	No. 5 Rod	100%	63°F. 79%	19	0	-	0	-	E
10/5/42 EE			200γ T.P.	100%	59°F. 78%	10	2	3	0	-	
		Single 2 mm. diameter drops of compound applied to the forearms of each of 5 men. A very feeble skin reaction occurred (less than a similar reaction of 1% solution w/w of mustard in dry benzene. It is therefore concluded that the compound is not appreciable vesicant being less than H/100....B-1203, CDR 1104 (Y.20346)									
Quinone											
10/6/42 R	396	1,4-Naphthquinone, 2-methyl- 	60γ T.P.	22% dioxane	59°F. 72%	10	0	-	0	-	N.V.
10/19/42 V			200γ T.P.	22% dioxane	68°F. 41%	12	0	-	0	-	
		MISCELLANEOUS HALOGEN COMPOUNDS									
9/21/43 L-2	936	Ethane, 1-chloro-2-fluoro- $ClCH_2CH_2F$	230γ	100%	65° 60%	10	0	-	0	-	N.V.
8/3/42 B	80	Butene-2, 1,4-dibromo- $BrCH_2CH=CHCH_2Br$	No. 3 Rod	43% dioxane	N.R.	18	0	0	0	0	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-hour Readings Erythema No.	Erythema Size	Blisters No.	Blisters Size	Status
8/18/42 A 10/5/42 T	80	Butene-2, 1,4-dibromo- (cont'd.)	No. 5 Rod	43% dioxane	72°F. 64%	21	0	0	0	0	N.V.
			200 γ T.P.	43% dioxane	59°F. 78%	10	0	0	0	0	
			Mice - Undiluted compound, No. 5 Rod, no necrosis.... TDMR 369								
10/12/43 X-1	971	Benzene, 1,3,5-tris- (chloroacetyl) $C_6H_3(C(=O)-CH_2Cl)_3$	200 γ	10% dioxane	80° 54%	14	0	-	0	-	N.V.

References to vesicant studies by other laboratories on specific compounds are given with those compounds in Section IV.

1. Armstrong, G. C., A Method for Quantitative Application of Minute Measurable Amounts of Undiluted Liquid Vesicants to the Skin (Rod Method); EATR 238, March 1937.

2. Black, S., DuBois, K. P., and Lipton, M. A., A Vapor Train Study of the Comparative Vesicancy of Mustard and Several Related Amines and Sulfides on Human Skin; OSRD 3944, July 1944.

3. Bloom, W., Murray, R. G., Savit, J., and Thomson, J. F., A Modification of the "Drod"; OSRD 1899, September 1944.

4. Bloom, W., Thomson, J. F., Goldwasser, E., Savit, J., and DeBruyn, P. P. H., *The Benesh Micropipette; OSRD 4230, October 1944.*

5. McMaster, P. D., A Method for Delivering Equal Amounts of Fluids of Differing Physical Properties; OSRD 683, Serial 287, July 1942.

6. Savit, J., Thomson, J. F., Goldwasser, E., DeBruyn, P. P. H., and Bloom, M. A., Tests of Chloroamide-Containing Ointments for Protection and Decontamination of Human Skin against Liquid Vesicants; OSRD 3386, March 1944.

7. Trevan, J. W., Lancet, April 22, 1922, p. 786.

8. Trevan, J. W., Biochem, J., 19, 1111 (1925).

9. Truckle, T. W. N., Technique of the Physiological Experiments Carried Out on Human Observers at the Chemical Defense Research Department, Porton. No date.

10. Wright, S., Analysis of Variations in Size of Blister after Application of H; OSRD 3943 , June 1944.

Appendix 1

COMPOUNDS NOT TESTED

The following compounds, submitted to the Toxicity Laboratory for vesicant tests, could not be examined for the reasons given.

TL No.	Name	Reason
73	Pyrosulfuryl chloride	Hydrolyzed in air
149	Lead, triethyl- selenocyanate	Decomposed
268	Phosphine sulfide, tris(amyl-naphthyl)-	Entire sample sent to C.S. Marvel, 4/2/43
286	Arsine, chlorodimethyl-	Oxidized by air
314	Acrylonitrile	High volatility
357	Pentane, 3-chloro-3-nitroso-	High volatility and decomposition
358	Chloroform, nitroso-	High volatility and decomposition
359	Propane, 1,2-dichloro-2-nitroso-	High volatility and decomposition
375	Phosphoryl dibromomonofluoride	Decomposed
394	Arsine, ethylbis(methylmercapto)-	Hydrolyzes in air
425	Arsine, ethyl-	High volatility
467	Arsine difluoromethyl-	Decomposed
474	4-Tridibenzothiophenearsine	No suitable solvent
484	Arsine, amyl-	Decomposed
499	Pyrrocoline, 2-methyl- HCl	Decomposed

TL No.	Name	Reason
519	Carbazole, 9-vinyl-	Same compound as TL 727
523	Arsine, difluoro(dimethylamino)-	Sample not available to Vesicant Laboratory
537	Phosphorus, tetrafluorophenyl-	Sample not available to Vesicant Laboratory
538	Phosphonium compound, (2-chloroethyl)triethyl- iodide	Decomposed
576	Phosphine selenide, triphenyl-	No suitable solvent
580	Phosphine, dicyano(2-phenoxathiin)-	No suitable solvent
582	Phosphorus, dibromodichlorophenyl-	No suitable solvent
589	Arsine, tris(N-ethylcarbazolyl-3)-	No suitable solvent
590	Carbazole, 3-dichloroarsino-N-ethyl-	Decomposed
591	Quinoline, 8-dichloroarsino- HCl	No suitable solvent
592	Benzothiazole, 6-dichloroarseno-2-phenyl- HCl	No suitable solvent
593	Arsine, dichloro(m-trifluoromethylphenyl)-	Decomposed
601	Arsine, tri-4-dibenzofuryl-	No suitable solvent
608	Carbazole, 3-dichlorophosphino-9-ethyl-	Decomposed
622	Quinoline, 3-bromo-2-(p-dimethylaminophenyl)-	Held for further instructions
643	Adamsite	Same as TL 644 (which was run)
653	Hemiacetal of chloral and chloretone	Request withdrawn
683	Arsine, diphenylthiocyano-	Decomposed by moist air

TL No.	Name	Reason
698	Diethylamine, 2,2'-dichloro-N-phenethyl-	Decomposed
703	p-Phenylenediamine, N,N'-dicarbomethoxy-	No suitable solvent
718	Sulfide, bis[2-(chloroformyloxy)-ethyl]-	Decomposed to CO_2 and H
752	p-Phenylenediamine, N,N'-dicarbethoxy-	Sample not available to Vesicant Laboratory
755	p-Phenylenediamine, N,N'-dicarbethoxy-2,5-dichloro-	No suitable solvent
757	p-Phenylenediamine, N,N'-dicarbethoxy-N,N'-dimethyl-	No suitable solvent
758	4-Pyrindane, 4-carbethoxyamino-2-p-toxyloxy-	No suitable solvent
786	Phosphine, dichloro[bis(2-chloroethyl)amino]-	Sample not available to Vesicant Laboratory
788	Phosphine, [bis(2-chloroethylamino)]bis(2-chloroethylmercapto)-	Decomposed
805	Arsine, ethyldifluoro-	High volatility; attacks glass
848	Diphenylamine, hexanitro-	Request withdrawn
877	Arsine, 2-chlorovinyl- selenide	No suitable solvent
908	Phosphine, dichloro(2,2'-dichloroisopropyl)mercapto-	Decomposed
972	Chromyl chloride	Too reactive to be handled by present techniques
973	Arsine, methylphenyl-	Oxidized by air
974	Furan, 2,5-bis(chloromercuri)-	No suitable solvent
1027	Arsine, tris(phenylmercapto)-	No suitable solvent

Appendix II

Daily Mean Outdoor Temperature

Day	1942											1943										
	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	20	34	45	73	61	71	77	70	56	40	22	34	14	19	50	42	78	4	66	78	67	52	38
2	15	34	54	69	67	66	76	76	68	38	6	34	26	6	32	58	80	70	82	72	60	44	35
3	26	34	40	57	74	68	72	64	68	36	7	28	38	8	36	52	76	79	74	74	56	36	37
4	34	40	60	47	73	67	70	64	60	42	16	16	34	32	52	55	70	81	74	72	51	42	44
5	36	41	53	48	68	73	70	66	56	42	22	13	40	22	42	71	62	74	71	73	56	43	42
6	35	40	54	55	76	64	70	68	60	38	18	26	28	16	38	67	62	72	72	66	64	44	38
7	32	46	38	48	63	66	71	68	61	46	16	28	25	6	50	51	57	70	76	64	63	46	34
8	26	32	39	58	64	70	72	71	68	44	18	22	32	6	56	45	56	70	80	60	63	34	42
9	24	34	38	54	67	72	72	71	59	54	25	24	41	32	52	48	60	72	82	56	67	32	36
10	27	38	44	48	73	78	73	70	54	38	28	25	32	25	40	50	66	75	78	58	60	30	32
11	28	40	36	61	76	78	66	70	54	35	18	24	10	22	44	48	64	72	80	54	66	32	26
12	27	36	42	60	75	80	64	68	58	43	8	10	18	32	46	48	60	80	80	54	68	38	26
13	28	36	48	68	58	82	70	67	56	36	10	10	10	40	32	46	74	63	81	60	58	30	9
14	30	36	50	58	56	72	75	78	60	34	6	28	2	46	30	50	77	78	74	60	50	30	8
15	36	38	68	44	53	70	76	77	56	51	22	22	7	52	37	55	78	75	74	61	41	32	6
16	36	48	68	52	61	83	70	76	55	57	13	23	12	40	50	58	76	74	68	53	40	26	12
17	20	42	48	64	62	88	70	75	56	52	28	28	23	30	40	48	72	76	64	52	40	36	20
18	8	37	40	64	71	87	72	78	56	48	20	24	30	28	2	52	74	76	65	57	50	46	30
19	10	42	41	56	71	82	73	66	58	62	12	6	46	30	40	59	80	80	68	63	48	41	34
20	18	52	46	54	71	80	78	54	58	54	10	2	42	27	36	48	72	80	72	54	62	36	29
21	23	41	49	50	67	73	82	54	50	41	16	23	39	30	44	60	80	82	76	57	56	38	26
22	27	44	57	52	67	70	78	52	40	36	34	30	46	32	52	68	76	69	77	66	50	37	10
23	26	43	64	58	60	70	62	50	38	39	34	36	42	38	52	64	76	75	78	53	44	34	16
24	26	46	67	58	62	74	59	43	38	42	34	30	30	48	58	59	80	80	79	53	46	36	15
25	28	52	68	66	63	78	62	38	36	45	34	10	26	49	55	54	83	80	80	50	44	36	36
26	29	50	66	58	66	80	68	44	30	26	44	10	22	44	51	58	86	78	76	52	46	36	37
27	33	38	68	58	72	78	73	40	35	24	44	19	34	35	60	62	74	80	68	62	42	30	37
28	32	32	64	74	80	77	78	42	44	34	34	25	29	33	52	64	75	75	66	70	47	28	31
29		31	74	78	85	74	80	48	56	26	34	31		44	52	72	58	76	67	67	51	30	26
30		32	80	82	78	74	81	59	56	24	32	33		54	46	74	56	75	76	73	47	32	26
31		39		73		82	79		46		33	24		60		77		78	84		57		24

VI

Supplement
to
University of Chicago Toxicity Laboratory Report No. 48
NDCrc 132, Division 9, NDRC
TESTS FOR VESICANCY ON HUMAN SKIN
January 1, 1944 - January 1, 1945

During the year 1944, 31 new compounds were examined for vesicant action on human skin. All tests were carried out on the flexor surface of the forearm.

Nine of these compounds were vesicant (V) at doses of 0.2 mg. or less, six were irritant (E) at 0.2 mg., one was doubtful (E-), and the remaining 15 produced no effect (NV) on human skin at 0.2 mg. Compounds were delivered by micrometer burette.

With the exception of TL 1263, 2,2'-dichloroisopropylmercapto-bis(2-chlorovinyl)arsine, all of the vesicants were compounds with 2-chloroethylmercapto- groups. The only vesicant amine, TL 1347, is in effect HN1 with the chlorine atoms replaced by $ClCH_2CH_2S$-.

The effect of this substituent in TL 1137, 2-chloroethylmercapto-bis(2-chlorovinyl)arsine, is doubtful, since the 2,2'-dichloroisopropyl analogue, TL 1263, is of the same order of vesicancy.

Among the sulfides, the "one-arm" mustards which showed vesicant action were benzyl (TL 1344), 2-chlorovinyl (TL 1302), 2-chlorocyclopentyl (TL 1385), and 2-chlorocyclohexyl (TL 1200). The 2,2-dichloroethyl (TL 1420) and p-tolyl (TL 1199) derivatives were non-vesicant at 0.2 mg. and allyl 2-chloroethyl sulfide (TL 1164) produced only erythemas. TL 1220, a more complex compound, was a mild vesicant, while the closely related TL 1219 was inactive.

TL 1302 and TL 1420 are of interest because of their presence in H which has been stored in steel (Woodhouse, et. al., OSRD 3179).

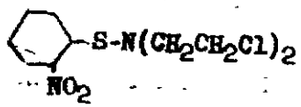
Also of interest is TL 1301, 1,2,2'-trichlorodiethyl sulfoxide. This compound was among those isolated from cloth containing CC-2 which had been exposed to H. The irritancy of this compound is very slight however.

Among the miscellaneous compounds, TL 1175, tetrakis(2-chloroethylmercapto)silicane, was one of the better new compounds examined during the year.

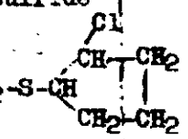
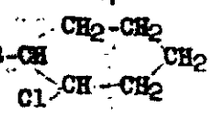
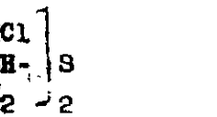
In addition to the compounds listed below, we have tested 87 samples of standard vesicants and mixtures during 1944. All of our vesicant tests have been reported in detail and discussed in NDRC Informal Reports 9-4-1-12-23 (1944).

AMINES

Series	TL No.		Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
7/25/44 A-2	1409	N-(3-fluoro-2-hydroxypropyl)-dimethylamine $FCH_2-CHOH-CH_2-N(CH_3)_2$	200 γ	100%	76°F. 59%	15	0	-	0	-	N.V.
3/7/44 L-2	1230	4-Chloropentyldiethylamine hydrochloride $CH_3CHClCH_2CH_2CH_2-N(C_2H_5)_2 \cdot HCl$	200 γ	28% in water	62° 24%	15	1	1	0	-	E-.
3/7/44 N-1	1194	N-(2-Chloroallyl)-2,2'-dichloro- diethylamine $CH_3-CHCl-CH-N(CH_2CH_2Cl)_2$	200 γ	29% in cellosolve	58° 27%	15	0	-	0	-	N.V.
7/4/44 J-1	1379	2,2'-bis[bis(2-chloroethyl)-amino]-propane dihydrochloride $[(ClCH_2CH_2)_2N]_2C(CH_3)_2 \cdot 2HCl$	200 γ	24% in water	80° 57%	15	15	9	0	0	E.
5/16/44 A-2	1341	1,3-bis[bis(2-chloroethyl)-amino]- propane dihydrochloride $(Cl-CH_2CH_2)_2N-CH_2CH_2CH_2-N(CH_2CH_2Cl)_2 \cdot 2HCl$	200 γ	47% in water	79° 65%	9	9	9	0	-	E.
5/16/44 C-2	1347	2,2'-bis(2-chloroethylmercapto)-triethylamine- hydrochloride $CH_3CH_2-N(CH_2CH_2-S-CH_2CH_2Cl) \cdot HCl$	200 γ	50% in water	79° 65%	15	15	14	7	10	V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Mon	48-Hour Readings Erythemas No.	Size	Blistors No.	Size	Status
3/13/44 H-Z	1228	2,2'-Dichlorodiethyl(o-nitrophenylsulfenyl)amine 	200 γ	17% in dioxane	75° 27%	20	0	-	0	-	N.V.
3/29/44 T-2	1297	Di[bis(2-chloroethyl)amino]-sulfide $[(Cl\text{-}CH_2CH_2)_2N]_2S$	200 γ	51% in dioxane	70° 29%	32	0	-	0	-	N.V.
		ARSENICALS									
3/7/44 L-1	1137	2-Chloroethylmercapto-bis-(2-chlorovinyl)arsine $(ClCH{=}CH)_2AsSCH_2CH_2Cl$	160 γ	100%	62° 24%	15	10	6	2	5	V
3/29/44 RS-1	1263	2,2'-Dichloroisopropylmercapto-bis(2-chlorovinyl)arsine $(ClCH{=}CH)_2As\text{-}S\text{-}CH(CH_2Cl)_2$	80 γ	100%	69° 35%	31	16	6	1	2	V
		PHOSPHINES									
3/7/44 M-2	1180	2-Chloroethylmercaptodicyano-phosphine $ClCH_2CH_2SP(CN)_2$	200 γ	100%	58° 27%	14	11	7	0	-	E

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/13/44 H-1	1214	2-Methyl-2-nitro-1-propoxy-dicyanophosphine	200γ	30% in dioxane	75° 27%	20	0	-	0	-	N.V.
3/29/44 RS-2	1264	Bis(2,2'-dichloroisopropyl-mercapto)phenyl phosphine	210γ	100%	69° 35%	31	0	-	0	-	N.V.
		SULFIDES									
3/7/44 K-2	1164	2-Chloroethyl allyl sulfide $ClCH_2-CH_2-S-CH_2-CH=CH_2$	215γ	100%	62° 24%	19	14	8	0	-	E.
5/16/44 C-1	1344	2-Chloroethyl benzyl sulfide $C_6H_5CH_2-S-CH_2CH_2Cl$	120γ	100%	79° 65%	15	14	10	2	4	V.
3/7/44 N-2	1159	2-Chloroethyl p-tolyl sulfide $ClCH_2CH_2S-C_6H_4CH_3$	230γ	100%	58° 27%	15	0	-	0	-	N.V.
3/29/44 V-2	1302	2-Chloroethyl 2-chlorovinyl $ClCH_2CH_2-S-CH=CHCl$	65γ	100%	70° 29%	18	18	6	2	7	V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/29/44 U-2	1302	2-Chloroethyl 2-chlorovinyl sulfide (cont'd)	130 γ	100%	70° 29%	15	15	3	1	1	V.
7/25/44 C	1420	2,2,2'-Trichlorodiethyl sulfide $ClCH_2CH_2\text{-}S\text{-}CH_2\text{-}CHCl_2$	210 γ	100%	76° 59%	15	0	-	0	-	N.V.
7/4/44 J-2	1385	2-Chloroethyl 2-chlorocyclopentyl sulfide 	220 γ	100%	80° 57%	15	13	14	3	9	V
3/7/44 O-1	1200	2-Chloroethyl 2-chlorocyclohexyl sulfide 	240 γ	100%	80° 27%	13	13	16	3	7	V.
5/16/44 B-1	1343	Bis(2-chlorocyclohexyl)sulfide 	200 γ	41% in dioxane	79° 65%	10	0	-	0	-	N.V.

Series	TL No.	Compound	Dose	Concn. and Solvent	Temp. R.H.	No. Men	48-Hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
3/7/44 P-2	1220	1,1,1-Tris(2-chloroethyl-mercaptomethyl)ethane	65γ	100%	58° 27%	12	10	15	0	-	V.
3/13/44 I-2		$(ClCH_2CH_2\text{-}S\text{-}CH_2)_3CCH_3$	130γ	100%	75° 27%	31	30	15	0	-	
3/22/44 A-1			260γ	100%	75° 27%	14	14	19	2	4	
3/23/44 I-1	1219	Tetrakis(2-chloroethyl-mercaptomethyl) methane $(ClCH_2CH_2S\text{-}CH_2)_4C$	260γ	100%	75° 27%	31	0	-	0	-	N.V.
4/19/44 N	1311	p-Xylene, α,α'-bis(2-chloro-ethylmercapto) 	50γ	33% in dioxane	72° 38%	32	29	5	0	-	E.
5/9/44 O-1			100γ	"	70° 44%	16	12	6	0	-	
5/10/44 A-1			200γ	"	79° 65%	9	8	6	0	-	
7/25/44 A-1	1408	3-Fluoro-2-hydroxypropyl propyl sulfide $FCH_2\text{-}CHOH\text{-}CH_2\text{-}S\text{-}CH_2CH_2CH_3$	215γ	100%	76° 59%	15	0	-	0	-	N.V.

SULFOXIDES

Series	TL No.	Compounds	Dose	Concn. and Solvent	Temp. R.H.	No. Men	24 hour Readings Erythemas No.	Erythemas Size	Blisters No.	Blisters Size	Status
10/17/44 J	95	2,2'-Dichlorodiethyl sulfoxide	200 γ	10% in nitro-ethane	75° 24%	15	0	-	0	-	N.V.
3/22/44 A-2	1301	1,2,2'-Trichlorodiethyl sulfoxide (α-chloro-H sulfoxide) $ClCH_2$-$CHCl$-SO-CH_2CH_2Cl	200 γ	38% in benzene	75° 27%	14	3	6	0	-	E.
		MISCELLANEOUS									
3/7/44 M-1	1175	Tetrakis(2-chloroethylmercapto)-silicane $(ClCH_2CH_2S)_4Si$	210 γ	100%	58° 27%	14	14	6	6	3	V.
3/29/44 T-1	1265	Tris(2-chloroethyl)borate $(ClCH_2CH_2O)_3B$	250 γ	100%	70° 29%	32	0	-	0	-	N.V.
3/7/44 K-1	1095	Methyl γ-fluorobutyrate $CH_3OOCCH_2CH_2CH_2F$	210 γ	100%	62° 24%	19	0	0	0	-	N.V.
5/16/44 B-1	1342	Thiophosgene polymer $(CSCl_2)_x$	210 γ	100%	79° 65%	10	0	-	0	-	N.V.

Six additional compounds submitted to the Vesicant Section of the University of Chicago Toxicity Laboratory were not tested for reasons as follows:

TL No.	Name	
1136	Ethanethiol, 2-fluoro-	Decomposed
1177	Arsine, tris(2-chloroethylmercapto)-	Decomposed
1189	Arsindole, 1,3-dichloro-2(diethylamino-methyl)- hydrochloride	No suitable solvent
1213	Phosphine, dicyanoethyl-	Hydrolyzed during test
1378	Chlorocyanoformaldehyde oxime	Too reactive to be handled by present techniques
1428	Diethylamine, 2-acetoxy-2'-chloro-N-methyl-	Polymerized

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to

November 10, 1943

by

F.C. Henriques, Jr. and A.R. Moritz (Official Investigators)

and

H.S. Breyfogle and L.A. Patterson

This report is based upon experiments reported in the Informal Monthly Progress Reports on Physiological Mechanisms of Chemical Warfare Agents, Section 9-5 of Division 9, N.D.R.C. (Formerly Section B4-C of Division B).