LOUSE CONTROL IN RELATION TO TYPHUS FEVER

by

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INTRODUCTION

For centuries medical men, biologists, and public health workers have endeavored to bring one of the world's most devastating diseases, typhus fever, under control. Its widespread prevalence during times of war has caused, in many instances, more deaths than the combat features of the war itself. Yet it is only recently that the real cause of typhus has become known.

Early in the present war, the importance of typhus control was expressed by the President's Executive Order No. 9285, creating the United States of America Typhus Commission. This broadly conceived executive order, with comprehensive mandates and authorizations, expressed the government's realization of the importance of typhus fever as a threat to the safety and general welfare of the armed forces and of civilian populations. Appreciating that the study and control of typhus fever were of immediate concern to the Army, Navy, and the United States Public Health Service, the order provided for a joint attach by these three services upon the problem of the disease. It provided also for securing the assistance of great civilian institutions of the country, such as the International Health Division of the Rockefeller Foundation. The broad intentions of the order directed and authorized the undertaking of such studies and the institution of such measures as would prevent typhus fever from exerting in these days the devastation it has caused in the past in times of war, famine and the dislocation of populations.

During the past year, the writer has been working almost exclusively on the louse control phase of the Army's typhus control program. The materials discussed and procedures outlined in this paper are the results of research and close cooperation between the writer and a number of other agencies: the Bureau of Entomology and Plant Quarantine; the Committee on Medical Research of the Office of Scientific Research and Development; the United States Public Health Service; and the Rockefeller Foundation.

This paper makes no pretense of being the final word in louse control. It merely describes the latest methods and discusses and evaluates the research by which such methods are developed.

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I

TYPHUS FEVER

Typhus fever has always been known by a number of names: war fever, ship fever, jail fever, camp fever, hospital fever, famine fever, el tabardillo (Spanish), fleckfieber (German), typhus exanthematique (French), Brill's disease, and others.

"Typhus fever is an acute infectious disease transmitted sporadically by the rat flea, in epidemics by the body louse; characterized clinically by sudden onset; continuous high fever, terminating by rapid lysis after about fourteen days; a general macular eruption tending to become hemorrhagic over trunk and limbs, but avoiding the face; a delirium which may pass into a final coma, and a tracheobronchitis often followed by bronchopneumonia. Pathologically it is characterized by proliferative and thrombotic lesions of the blood vessels of the skin, musculature, and central nervous system." (Wolbach, 1943)

The causative microorganisms -- Rickettsiae -- are difficult to satisfactorily characterize. At the present time all very small gram-negative bacterium-like microorganisms found in arthropods are called Rickettsia. Some are very pleomorphic; others have a uniform morphology, coccoid and diplococcoid; all stain poorly with the ordinary stains employed for bacteria. None can be cultivated outside of cells. The pathogenic rickettsiæ tend to be pleomorphic and multiply only within the cytoplasm of living cells. The smallest dimension of Rickettsia Prowzaki, the cause of typhus, is commonly given as 0.3 microns but forms which appear smaller than this and which are almost on the borderline of visibility are occasionally seen within cells. As seen in paraffin sections, Rickettsia Prowzaki is always intracellular. In its most characteristic form it appears as a minute microbacillus, each member of the diploid form averaging 0.6 x 0.3 microns. Short chains are not uncommon. In very heavily infected cells, the individual organisms appear as minute coccoid bodies.

Epidemiologically there are two types of typhus, one of the classic European type exemplified by louse-borne epidemics throughout the world; the other the murine type with the natural reservoir in rats and therefore endemic in most every country. Based upon cross immunity tests, both types are caused by only one species of rickettsia, R. prowazeki, with different strains or subspecies for the two types: R. prowazeki prowazeki for the epidemic form and R. prowazeki mooseri for the murine form. Some authorities, however, raise these to the rank of species, R. prowazeki and R. mooseri.

In addition to the two well known types of typhus, there are two other distinct strains: Brill's disease in the northern states and the tabardillo of Mexico.

Brill's disease, first observed by Brill in New York in 1898, was believed by Zinsser (1937) to be a mild recrudescent form of louse-borne typhus. Zinsser, after detailed studies of 538 cases in New York and Boston concluded that although this form was endemic in the cities of the northeastern seaboard it was of European origin. Over ninety-four per cent of all cases occurred in foreign-born individuals, over eighty per cent of all cases being Jews that had migrated from Russia in earlier years. Moreover, in spite of a constant increase in the proportion of native-born of the same race and habits, the high percentage among the foreign-born continued. The comparison of age groups in the two decades he studied (1910-1920 and 1920-1933) showed that the concentration of cases in the second decade was in a group ten years older than the first decade. Thus Zinsser's epidemiologic studies (1934) convinced him that Brill's disease is an imported mild recrudescent form of louse-borne typhus, endemically established in cities with large immigrant populations. Some other authorities are not so convinced and regard it as a form of murine typhus. The recent seriological tests of Plotz (1943), however, further indicate that Brill's disease is mild epidemic typhus.

Tabardillo, the Mexican form of typhus, is epidemiologically and seriologically identical with the European type, except that it has a lower mortality than the European and somewhat higher than Brill's disease and murine typhus.

All the types or strains of typhus above mentioned --classic European epidemic, murine endemic, Brill's disease and tabardillo--may be transmitted from man to man by the body louse, <u>Pediculus humanus corporis</u>. Löffler and Mooser (1942) state that, contrary to usual belief, head lice (<u>Pediculus humanus humanus</u>) play an important part in transmitting typhus. Typically, however, murine typhus is transmitted to man from the rat by the tropical rat flea, <u>Xenopsylla cheopis</u>. Furthermore, Dave and Shelmire (1931) have shown that the tropical rate mite, <u>Liponyssus bacoti</u>, is a positive vector. The rat louse, <u>Polyplax spinulosus</u>, also transmits the disease from rat to rat. As previously stated, all man-to-man transmissions may be accomplished by the human louse.

History and Geographical Distribution

The trail of typhus fever as a mass killer may be traced far back into history. Hirsch notes that its biography belongs to the dark pages of the world's story at times when war, famine and misery of every kind are present. When the Pelopennesians Army invaded Attica, with it came the plague of Athens, 430-428 B.C., and there is a strong evidence that this was typhus, according to Holmes (1940). Three years before Columbus discovered America, Ferdinand, husband of Isabella, lost 17,000 soldiers from typhus as his army besieged the Moors in Granada. For more than four centuries since, typhus has insidiously accompanied war, famine and other mass disasters throughout Europe. Furthermore, typhus has spread from land to land via the sea in the form of "ship fever." In the time of Queen Elizabeth the British jails were emptied to provide men for the navy, and with them went lice and typhus. Holmes makes the interesting observation that typhus did not strike the slave ships because the aborigines had no clothes to provide shelter for lice. Although typhus was not known to exist in colonial America, lice must have been present. Mummified Indians with head lice have been found in a number of ancient ruins, particularly in some of the western states.

Epidemics of typhus have very frequently been associated with war. In fact typhus has raged in every recorded major conflict with the exception of the Franco-Prussian in 1870 and our own Civil War. Although there was practically no recognized typhus in the latter, epidemics raged in the English mill towns suffering from the depression caused by the cotton blockade.

During the Thirty Years War in the Seventeenth Century, typhus fever spread over all of Central Europe. The disease persisted in epidemic form throughout the duration of the Napoleonic Wars and did not begin to subside until the conclusion of peace in 1815 after the Battle of Waterloo. This epidemic of typhus is said to have been the severest one ever recorded on the continent.

In World War I, the epidemic which raged in Siberia in 1915 was one of the most severe which has occurred in modern times, there being over 150,000 deaths in a population of 2,500,000. Following the war, Rumania recorded 800,000 typhus deaths and in Russia it is estimated that some 5,000,000 cases occurred between 1919 and 1922.

Generally speaking, there are two major endemic foci of typhus, Russia and Poland, but the incidence of cases had declined rapidly in both countries until the present war. Rumania is another country in Europe possessing a fairly important focus. During the last twenty years, the disease has been related to three distinct regions: (1) Central and Eastern Europe to the east of a line from the Gulf of Finland to the Adriatic; (2) the Iberian Peninsula; (3) the British Isles. The latter two cannot truly be regarded as endemic regions, but are rather districts with winter or spring recurrences of small and sharply limited outbreaks. The Mediterranean is virtually surrounded by countries more or less affected with typhus since the disease appears in sporadic or endemic form in Asia Minor, Syria, Palestine, and all the countries of North Africa. Typhus has appeared in epidemic form in Uganda, in Urandi, Union of South Africa, Basutoland, and in the Transvaal. Louse-borne typhus is prevalent in the northern half of the continent of Asia and extends southward to the mountainous parts of Iran, Afghanistan, British India, Northern Indo-China, Southwestern China and extends into Korea and Japan.

In the Western Hemisphere louse-borne typhus is the common variety of typhus in parts of Mexico, Guatemala, and other states of Central America. It occurs in the Pacific Coast countries of South America (Chile, Peru, Ecuador, Colombia) and is prevalent in Venezuela and in Sao Paulo State, Brazil.

The United States has not always been free from classic epidemic European typhus. Philadelphia had a rather extensive outbreak in 1836. Several fairly extensive epidemics have occurred in a number of American seaports along the Atlantic Coast and the Gulf of Mexico, which were traceable to recently arrived immigrants from Europe. The last outbreak was in New York in 1892 and 1893.

According to Gordon (1943), "The only true louse-borne typhus of the North American continent is the tabardillo of Mexico. This has occasionally been imported into the United States, leading to localized outbreaks with relatively high fatality. Examples of such outbreaks are contained in the reports of Boyd (1917) in Iowa, Cummings and Senftner (1917) in California, and Armstrong (1922) in New Mexico. Currently the only true typhus fever in the United States is the mild Brill's disease of the northern states and endemic murine typhus in the South."

As to murine typhus, Georgia is the chief area of endemicity with about one thousand cases yearly; Alabama, Mississippi, South Carolina, Louisiana, and Texas, taken together, have about the same number of cases. Cases are reported every year from Boston, New York, Baltimore, Norfolk, Wilmington, Charleston, and Savannah. Recently, cases have occurred in Tennessee and California. The disease is mostly urban but increasing numbers of cases are bing reported from rural areas in the southeastern states. Isolated cases have been reported from Richmond, Washington, St. Louis, Cleveland, and Cincinnati.

Recent information indicates that typhus is again on the march in Europe, Asia Minor and North Africa. In 1941 it struck the Warsaw ghetto and became a serious menace in other parts of Poland and on the Russian front. So severe was the disease in Eastern Poland and Occupied Russia that in January of 1942 it was reported that the German Sanitary Commission for this region had ordered the death of civilians with typhus if they could not be isolated and given medical attention.

It has been reported in Belgium, in Holland, in Finland, in Norway and in Denmark. There were severe epidemics in Spain in 1941 and 1942. Argentina is so concerned over European typhus that she has decided to disinfect all mail from Europe.

Transmission

Many investigators of considerable experience have inclined to the belief that murine typhus was primarily an endemic sporadic variety, whereas the classical European represented the epidemic typhus. Zinsser (1943) is of an opinion distinctly opposed to this. He believes that both typhus may be either endemic or epidemic for the following stated reasons: "Although the murine disease reaches man first from infested rats by flea vectors, this virus can also, like the European, pass from man to man by the louse. Strains have been started in guinea pigs from lice taken from patients in Mexico, and Mooser and Dummer (1930), as well as Castaneda (1930) and ourselves (Castaneda and Zinsser 1930), have by the Weigl method passed murine typhus through lice, the louse infections being in no important respect different from that observed in similar passages with the European virus. The louse is therefore without question capable of epidemic dissemination of the murine, as well as the class typhus. In Mexico, the majority of the strains, isolated from sporadic cases and from short-lived epidemics in Mexico City, behave in the typical murine manner when inoculated into guinea pigs. On the other hand, isolations of strains from patients in the course of prolonged epidemics in Mexico have shown that such strains, passed for considerable periods through the cycle man-louse-man, may be temporarily modified in the direction of the European type characteristics (Mooser, Varela, and Pilz, 1934)."

Some workers on typhus have assumed that the difference in morbidity between the two types of true typhus is caused by inherent differences in the abilities of the strains themselves. How explain, then, the fact that where the classic European disease occurs endemically, as in Southeastern Europe and in the form of Brill's disease in our northeastern cities, the mortality is likewise low. On the other hand, when the murine disease spreads in epidemics, it may attain a severity approaching that of European epidemics.

Although the two diseases, as they occur in man, present identical clinical pictures, except that the so-called murine type is apt to be a little milder and the death rate a little lower, nevertheless they can be differentiated by animal experiment and by serum reactions. The murine type is more virulent for rats than the European, more often produces temperature in these animals and produces a much greater number of intraperitoneal rickettsia. Furthermore, the murine virus will survive indefinitely in mouse passage, whereas the classic European attenuates in these animals and cannot be carried beyond the third or fourth generation.

The search for insects, other than the louse and flea, that could harbor the typhus virus have been undertaken by many investigators. This has been accomplished in case of some varieties of ticks and also in bedbugs. They have not, however, succeeded in transmitting the infection to new animals by the bites of such insects.

The problem concerning the virus reservoir in which the classic European disease is maintained between epidemics is still quite obscure. Considering the fact that typhus-infected lice rarely live more than twelve days, it is difficult to accept the explanation that classic typhus is kept going endemically by constant trickles of mild cases. Zinsser (1934) has done considerable research on this problem and suggests that at least one reservoir of the classic European typhus is the human carrier. He is convinced that sporadic epidemics may start from recrudescences of later infections in human beings. Furthermore, he believes that it is not at all out of the question that true epidemics of what appear to be the classic disease may take origin in rats in various localities. In experimental studies, Mooser (1934) has demonstrated the difficulty of causing a reversion to murine characteristics of a strain that has passed through the man-louse-man cycle for any length of time.

<u>Mode of Transmission</u>. Although it is known that the feces of infected lice always contain rickettsiae and the louse regularly deposits feces while it feeds and then may infect man via his scratching the feces into the wound of the bite, there is considerable doubt whether the virus is deposited in the human victim with the bite. Since the rickettsiae do not collect nor develop in the mouth-parts of the louse, it must follow that transmission via the feeding mechanisms would depend on regurgitation. This hardly seems likely considering the morphology of the feeding mechanism and the musculature of the head cavity.

The feeding equipment of the true louse is a highly specialized piercing and sucking mechanism. The elongate head terminates anteriorly in a small, protractile, snout-like rostrum. The organ appears to be the labrum. It has a terminal aperture continued into a median vetral cleft, and its inner walls are armed with recurved teeth, which, when everted, enable the parasite to obtain a hold on the skin of the host. In the resting position the mouth-parts and sucking apparatus of the louse are entirely concealed within the head.

The apparatus for ingestion of food consists of two parts, the proboscis and the sucking mechanism. The general outline of both can readily be seen in cleared preparations.

In dissections, the constituent parts of the proboscis are found to consist of three superposed stylets arising posteriorly from the walls of the containing sac, and, in the retracted condition, their distal ends extend to the base of the labrum in the preoral cavity, where they are ensheathed in folds of the walls of the cavity. The most dorsal stylet appears to be formed of two united appendages, the distal parts of which have their free edges rolled upward to form a tubular channel, which is the food canal serving to conduct the ingested blood from its source to the mouth. The intermediate stylet is a slender rod traversed by the salivary duct, which opens on its extremity. The ventral stylet is a broader appendage with distinct dorsal and ventral walls, the dorsal wall being deeply grooved by a channel containing the medial stylet.

These stylets have been generally assumed to represent the mouth-parts of the louse. Enderlein (1905) and Vogel (1921) contend that the dorsal stylet represents the united maxillae, that the intermediate stylet is the hypopharynx, and that the vetral stylet is the labium. This interpretation appears to be confirmed by a more recent study of Fernando (1933) on the embryonic development of the mouth-parts.

The sucking apparatus is easily dissected out of the head in cleared specimens, as its wall is chitinous throughout. From the posterior end of the preoral cavity the mouth opens dorsally into a two-chambered sucking pump which terminates in a slender oesophageal tube. These chambers are connected with one another by a membraneous canal. At the anterior end of the buccal cavity there is a circlet of minute chitinous teeth surrounding the mouth opening.

The muscles inserted into the buccal cavity are numerous and are adapted for two primary purposes, the protraction of the whole structure and the dilation of its lumen. Four principal pairs can be distinguished. Of these four pairs of muscles, three are protractors whose function it is to thrust the buccal cavity forward. When protraction occurs the teeth at the mouth opening are rotated on their bases so that their points are turned backward, the rotation being a result of their position and method of attachment. The membraneous portion of the canal, which connects the buccal cavity and the pharynx, is bent into a short loop in the resting position, passing upward, backward, and again downward. The presence of this loop allows for the necessary extension when the buccal cavity is thrust forward.

The pharynx appears to be composed of one dorsal and two lateral plates of chitin, with a smaller plate ventrally in the anterior part of the wall. To each of the dorsal and lateral plates there is attached a strong dilator muscle, which passes inward from the wall of the head. In addition, there are well-defined sphincter muscles, the arrangement of which makes it possible for the pharynx to be shut off from the buccal cavity in front and from the oesophagus behind.

In addition to the muscles which regulate the size of the pharynx there is another pair which passes to the chamber from the posterior part of the head. These arise from the lateral wall of the head cavity posterior to the brain and pass inward and forward, converging towards the oesophagus, with which they pass between the supra- and infra-oesophageal ganglia, the substance of the muscle being replaced by tendon as it passes forward. These tendons spread out to gain insertion over a considerable area of the wall of the pharynx and probably also pass forward to reach the tube which connects it with the buccal cavity. Their position suggests that their function is to retract the buccal cavity at the end of the act of sucking by reducing the membraneous portion of the canal to the loop which it forms in the position of rest.

In the looped region of the canal there are several strong bands of muscle which pass obliguely from the middle line dorsally to the lateral walls of the head in the region of antennae, extending as far as the origins of the dilator muscles of the pharynx. These are not attached to the stomodaeum at any point, so that their only action can be to approximate the dorsal and lateral walls of the head, and thereby to reduce its transverse diamter. The most probable function of these muscles would appear to be the increase of the intracranial pressure; an alternation of contraction between these muscles and the dilator muscles of the pharynx and buccal cavity would materially assist in the propulsion of the blood from these chambers into the oesophagus. (Modification of description given by Snodgrass.)

<u>Process of Feeding</u>. Patton and Cragg (1913) sum up the actual process of feeding as follows:

"The anterior end of the head is thrust against the skin of the host with the teeth in their normal closed position, the hind end of the body being at the same time elevated in order to assist the insect in gaining a purchase, and to bring the mouth-parts into a suitable position. The protractor muscles of the buccal cavity then contract, and as the organ is thrust bodily forward the teeth are rotated on their bases so that their points are turned outward and thrust into the skin. Possibly this is repeated several times until the outer cuticle is pierced and the head firmly attached to the skin. The next occurrence is the protraction of the proboscis from its sheath into the wound. It emerges at the mouth orifice between the two rows of teeth which make up the circlet, and is alternately protracted and retracted until the teeth on the maxillae then form the channel up which the blood flows to the buccal cavity, and at the same time the saliva is conveyed downward through the hypopharynx."

II

LOUSE CONTROL

In order to be effective, measures for the control of lice must accomplish complete disinfestation of both the individual and the unit to which the infested man or troops belong. Every piece of clothing belonging to the infested individual and every man belonging to any infested unit must be disinfested. Otherwise, a source of infestation will remain from which lice will spread and produce reinfestation for if even a single impregnated female louse escapes destruction by delousing measures she will probably serve as a source of reinfestation of the individual and the unit.

If a louse control measure is to be effective in preventing reinfestation, it must destroy the eggs as well as the nymphal and adult forms and the effectiveness of any delousing method or procedure is determined by its effect on the eggs. Any method which will kill the eggs will, as a rule, also kill the larvae and adults.

All lice control measures necessarily deal ultimately with the individual soldier and therefore administrative factors play an important role. In open warfare the proper administration of a disinfestation program is extremely important and far reaching in its implications. At mobilization and training camps in the zone of interior, at ports of embarkation or debarkation, or in any similar situation where large numbers of troops or civilians under military control are assembled, disinfestation is usually a function of some one agency operating directly under camp or post headquarters and is accomplished by means of delousing plants.

In a theater of operations, disinfestation is usually carried out by means of portable or mobile disinfesters, or improvised devices, rather than by permanent delousing installations. One or more temporary delousing plants may be installed for the purpose of disinfesting all the troops of a division and such plants may be operated by the personnel of the division or by a special delousing unit.

In the following pages are discussed the development and usage of procedures by which the individual soldier may delouse himself and also materials and methods by which large units or whole populations may be treated.

1. Louse Powders

Probably the earliest really effective louse powder was that used by Florence Nightingale during the Crimean War. She stubbornly insisted that the war-borne diseases could be controlled by adequate sanitation.

There is eloquent evidence that her methods of sanitation, especially her lice powder, were effective. In the French Army, there were more than 35,000 cases of typhus fever, with more than 17,500 deaths. In the English Army there were but 167 cases with but 52 deaths. Miss Nightingale did not then, of couse, know that lice transmitted typhus fever; indeed, this was more than thirty years before the discovery that bacteria cause disease. According to Lytton Strachy, "Years after the discoveries of Pasteur and Lister, she laughed at what she called the 'germ fetish'; she had never seen it; therefore it did not exist." Be that as it may, she had seen vermin, and to her, vermin meant filth and filth, disease. Even if her reasoning was not scientific, her sanitary measures were. History, unfortunately, fails to record the ingredients of her louse powder. It would be of at least academic interest to know.

Since Miss Nightingale's time, many workers have experimented on louse powders with varying degrees of success. When this country entered the present war, the search was given added impetus and official recognition of the need of an effective louse-killer that could be carried in the individual soldier's pack and used by him when needed. In the minds of a multitude of veterans of the last war were memories of countless days spent "cootie" hunting.

Experimental Methods. In the beginning of the present louse-powder research, each investigator was employing his own methods of testing. The writer used a patch variation of Professor Buxton's rearing technique. Dr. Davis of the Rockefeller Foundation used another type of patch based on Buxton's methods. The Orlando Laboratory of the Bureau of Entomology and Plant Quarantine used still other methods. Proper comparisons of evaluation were not possible with such a variety of testing methods. Since the Orlando Laboratory was doing the great majority of the research and had become an integral part of the OSRD, their methods became the standard for most research.

To the present time, something over a thousand materials, mostly synthetic organic compounds and combinations thereof, have been tested at Orlando. It was soon obvious that simple and reliable methods had to be devised. As G. W. Eddy was responsible for basic laboratory testing there, the method may be referred to as the Eddy method.

Essentially he uses three progressive types of testing: (1) beaker test; (2) arm-and-leg method; and (3) dust impregnation of clothing. In preliminary testing, all tests were made with powders of five per cent concentration.

In the beaker test, one inch squares of woolen cloth are dusted and placed in a 50 ml. beaker otherwise empty. Twenty-five and fifteen eggs are introduced. Mortality counts are made at the end of twenty-four hours. Another count is made after forty-eight hours.

The arm-and-leg method is self-explanatory. Cloth sleeves, similar to those once so popular with office workers, are treated and slipped on the arm and the tops and bottoms closed by drawstrings. Similar sleeves are made for the legs. In testing, twenty-five lice are placed in each sleeve and leg and mortality counts made after twenty-four hours. If results are significant, another twenty-five lice are added to one arm sleeve and one leg sleeve and another mortality count made at the end of forty-eight hours. If desired different materials could be tested in the arm sleeves and the leg sleeves.

Just as those materials that show promise in the beaker test are checked with the arm-and-leg method, so are those that pass this latter test graduated to the impregnated clothing method. In this test, a natural infestation is simulated. Five hundred lice are placed within the underwear of the host and eight hundred eggs are attached thereon at various places. The host is then allowed normal bodily activity for six hours to allow the lice to settle after which the underwear is removed and the lice counted. At this time, one ounce of the powder is sprinkled on the underwear and rubbed in with the hand. Mortality counts are made twenty-four hours after treating and again after twenty-four additional hours of wear. The underwear is then worn continuously for several weeks with weekly mortality counts. A kill is considered complete if there are no survivors after forty-eight hours. Reference to a three-weeks kill would thus mean a complete kill in forty-eight hours on a garment that had been treated three weeks previously and worn continously.

Materials Tested. Since a number of lousicide powders were already described in literature, it was but natural that they should be the first tried in an attempt to make improvements.

One of the earliest materials tested was finely ground derris or cube powder containing two to three per cent rotenone. To eliminate an infestation, it was found that this powder had to be used frequently and persistently.

Its prophylaxis value was quite unsatisfactory and skin irritation was excessive.

Powders containing .05 to 5.0 per cent pyrethrum were discarded for the same reasons as above. Furthermore, the stock of pyrethrum available was too low that it was deemed advisable to search for a powder based on some toxic substance other than pyrethrum or rotenone.

Various NCI powders were used. The most effective proved to be:

Naphthalene. . .	96%
Creosote	2%
Iodoform	2%

It, too, proved too irritating for use by fighting men. Rather severe burns were noted in the scrotal region.

Two other pre-war powders tested rather extensively were NCI-2 and Sulfur-Creosote, the most effective combinations being:

(1)	Talc.	20 grams
	Naphthalene . . .	½ gram
	Iodoform	½ gram
	Creosote	1 cc
(2)	Talc.	20 grams
	Sulfur	½ gram
	Creosote	1 cc

The former was only slightly less irritating than NCI-2. The latter was somewhat less irritating and many times more effective. Both, however, had a very undesirable odor, particularly the latter. Both were sufficiently irritating to preclude regular usage.

The first really practical louse powder was developed by the Orlando Laboratory in sufficient time to accompany the first American troops arriving in Africa. The formula is:

(ANI Louse Powder)

Pyrethrins (from 20% conc.)	.0.2%
IN-930 (N-isobutylundecylene-amide).	.2.0%
"Phenol S" (a by-product of thymol mfg.)	.1.0%
Pyrax (Pyrophyllite) to make . . .	.100%

This powder was quite effective on both nymphs and adults but had no ovicidal value. The average effectiveness was about one week.

Shortly afterward this same laboratory made an improvement on the above by adding 2,4-Dinitroanisole as an ovicide. The new formula was:

(MYL Louse Powder)

Pyrethrins (from 20% conc.) . . .	0.2%
IN-930	2.0%
2,4-Dinitroanisole	2.0%
"Phenol S".	0.25%
Pyrax to make	100%

As the writer has been actively engaged in louse control in the Army's Typhus Control Program for a considerable portion of time covered by this paper, he has had the opportunity to try some of the most promising materials tried by the Orlando Laboratory, the Rockefeller Foundation, and the U.S. Public Health Service.

The more extensive tests were carried out with varying percentages of 2,4 dinitro-o-cyclo-hexyl phenyl, 2,5 dinitro-phenol, 2,6 dinitro-phenol, n-isobutyl undecylenamide, isobutyl-p-aminobenzoate, 2,2-bis-(p-chlorophenyl)-1,1,1-trichlorethane and a number of materials received with code designations only.

The following materials were tested, using pyrax as a diluent:

I.	2,4 dinitro-o-cyclo-hexyl phenol	2.0%
II.	2,4 dinitro-o-cyclo-hexyl phenol	.3%
	n-isobutyl undecylenamide	1.5%
III.	2,4 dinitro-o-cyclo-hexyl phenol	.3%
	n-isobutyl undecylenamide	1.0%
	Pyrethrum conc. (20% pyrethrins)	.2%
IV.	2,4 dinitro-o-cyclo-hexyl phenol	.6%
	Phenyl cellosolve	8.0%
V.	2,4 dinitro-o-cyclo hexyl phenol	2.0%
	2,4-dinitroanisole	2.0%
VI.	2,4 dinitro-o-cyclo-hexyl phenol	0.5%
	3,6-dioxadedecianol-1	5.0%
VII.	isobutyl-p-aminobenzoate	0.6%
	Pyrethrum conc. (20% pyrethrins)	0.2%
VIII.	2,5 dinitrophenol	0.8%
IX.	2,6 dinitrophenol	0.8%
X.	n-isobutyl undecylenamide	3.0%
	dinitroanisole	2.0%
XI.	n-isobutyl undecylenamide	2.0%
(MYL)	2,4-dinitroanisole	2.0%
	Pyrethrins (20% conc.)	0.2%
	"Phenol S"	0.25%

XII. (DDT)	2,2-bis-(p-chlorophenyl)-1,1,1,-trichlorethan	10%
XIII.	Pyrethrins (20% conc.)	0.2%
	n-isobutyl undecylenamide	2.0%
	"Phenol S"	1.0%
XIV. (AL-63)	Naphthalene	5.0%
	Rotenone	1.0%
	Tar acid, high boiling	2.0%

In addition to the above, eleven other materials of unknown formulae were tested. These may be designated as R-1 to R-11.

The results of these tests, using the arm-and-leg method, are shown in Table I. It is noted that perfect kills were obtained by DDT and MYL with AL-63 a close third. Furthermore, good kills resulted in those powders containing the higher percentages of dinitro-o-cyclo-hexyl phenol. With this increase, however, went a more severe skin irritation. AL-63 also caused considerable rash. The effectiveness of DDT was more persistent than any of the others.

Dr. Davis of the Rockefeller Foundation, working semi-independently and using variations of a number of the above tested materials, was allowed to make tests under field conditions on a number of conscientious objectors on a volunteer basis.

TABLE I

Comparative Efficacy of Louse Powders (Ritchie)

Treatment	Sleeves Treated	% Decrease in Lice Count: 24 Hour Count	48 Hour Count	96 Hour Count	7 Day Count
I	2	90	95	70	35
II	3	95	98	92	70
III	3	95	100	100	95
IV	3	92	80	72	80
V	2				
VI	2	96	96	78	66
VII	2				
VIII	3				
IX	2				
X	2	100	100	96	85
XI	4	100	100	100	95
XII	6	100	100	100	100
XIII		100	100	70	
XIV		100	100	100	92
R-1	2	82	82	66	50
R-2	2	84	80	66	45
R-3	2	72	70	50	32
R-4	2	67	75	60	25
R-5	2	30	50	35	20
R-6	2	20	18	25	20
R-7	2	83	80	33	33
R-8	2	64	66	25	25
R-9	2	25	25	30	25
R-10	3	20	30	20	20
R-11	3	30	20	10	13

During these experiments, covering three weeks, very few rules of conduct were laid down. The men were urged to go about their business as usual; no lice were to be deliberately killed; bedding and underwear were not to be changed; the underwear was to be removed only for bathing. Both summer and winter underwear was used in the test. Each man was artificially infested with the same number of lice and sufficient time was allowed for the lice to settle and for the men to become accustomed to the infestation before the treatment began. Each man was allowed to treat himself after brief instructions. Approximately one ounce of the powder was given each man.

Dr. Davis used the following powders in his tests:

A-1	Frianite	50%
	Talc	35%
	Rice Flour	8%
	Zinc Sterate	5%
	Boric Acid	2%

A-1 contained no active ingredients and served as the control as well as the diluent for powders D-1, D-2, D-3, and D-4. Pyrophyllite was used as the diluent for D-5, D-6, D-7, D-8, D-9, D-10, D-11, D-12, D-13, and D-14.

D-1	2,4 dinitro-o-cyclo-hexyl phenol	0.8%
D-2	2,4 dinitro-o-cyclo-hexyl phenol	0.8%
	Phenyl Cellosolve	10.0%

D-3	2,4 dinitro-o-cyclo-hexyl phenol	0.8%
	Phenyl Cellosolve	5.0%
	2% Pyrethrins (in base oil)	5.0%
D-4	2,4 dinitro-o-cyclo-hexyl phenol	0.8%
	3,6-dioxadodecanol-1	5.0%
D-5	2,4 dinitro-o-cyclo-hexyl phenol	1.5%
D-6	2,4 dinitro-o-cyclo-hexyl phenol	1.5%
	Phenyl Cellosolve	1.0%
D-7	2,4 dinitro-o-cyclo-hexyl phenol	0.7%
	Phenol Cellosolve	1.0%
	Pyrethrum (1% pyrethrins)	10.0%
D-8	2,4 dinitro-o-cyclo-hexyl phenol	0.4%
	n-isobutyl undecylenamide	1.0%
D-9	2,4 dinitro-o-cyclo-hexyl phenol	0.2%
	n-isobutyl undecylenamide	0.5%
	Pyrethrum conc. (20% pyrethrins)	0.25%
D-10	2,4 dinitro-o-cyclo-hexyl phenol	0.6%
	n-isobutyl undecylenamide	0.5%
	Pyrethrum conc. (20% pyrethrins)	0.5%
D-11	n-isobutyl undecylenamide	1.0%
	2,4-dinitroanisole	2.0%
	Pyrethrum conc. (20% pyrethrins)	0.25%
	"Phenol S"	1.0%
D-12	2,4-dinitroanisole	2.0%
	n-isobutyl undecylenamide	2.0%

D-13 (MYL)	2,4-dinitroanisole	2.0%
	IN-930	2.0%
	Pyrethrum conc. (20% pyrethrins)	0.2%
	"Phenol S"	0.25%
D-14	Flowers of Sulfur	20%
D-15	NLE (formula unknown)	
D-16	YAT (formula unknown)	

Dr. Davis' results were more or less what was expected as a result of previous laboratory experimentation. The group results of these tests are shown in Table II. It is apparent that all active powders accomplished a marked decrease in the louse counts although only D-5, D-6, D-7, D-10, and D-13 were outstanding in their effectiveness. Other features, however, must be considered in the evaluation: staining characteristics and skin or nasal irritation. D-5 and D-6 were so irritating to the nasal passages that their usage would be impractical. Minor irritations of the skin were noted with several of the treatments. D-15 caused severe scrotal irritation. A yellow staining of the body and clothing followed the usage of all powders containing the dinitro-o-cyclo-hexyl phenol. D-13 thus is to be considered as the most practical of the group.

Davis (1944) sums up his findings as follows: "The first point to emerge was that good louse-killing powders can be obtained from a variety of substances on several different carriers. Second, the effectiveness did not correspond

TABLE II

Comparative Efficacy of Louse Powders (Davis)

Treatment	Louse Counts on Test Days								
	Day Treated	1st Day	2nd Day	4th Day	6th Day	7th Day	8th Day	9th Day	11th Day
A-1	51.0	68.8	72.8	107.6	125.4		123.0		33.5
D-1	50.0	3.2	2.4	12.2	24.8		21.8		
D-2	51.4	1.2	3.2	8.4	9.9		18.0		
D-3	123.0	5.6	3.6						
D-4	48.2	2.4	3.0	10.8	16.6		21.2		
D-5	31.0	0	0	0	0				
D-6	11.0	0	0	0	0				
D-7	31.4	0.2	0	0.2	0 *		1.8		
D-8	54.4	2.0	0.8	1.2	17.0 **	46.6	22.0	22.0	18.0
D-9	53.2	0.8	0	1.0	6.4 **	23.4	15.6	14.6	13.0
D-10	59.2	0.2	0	0	0 *	21.2	5.4	4.6	2.4
D-11	61.2	1.5	0.8	1.8	2.2				
D-12	50.0	0.7	0.7	4.7	8.7 ***	0	0.3		0
D-13	51.8	0	0.2	0.4	0.6 **	13.6	5.0	2.2	0.4
D-14	52.6	46.0	48.4	64.8	61.2				
D-15	50.8	5.0	1.6	12.4	13.8		11.0		
D-16	47.2	0.4	0.2	4.2	7.2		6.2		
None	100.0		23.5	10.5	10.5		16.0	16.0	33.5 (1)

* -- Given 24 lice
** -- Given 100 lice
*** -- Retreated
(1) -- 12th day

to the speed of action of the powder in the laboratory. Materials, such as pyrethrum, which act rapidly in vitro, might be little better on man than the rotenone powder, the action of which is so slow as to be inappreciable in laboratory tests. Third, several powders were more active against lice after being worn for a week. These powders had one point in common: all had several multiples of the dose of louse-killing agents present in the powders which were only briefly active...." For example, the very effective D-5 may be considered as two doses of the only mildly effective D-1. Of course, increasing the active agent also intensifies the staining and irritating effects. The desirable effectiveness, on the other hand, of D-7 and D-10 appears to be due to the combination of two louse-killing agents.

The British, too, were making many tests on materials for lousicidal value. The most effective worker was Major Crawford-Benson who produced the British Army Louse Powder known as AL-63 with the formula as follows:

Naphthalene	5%
Rotenone (based on ground derris). .	1%
Tar acid, high boiling. .	2%
Inert clay to make. . .	100%

The effectiveness of this powder is about four days. Although Professor Buxton minimizes the irritating effect of this lousicide, E. F. Knipling of the Orlando Laboratory and the writer at San Francisco used it on themselves and their associates and experienced scrotal burn in all cases. In one case dermatitis was very severe, resulting in hospitalization. (In April of 1944 Professor Buxton recommended adding 5 per cent DDT to AL-63. This should result in an increase in its period of effectiveness.)

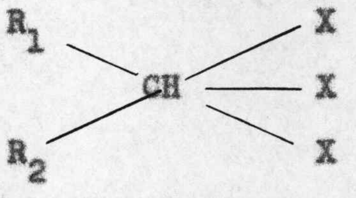
To the present time, the U.S.S.R. has produced no effectual lousicide. The active ingredients of their product is 25 per cent diphenylomine - quite ineffective on lice and of a foul odor.

DDT: the Army Louse Powder

Much official secrecy has surrounded all research, production, and usage of this new lousicide. This secrecy still holds to a certain extent, but not in its entirety. In a recent conference with Dr. Roark of the Division of Insecticide Investigations, he stated that his office had listed sixty-five times that DDT had been discussed in various publications. The writer has read a number of these so he feels no reticence in discussing its usage in control of louse. This synthetic organic was patented in Switzerland on March 7, 1940, and British patents were issued in September, 1942. The American patent, No. 2,329,074, is dated September 7, 1943.

British patent No. 547,874 for dry products reads: "This invention relates to the manufacturers of solid insecticidal compositions and to their application as insect-destroying agents. All attempts to find artificial substances which act rapidly and with certainty on insects, while being almost or entirely odorless and which do not exert any irritating action on human beings, were more or less unsuccessful up to the present. Thus, for example, even the use of halogenated nitriles, especially trichloracetonitrile, has been restricted to unhabited dwellings or to closed containers, as these halogenated compounds, even in the weakest dilution, act extremely strongly on the mucous membranes of human or animal eyes.

It is therefore very suprising to find that compounds of the general formula "A"



wherein "X" means chlorine or bromine, R_1 means an organic radical containing at least three carbon atoms, and R_2 means an organic radical with at least carbon atoms, admixed with solid, finely divided or porous inert diluents or carriers from excellent insecticidal compositions. They have a sure deadly action on insects, have only a weak and in no way disagreeable odor, and exert no irritating action whatsoever on the mucous membrane of the nose, eyes or throat.

According to the invention, the above-mentioned active insecticidal ingredient is admixed in solid form or dissolved with a solid, finely divided or porous inert diluent or carrier. When a solvent is used, it must be expelled finally from the resulting mixture. Best effects are obtained when an inorganic natural colloid, such as bentonite or bole, is employed as a solid compound. The term solid is not intended to exclude a powder."

Example 1 of this same patent reads: "Talcum powder is steeped with a solution of five parts of $p.p^{1}$-dichloro-diphenyl-trichlorethane in fifty parts of benzene, dried and milled in a ball mill. A fine powder is obtained suitable for application as an insecticidal powder.

"The $p.p^{2}$-dichloro-diphenyl-trichlorethane may be made as follows:

Two hundred twenty-five parts of chloro-benzene are mixed with one hundred forty-seven parts of chloral or corresponding amount of chloral hydrate and then one thousand parts of sulfuric acid monohydrate are added. While stirring well, the temperature rises to 60° C. and then sinks slowly down to room temperature, the mass then containing solid parts. It is poured into a great deal of water whereupon the product separates into solid form. It is well washed and crystallized from ethyl alcohol forming five white cyrstals, having a weak fruit-like odor."

As noted above, diphenyl trichlorethane is the active ingredient of this Army Louse Powder. A more exact chemical designation of this product is 2,2-parachlorophenyl-1,1,1-trichlorethane, a dyestuffs intermediate. The powder as used is composed of ten per cent of the diphenyl trichlorethane with ninety per cent of prophyllite, an inert extender.

An Army specification known as GNB-A covering the active ingredient states that it shall contain not less than forty-eight nor more than fifty-one per cent of organically-bound chlorine. The material shall melt to a clear liquid at 107° C. and shall be substantially free from chloral, polymerized chloral, chlorobenzene, and water. It shall be neutral in reaction and upon ignition, ash shall not exceed 0.5 per cent. It shall have a minimum setting point of 88° C.

Development of DDT as a Lousicide

DDT was first prepared by some unrecorded chemist in 1874 in a laboratory in Neu-Allschwil, near Basel, Switzerland. It was not until 1939, however, that it was known to have insecticidal value. Its first usage was as a mothproofer, being developed as such by the dyestuffs firm J. R. Geigy A.G. of Basel, Switzerland. This company is quite well established in the United States, the Geigy Company of New York being a part owner of the Cincinnati Chemical Works along with the Ciba Company and the Sandoz Chemical Works.

Since Colonel Stone of the Army Surgeon General's Office and Dr. Roark of the Bureau of Entomology and Plant Quarantine had requested that all the larger manufacturers of synthetic organics make available samples of their products for study as lousicides, it was but natural that diphenyl trichlorethane should eventually be submitted along with many others to the Orlando Laboratory. After some six weeks it was tested by the beaker method for three weeks. The sample received was so small that additional checks had to await receipt of more material.

The initial lot of DDT in this country was a shipment of approximately two hundred pounds from the Geigy Company of Switzerland to its affiliate in New York. The Orlando Laboratory used over one half of this lot before rendering any report whatsoever.* The results were startling but nothing was known of its toxicological effects on man.

Toxicology of DDT. Four outstanding authorities in the field of toxicology were assigned the task of determining the toxicology of DDT: Dr. Roark, Principal Chemist of the Bureau of Entomology and Plant Quarantine; Dr. Neal of the United States Public Health Service, Dr. Calvery of the Food and Drug Administration, and Dr. Foulger of the Haskell Laboratory of Industrial Toxicology.

Dr. Calvery and Dr. Neal worked on the effects of oral dosage. Dr. Roark and Dr. Calvery studied the effects on skin contacts of DDT. A special study on circulatory and heart sound studies was conducted by Dr. Foulger.

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* The writer received only two pounds of the original lot for testing.

In the oral dosage studies, corn oil was used as the diluent. Briefly, the results were:

LD_{50} **

Rat	200 mg/kg
Mice	400 mg/kg
Guinea pig	400 mg/kg
Rabbit	500 mg/kg

<u>Daily Sublethal Minimum</u>

Rat	30 mg/kg
Guinea pig	40 mg/kg
Dog	50 mg/kg

Poisoning by DDT was manifested by violent trembling which could be stopped by barbital. In sublethal studies, recovery was rapid when DDT was stopped. Calvery has estimated that man is five to ten times as resistant to DDT as is the rat. No evidence was found that DDT in the powder form was even slightly toxic to the skin. This also applied to spray or aerosol applications.

Dr. Foulger, using a special blood pressure method and a newly designed Differential Heart Sound Meter concludes: "It appears, therefore, that exposure by skin contact in the powder form or when in solution will produce a measurable depression of the circulation which is temporary in nature. We have been unable to demonstrate any cumulative effect in the group of individuals tested." (Personal letter.)

** 50% lethal dosage: a dosage sufficient to kill 50% of animals tested

__Discussion__. The advantages of the use of a powder for louse control in a number of situations are obvious. It may be used by the individual soldier and needs no dispensing equipment, other than its container. A powder will drift into every seam and crease of clothing better than a spray can be driven.

Powder also lends itself to large scale delousing. Extensive delousing of five heavily infested villages in Mexico by the Rockefeller Foundation resulted in a lowering of the infestations from ninety-eight per cent to less than four per cent within four weeks. The Typhus Commission completely eradicated lice among a large group of French Moroccan soldiers. That such valuable administrative procedures were worked out in these two tests is attested to by the remarkable results attained in the recent delousing of typhus-ridden Naples. In the vicinity of Naples over 1,300,000 persons were disinfested in January, 1944, alone. February topped this figure. The incidence of typhus dropped from over two hundred new cases per day to practically zero. The technique used in mass delousing of civilian populations is quite simple. The powder is dusted by the use of a mechanical duster up the sleeves, down the neck and down the loosened trousers or skirt. The individual is requested not to change clothes for a few days.

For living quarters it may be applied with a Paris Green type duster. The powder (DDT) will provide almost complete protection for some four weeks and give effective control for a longer period. Although DDT has no ovicidal properties, its period of effectiveness extends beyond the normal range for incubation of body louse eggs. It is equally effective for head and crab lice.

That DDT as a powder can be improved is not questioned. Since the powder diluents to use with DDT may be of considerable importance, further studies should be made with other types of carriers. Tests using the arm-and-leg method indicate that two types of talc were equally or more effective than pyrax. Kolin proved about equal to pyrax, whereas Inert C and Secco Clay were somewhat inferior. In tests on grossly infested subjects, DDT in Inert C was distinctly less effective than pyrax.

It would be desirable to have a louse powder causing more rapid kill of lice than the ten per cent DDT powder. While MYL immobilizes in about thirty minutes, some six hours are required for DDT. Feeding, however, ceases about the same time, usually within eight minutes or less.
Some consideration has been given to combining the DDT and MYL powders. Since pyrethrum is needed for other uses, it should be ruled out. Valone and tert-butyl Valone has been suggested but they cause some staining. Stains, however

at the low concentration of 0.5% added to 10% of DDT powder is not apparent. This combination caused treated lice to become paralyzed in one hour, and at thirty minutes most of the lice were sufficiently immobilized to preclude feeding. Human toxicology at this low concentration has not been studied.

Colonel Stone of the Army Surgeon General's Office mentions the need of having the powder with a higher percentage of DDT so that less powder would have to be used to obtain the desired dosage of DDT. Knipling and Jones doubt this is feasible as the higher percentage of DDT would probably interfere with the dusting qualities of the powder but suggest that the addition of conditioners may overcome this objection.

2. Fumigation

Experience in World War I had shown that the old steam sterilization method for delousing of clothing caused shrinking of woolens, a residual dampness, and resulted in creases and wrinkles that were quite persistent. Furthermore, articles of leather, rubber, or webbing were severely injured.

To replace the use of steam, a fumigant was desired that would be rapid in action, non-injurious to clothing and equipment, effective at both low and high temperatures, not too dangerous to handle, and without undesirable post-fumigation residues or unpleasant odors. Features desired in the proposed fumigation equipment included lightness of weight, use of non-critical materials, self-contained operation, and small volume for shipping.

Test Methods. In the laboratory testing, an extremely simple apparatus was used, consisting essentially of a 6.2 Erlenmeyer flask fitted at the top with a rubber stopper through which was fitted two glass tubes. To one of these tubes was attached a two-way stopcock. To the terminal end of the other was firmly cemented a rubber bulb for agitation of the gas, simulating a circulating fan to prevent stratification of the fumigant.

In all tests, one lot of ten lice and twenty eggs were placed in short lengths of cardboard tubing with both ends closed with cotton wadding. The whole was then wrapped with several layers of woolen cloth. Most of the fumigating materials were measured under a hood with a micropipette. Just prior to introduction of the fumigant, a slight vacuum was achieved by pressure on the rubber bulb and its release at the actual time of gas entry. This not only facilitated the entry of the gas but also acted to relieve the slight increase in pressure due to its vaporization.

<u>Materials Tested and Results</u>. In these tests the writer worked on six fumigants:

F-1	Hydrocyanic Acid
F-2	Methyl Bromide
F-3	Ethylene Oxide
F-4	Chloropicrin
F-5	Carbon Tetrachloride
F-6	Carbon Tetrachloride-ethylene dichloride (3:2 by volume)

Results are shown in Table III. It is apparent that the only satisfactory kills were obtained with methyl bromide and chloropicrin with hydrogen cyanide a close third. The other three tested fumigants failed to give a complete kill with a full two-hour exposure period. With a decrease in time of exposure, the efficiency of hydrogen cyanide also dropped. As the time of exposure dropped in combination with a drop in temperature, only methyl bromide remained effective, provided there was a corresponding increase in dosage.

Randall Latta et al, working with the Bureau of Entomology and Plant Quarantine and under a contract with the Office of Scientific Research and Development, also concluded that methyl bromide was the most satisfactory of tested fumigants. Although the writer has not had access to the details of Latta's research reports and is unfamiliar with his methods of testing or evaluating fumigants, it is safe to assume that he tested many more fumigants under more varied conditions. Latta's recommendation of nine pounds of methyl bromide per thousand cubic feet for a period of thirty minutes has been accepted as the official standard by the Army. Tests by Latta also demonstrated that methyl bromide was effective at temperatures down to the point where exposure to cold alone for the same period completely destroyed the lice, leaving no objectionable odors in fumigated clothing except an occasional temporary slight musty smell.

Post-Fumigation Effects. Latta and the writer have demonstrated by quantitative methods that, after fumigation, clothing could be freed of any injurious amount of absorbed gas by shaking out each garment in the open air or a room well ventilated with an exhaust fan.

TABLE III

Comparative Efficacy of Tested Fumigants

Fumigant and Exposure	Dosage per 1000 Cu. Ft.											
	2 lbs				4 lbs				6 lbs			
	40°F	50°F	60°F	70°F	40°F	50°F	60°F	70°F	40°F	50°F	60°F	70°F
F - 1												
1 hour			O	X			XX	XX	X	X	XX	XX
1½ hr.			X	X			XX	XX				
F - 2												
1 hour				O	X		X	X	X	X	XX	XX
1½ hr.				O	X		X	XX	X	X	XX	XX
F - 3												
1 hour				O		O		X			O	XX
1½ hr.				O			O	X		O	X	XX
F - 4												
1 hour				O				O			O	XX
1½ hr.			O	X		O	X	XX		O	XX	XX
F - 5												
1 hour				O				O			O	X
1½ hr.				O				O			O	XX
F - 6												
1 hour				O				O				X
1½ hr.				O				X			O	X

XX - complete kill of all nymphs and adults
X - 90% to 99% kill
O - less than 90% kill
Blanks - untested

Tests made by the U.S. Public Health Service and by the Food and Drug Administration showed that clothing could be worn directly after fumigation without danger of skin irritation or injury from inhalations if properly shaken out. In over a thousand fumigations supervised by the writer, using a dosage of nine pounds per thousand cubic feet, no untoward effects have been noted on any person or commodity.

Fumigation Equipment. Randall Latta and Alfred E. Yeomans of the Bureau of Entomology and Plant Quarantine developed two primary types of fumigation equipment, a demountable vault and an individual fumigation bag designed to hold about twenty-five pounds of clothing and equipment.

Vault Fumigation

In discussing the demountable vault, Latta says: "The Army authorities desired to make the fumigation of clothing a part of a continuous procedure and for that reason, the size of each vault unit was limited to one that could be transported readily and unloaded quickly. The first one designed and demonstrated was of two hundred fifty cubic feet capacity and held about fifty barracks bags of clothing, but the size was later increased to three hundred thirty cubic feet. The vaults were intended for use in batteries.

"The vault is built of half-inch plywood with the top, sides, bottom, and ends as separate panels to be bolted together. One end serves as a door. All the operational equipment is placed on the back panel and consists of a motor-driven blower at the floor level, a duct from the blower toward the ceiling, and a vent at the end of the duct, which, when open, diverts the air stream to the exhaust system. A gasoline motor operates the blower which furnishes circulation during fumigation and venting afterwards. All joints are sealed with a non-hardening bituminous compound. The door and vents fit against molded sponge-rubber gaskets. The entire vault weighs slightly less than eight hundred pounds.

"The clothing to be fumigated is placed in barracks bags. In the vault the bags are set on removable racks in three layers, with about six inches of clearance between each layer.

"The fumigant is released from one-pound cans by use of a proprietary applicator which punctures the can as a clamp is tightened and delivers the contents into the air stream above the blower.

"In operation, less than ten minutes are necessary to load and close the vault and at the end of the fumigation period, less than ten minutes are required to clear the gas from the vault to allow unloading."

In actual practice, the above described plywood chamber (OQMG) was quite unsatisfactory. It was far from leak-proof and consequently was not approved by The Surgeon General. This type has been superseded by a metal-wood chamber (OQMG Specification 90A). The writer was of the opinion that such a change was not necessary. His testing lead him to believe that the leaking of gas was caused by the pressure of the initial volatilization of the fumigant. It was found that by slightly cracking the damper in the exhaust vent while the first two pound cans of a three-can dosage were injected this pressure was reduced and the vault seal was not broken. The halide detector indicated that only a very small amount of gas was lost by such cracking.

There is quite an advantage in the use of gas over steam sterilization in that the comparatively light fumigation chambers can be moved to the very fringe of the combat zone, over terrain which cannot be traversed by the heavy and cumbersome sterilization and bath van-type semi-trailers.

Furthermore, since steam requires water, the steam sterilization outfits can operate only in areas adjacent to ponds or streams. The gas chambers, on the other hand, can be set up under difficult conditions of warfare and require for their operations only a small gasoline engine and a supply of methyl bromide. It is easy to move, simple to set up, and operate and requires only a small amount of cover to conceal. When assembled each chamber is only nine feet six inches long, six feet wide, and six feet three inches high.

At ports of embarkation and debarkation, the demountable type of fumigation vaults have been found too flimsy in structure to withstand the usage required. Capt. D. E. Bonnell and the writer have designed concrete and structural steel vaults of the same size as the demountable vaults that have been approved for all the major ports. Instead of the barracks bags being placed on poles or shelves, wheeled tiered racks are used. This greatly facilitates the loading and unloading of the vaults.

Fumigation Bags

The individual fumigation bag developed by the Bureau of Entomology and Plant Quarantine is made of closely-woven duck and treated with ethyl cellulose or neoprene. The bag is closed by three times folding over the top edge, which is reinforced with strips of webbed canvas belting and the folds are then secured by tape ties. This closure proved to be tight enough to retain a lethal concentration of the gas in the bag.

The clothing to be fumigated is placed in the bag, the 20 cc glass ampule of fumigant is placed in the special pocket provided, and the bag is closed and tied. The bag is then laid on its side with the ampule packed on top and the ampule broken by a sharp blow on the bag. Fumigation is accomplished in forty-five minutes at temperatures above 55° F. For each ten degrees drop below 55° F, one-half hour is added to the fumigation period.

Major R. H. Ozburn of the Canadian Army has demonstrated that a paper improvision of the above-described bag may be used for delousing. The equipment regularly issued to the Canadian Forces include a three cubic feet anti-gas paper bag. These bags are constructed of four-ply asphalt laminated kraft paper, stitched across the bottom and have the side seams glued. Three pairs of tapes are attached by staples approximately ten inches from the top of the bag. Ozburn found that by simply folding over the top three times and tying the tapes that a complete kill was obtained in thirty minutes at a temperature of 70° F. with a dosage of 20 cc. Escape of gas around the top was about 100 p.p.m., at the seam, about 100 p.p.m. In later tests, he modified the bag by sealing the stitching and staple holes with gummed paper and then using Parakota on the first and third layers. The leakage of gas was so reduced that these bags could be used inside buildings with comparative safety under average conditions of good ventilation.

The writer has found that delousing may be achieved by merely digging a hole in the ground, tossing in the clothing, followed by a paper bag containing a broken ampule and replacing the soil on top. The kill should be complete in one hour.

3. Body Sprays

There are a number of situations in which it is desirable to completely eliminate all lice on groups of individuals in a short period. This is particularly true at ports of embarkation and debarkation. At the San Francisco Port of Embarkation, the writer has had occasion to use four of the recently developed lousicide sprays.

The first formula used was:

Pyrethrum conc. (20% pyrethrins)	1%
Phenyl cellosolve	29%
Carrier: Acetone	

Although the writer used this spray only once, and with good results, it was immediately replaced by the following recommended formula developed by the Orlando Laboratory.

Pyrethrins	0.2%
IN-930 (n-isobutyl undecylenamide)	0.5%
2,4-dinitroanisole	2.0%
Carrier: 95% ethyl alcohol	

This formula gave a complete kill of all lice, including the eggs. Again, however, the formula was changed after only one usage. Since an increase in the number of cases of scabies among troops from overseas was noted, 10% benzyl benzoate was added to the spray formula as a scabicide. This spray now contained not only a treatment for scabies but also an ovicide in 2,4-dintrioanisole and n-isobutyl undecylenamide as an activator for the pyrethrins. This was known as the SLYN formula.

Due, however, to the strategical importance of pyrethrum, the War Department requested continuous research for a lousicide containing no pyrethrum. The Orlando Laboratory soon recommended the following:

EEAY Formula

DDT (2,2-Bis-(p-chlorophenyl-1,1,1-trichlorethane)	1%
Benzocaine (ethyl p-aminobenzoate)	2%
Benzyl benzoate	10%
Carrier: 95% ethyl alcohol	

The ovicidal and anesthetic properties of ethyl p-aminobenzoate make this formula superior to the slower immobilizing 2,4-dinitroanisole. Since benzyl benzoate had proved itself as a scabicide and was a good solvent for DDT, it was retained in the new formula. Although both pyrethrum and DDT are effective in killing all stages of lice, the latter assures a residual action extending beyond the incubation period of the eggs. This may be particularly appreciated in treatment for head lice where the hair is not cut short.

<u>Preparation</u> <u>of</u> <u>EEAY</u>. The ethyl p-aminobenzoate and DDT are dissolved in the benzyl benzoate in the preparation of 2:1:10 parts by weight. Moderate heat increases the rate of solution. The concentrate is diluted with 95 per cent ethyl alcohol at the rate of 13 gms. of concentrate to 100 ml. of final solution. This is equivalent to approximately 13.5 ml. concentrate to 100 ml. 95 per cent ethyl

alcohol.

Spray application. Application of the spray may be by use of a spray gun or sponged on and should be applied to the entire body, paying particular attention to the infected areas. Approximately 50 cc of the solution is required per individual treated and the treatment should be allowed to remain on the body for at least twelve hours. All the sprays described are effective on body, head and pubic lice.

Discussion. The louse-scabies spray containing one per cent DDT, ten per cent benzyl benzoate and two per cent benzocaine is considered by disinfestation plant operators to be a fire hazard in view of the location of some plants in congested urban areas. There has also been some criticism that it causes some discomfort due to temporary burning in the scrotal area. To overcome these objections efforts have been made to incorporate the ingredients in an aqueous solution. One emulsifier, Vatsol OT, proved irritating, and another, Triton X 100, is considered by Dr. Calvery of the Food and Drug Administration to be safe for a limited number of applications. Mr. Knipling has combined Sorbitan monolaurate (Span 20) and a polyoxyalkylene derivative of Tween 20 as an emulsifier and preliminary tests indicate no unfavorable toxicological reaction. Treatments with this combination are equally as effective as the alcohol formula now being used.

4. Clothing Impregnation

Since the body louse is primarily a clothes louse and inasmuch as experience with DDT louse powder has demonstrated its long residual effect, a number of workers toyed with the idea of impregnating underwear prior to its issue to the individual wearer. The writer, in common with other investigators, has experienced some difficulty in assuring himself in testing powders with the arm-and-leg technique that the sleeves, to be used, held no residue of a previously tested material. This suggested the possibility of deliberate impregnation.

To avoid the cosmetic effects of DDT in powder form, it was desirable to use a volatile solvent. Mr. Jones of the Orlando Laboratory has furnished the writer with the rather comprehensive list of solvents, with their range of solubility, shown in Table IV.

The method of solubility determination used was an approximate one. Increments of solvent were added to given weights of DDT with an appreciable lapse of time and intermittent agitation between additions of solvent, as judged by visual examinations, the DDT completely dissolved. Tests were made in tightly stoppered tubes kept in a water bath at 27° to 30° C. The DDT used was recrystallized once from the commercial concentrate. It had a melting point of 108° C. This was to verify the purity of the DDT being used in the tests.

The two solubility values given in Table IV for the better solvents represent the range within which the solubility lies. The second value corresponds with the last increment of solvent at which the DDT was not completely dissolved; the first is that of the next increment of solvent at which the DDT dissolved completely. As may be judged from the method used, the values listed are only approximations.

The first practical method of clothing impregnation was designed by L. C. McAlister of Orlando, using a one per cent aqueous solution of DDT.

The concentrated solution is prepared by dissolving the DDT (one part by weight) in xylene (three parts by weight) and adding Triton X 100 (one part by weight). This is equivalent to approximately two pounds six and one-half ounces each of DDT and Triton X 100 to one gallon of xylene. This proportion of DDT will dissolve readily, but solutions may be hastened by slightly heating.

In preparing an aqueous solution for louseproofing garments, seven fluid ounces of the concentrate is added to

TABLE IV

Solubility of DDT in Organic Solvents at 27°-30° C.

Solvent	Solubility (g.DDT per 100 ml. solvent)
Cyclohexanone	100-120
Dioxane	91-100
Methyl chloride	84-91
Benzene	77-83
Trichloroethylene	72-83
Koppers Solvent No. 327 (1)	63-71
Anisole	63-71
Acetophenone	63-71
O-Dichlorobenzene	63-71
Tetrahydronaphthalene	63-71
Ethyl benzoate	56-62
Velsicol AR-60 (2)	56-62
Ethylene dichloride	56-62
Xylene	56-62
Acetone	50-55
Methyl isobutyl ketone	46-60
Carbon tetrachloride	46-48
Tetrachloroethylene	42-45
Safrole	39-41

TABLE IV (continued)

Solvent	Solubility (g. DDT per 100 ml. solvent)
Methyl salicylate	39-41
Benzyl benzoate	39-41
Amyl acetate	39-41
2-Nitropropane	34-40
Diethylene glycol monobutyl ether acetate (butyl "carbitol" autate)	34-35
Dimethyl phthalate	31-35
Butyl phthalate	31-35
Arcolor 1248 (3)	29-33
Nitroethane	29-33
Indalone	29-33
Ether	27-28
Tetrahydrofurfuryl alcohol	18-22
Ethylene glycol monoethyl ether ("Cellosolve")	17-18
Ethylene glycol monoethyl ether phthalate ("Cellosolve" phthalate)	Approx. 16
Diacetone alcohol	Approx. 15
Pine oil (Hercules "Yarmor 302")	Approx. 15
Butyl stearate	Approx. 10
Diethylene glycol monoethyl ether ("Carbitol")	Approx. 10
Sesame oil	Approx. 10

TABLE IV (continued)

Solvent	Solubility (g. DDT per 100 ml. solvent)
Fuel oil, No. 2 (Standard)	Approx. 10
Benzyl alcohol	Approx. 10
Ethylene alcohol monoethyl ether (Phenyl "Cellosolve")	Approx. 10
Cottonseed oil	Approx. 9
Stoddard solvent (4)	Approx. 9
Kerosene, crude	Approx. 8
Fuel oil, No. 1	Approx. 8
Oleic acid	Approx. 8
Phenol S (5)	Approx. 7
Castor oil	Approx. 7
Dipropylene glycol	Approx. 5
Kerosene, refined, colorless (Deobase)	Approx. 4
iso-Propyl alcohol	Approx. 2.5
2-Ethylhexanediol-1, 3 (Rutgers No. 612)	Approx. 2.5
Ethyl alcohol, 95%	Approx. 1.5
Triethanolamine	Less than 1.5
Propylene glycol	Less than 1.5

(1) Kopper's solvent No. 327 - Mixture of hydrocarbons from coal tar, boiling range from 230° to 270° C.

(2) Velsicol AR-60 - Alkylated naphthalene

TABLE IV (continued)

(3) Arcolor 1248 - chlorinated diphenyl

(4) Stoddard solvent - refined petroleum hydrocarbon used in dry cleaning industry, distillation end point 210° C.

(5) Phenol S - by product from preparation of thymol, primarily mono-and di-iso-propyl cresols

each gallon of water, stirring thoroughly while the concentrate is being added and again before use. This emulsion is quite stable.

Directions for Use. The following is a quote from a report received from Mr. H. H. Stage of the Bureau of Entomology and Plant Quarantine:

"Under the conditions of the experimental tests described in reports on this subject, 1 per cent emulsions or solutions of DDT gave about 10 gm. DDT per suit of regulation 50 per cent wool, two-piece underwear. However, it is more important to specify the dosage per suit or better the dosage per weight of cloth. Consequently, under other conditions of wringing, etc., the concentration must be adjusted so that the proper dosage per suit is obtained. It is suggested that the DDT amount to 1.5 to 2 per cent of the weight of the suit, whether the cloth is part wool or cotton. This would give 10 to 13 gm. per suit in the regulation 50 per cent wool, two-piece underwear. The concentration is adjusted to give this dosage depending on the amount of emulsion retained by the garment under the conditions of the large scale impregnation."

Effectiveness. D. Thorp and A. J. Musgrave of the British Ministry of Production have worked on the biological assessment of the effectiveness of garments impregnated with the results of chemical analysis. The method of impregnation was as described above and the garments then subjected to wearing and washing treatments and storage.

In the biological assessment the lice were confined in metal boxes and allowed to feed through batting cloth covering openings cut in the metal. An area 2 cm. x 3 cm. of the fabric under test (cut from the garments) was put into each box. The percentage of DDT on the garments was calculated on the basis of a chemical analysis to determine the amount of chlorine present. Results are tabulated in Table V.

Except for one garment found to have 0.1% DDT with a kill of less than 50 per cent in 96 hours, the actual content of DDT and the insecticadal power ran parallel. As uniformity of impregnation cannot be expected after periods of wearing and washing, the agreement may be considered excellent. (The original impregnations were 0.5 per cent and 1 per cent.)

<u>Discussion</u>. The louseproofing of garments by impregnation with DDT has not been adopted as a method of control by the Army although such recommendations have been made by OSRD for use by the Armed Forces. Preliminary tests have proved favorable, but no large scale impregnations has been reported. Five thousand suits of underwear were given

TABLE V

Assessment by Biological Assay	Per Cent DDT by Chemical Analysis				
	Less than 0.04	0.04-0.08	0.09-0.19	0.2-0.5	More than 0.5
24 hour kill	8	2	1	0	0
48 hour kill	2	2	1	0	0
96 hour kill	0	1	3	0	0
50% 96 hour kill	0	0	0	3	1
Less than 96 hour kill	0	0	0	1	2

a two per cent impregnation, using ninety-five gallons of the concentrate, for shipment to a lousy area in Africa but only four hundred of these garments reached their destination. Reports on this small number were considered inconclusive. It appears from tests, however, that the issue of two DDT-impregnated suits of underwear would provide freedom from lice during an entire winter when lice are most prevalent.

The writer has found that the duration of the effectiveness of impregnated regulation underwear depends on the concentration of the DDT thusly:

5g DDT withstands one to three washings
10g DDT withstands three to five washings
15g DDT withstands six to eight washings
20g DDT withstands nine to ten washings

No depletion in concentration was noted with many batches of clothing impregnated in a given lot of solution.

Major Crawford-Benson of the British Army has experienced excellent results in impregnating only the undershirts and his preliminary tests indicate that favorable results may be obtained by impregnating only the outer shirt. This is probably a little too optimistic.

5. Overseas Control Units

Disinfestation overseas is primarily the responsibility of the Quartermaster Corps under the technical supervision of the Medical Department. In practice in overseas theaters, delousing is accomplished by a mobile unit called Fumigation and Bath Company. Each company has two platoons, each of which can operate independently. Each platoon has three of the demountable vaults previously described and one trailer-type flask boiler for heating water for the showers. These units travel by truck and can locate along the bank of a stream, set up their fumigation vaults and tents, and be in operation in less than one hour.

Captain L. G. Vaile of the Quartermaster Corps and the writer have had the assignment of instituting a training and operations program for all fumigation and bath units activated in the staging areas of the San Francisco Port of Embarkation. Formerly these units were Sterilization Companies and therefore the training manuals were written for steam. The change over to fumigation permitted a revamping of the entire unit.

The following pages evolved as a tentative training manual and copies were issued to all fumigation and bath units staged in the San Francisco area. It has subsequently been approved by the Quartermaster General and the Surgeon General for the training and guidance of all Fumigation and Bath Companies.

SECTION I

GENERAL

1. Purpose. The purpose of the fumigation and bath company (mobile) is the disinfestation of personnel and their equipment. Three important diseases, namely typhus, relapsing fever, and trench fever, are carried by body lice. All of these reach epidemic proportions if not brought under control immediately. Even small outbreaks incapacitate troops for duty, and epidemics can quickly bring about disastrous tactical situations. These can be prevented by adequate delousing.

2. Procedures. Delousing consists of two essential procedures:

a. The treatment of all clothing, bedding and equipment, to kill lice and their eggs. In the usual delousing procedure, this is done by fumigation with methyl bromide gas.

b. The treatment of each man to destroy any lice and eggs that may be present on his body. This is done by spraying the head and hairy parts of the body with a special louse spray which destroys all lice and eggs, and will control further infestation for several days if allowed to remain.

(1) Preliminary to the spraying, a cleansing shower with mild soap is taken by each man. The head is thoroughly shampooed and the rest of the body adequately cleansed. This process may take five minutes or longer. A clean towel, either paper or cloth, is furnished to each man after the shower. In case of failure of the towel supply, excess water is removed from the hair and the hairy parts of the body by squeezing it out and whipping or fluffing the hair with the hands.

(2) Spraying is accomplished by the use of ordinary hand sprayers (QM No. 41-S-4110-12) or other suitable sprayers for atomizing liquids. Delousing spray should be used only on the human body, and applied as described below. It is obtainable upon requisition from the Quartermaster.

3. Methyl Bromide. Fumigation is a dry process employing methyl bromide gas. It is essential that certain precautions be observed in the use of this agent.

SECTION II

FUMIGATION AND BATH OPERATING UNIT

4. Layout. The attached chart is submitted as a suggested layout for the practical operation of one platoon of the Quartermaster fumigation and bath company (mobile).

5. Site. In contemplating theater of operation conditions, the primary considerations of the unit commander in selecting a site of operations are:

a. Proximity to adequate supply of water which is safe for bathing.

b. Well-drained ground, from which the used bath water may be diverted to a point downstream from the place where fresh water is obtained.

c. Fairly even terrain which will permit the chambers to be leveled with a minimum amount of labor.

d. An area free from disease-bearing insects (mosquitoes, flies, mites and fleas).

e. Security with respect to overhead covering and some protection from attacking ground forces.

f. Accessibility to the road net to permit transportation of equipment and troops to and from the fumigation and bath area.

g. Operation area must be to the up-wind side of the fumigation chambers to assure dissipation of methyl bromide gas into the wind after it passes this area.

SECTION III

METHYL BROMIDE GAS

6. Advantages. Methyl bromide is a well-known chemical, whose use as a fumigant is relatively recent. It has been adopted for this function because of the following properties:

a. It is apparently effective against all forms of insect life including spiders and lice and against various rodents.

b. It has unusual properties of penetration, which make possible the destruction of insects in protected environments.

c. It is effective at much lower temperatures than most fumigants.

d. Its effectiveness is not decreased by the presence of moisture unless enough to form a film of water which prevents penetration is present.

e. It has been shown by recent studies to be completely effective against all stages of the body or clothes louse in a relatively short exposure period when properly employed.

7. Handling. The following instructions for hot climates should be followed in the care of methyl bromide in one pound cans:

a. Care must be exercised in handling and opening shipping containers.

(1) Do not drop or bang.

(2) Do not permit dents to be made in the cans as any change in the shape of the can will weaken it.

(3) Accidental puncture of the cans which will release the contents with considerable force must be avoided.

b. Store in a well-ventilated location.

c. Avoid contact with the hot ground by placing cans on a platform of some type which will provide ample air circulation between the ground and the platform.

d. When the cans are stored (as indicated in c) a tarpaulin or some complete covering should be used to protect them from the sun's rays. An air space of at least two feet between the top layer of cans and the tarpaulin must be provided.

8. Characteristics. a. Methyl bromide is a colorless, odorless, volatile liquid with a specific gravity of 1.732 and a boiling point of 40.1° Fahrenheit. It is, therefore, a gas at all ordinary temperatures in which state it is approximately 3.5 times as heavy as air.

b. Because of its usual gaseous state, methyl bromide is generally limited to fumigation within tight enclosures.

9. Toxic Concentration. a. Toxic effects. When a high concentration of methyl bromide is present in the air for a sufficient length of time, it can cause injury or death to men and to all other warm-blooded animals. Accidental momentary exposures of operators to fumigation concentrations are not likely to cause injury, but working many hours in low concentrations may be harmful. The toxic effects are:

(1) Continued exposure to low concentration may cause paralysis from which complete recovery is possible upon removal from the environment of the gas.

(2) Higher concentrations can cause lung irritation which sometimes develops into pneumonia.

(3) The effects of exposure to methyl bromide are additive, that is, exposures

repeated at close intervals can cause as much harm as a single intense exposure. When exposures are irregular and at intervals of several days, the effects can apparently be thrown off by the body without noticeable injury.

b. Protective measures. In carrying out the fumigation method subsequently described, there is no reason for operators or other personnel to be exposed to harmful concentrations of methyl bromide if directions are observed and carelessness is avoided. If instructions are correctly followed, all the fumigation work necessary for the delousing of clothing by these methods can be safely accomplished without the necessity for any of the personnel concerned to wear gas masks. A halide leak detector is the easiest and most trustworthy means of determining the presence of harmful concentrations of methyl bromide.

(1) This device operates on the principle that the fumes of any halide (such as bromide) directed across red-hot copper will produce a colored flame. Therefore, the largest part of the lamp is merely an alcohol torch which supplies a colorless flame to heat a copper ring.

(2) The sampler tube, due to the suction caused by the flame, tends to pick up lint and dust which accumulate at the throat of the lamp or on the small screen directly below the ring. Such material interferes with the flame so that it will not properly heat the copper ring and also causes it to have a green color. Therefore, the tube and screen should be cleaned before each using. If the flame is weak or spreads around the copper cone, there is some interference with the air flow in the burner. If the flame is strong and direct through the center of the cone, the flame will be colorless and the cone will rapidly turn red-hot, an indication of correct operation.

(3) When the sampling tube is placed in air containing methyl bromide, a green or blue flame will be seen in the torch, depending on the concentration. The following table gives the approximate methyl bromide concentration associated with color intensity in the flame:

Parts methyl bromide per million	Flame color
0	Almost invisible
40	Rather faint green
100	Moderate green
130	Strong green; slightly blue at edges
180	Strong green; rather blue
360	Strong blue-green
800	Strong blue

The following table indicates the lethal concentrations of methyl bromide for man and other warm-blooded animals:

	PPM
Concentration which kills most animals in short time	20,000-40,000
Dangerous to life in 30-60 minutes	2,000- 4,000
Maximum concentration for prolonged exposure (8 hours)	50- 170

(4) Concentrations up to one thousand parts per million may be tolerated for sixty minutes without serious disturbance, but for prolonged exposure for operators of fumigation plants, the maximum allowable does not exceed fifty to one hundred and seventy parts per million.

Sufficient testing should be done about the fumigation chambers and in areas where fumigated clothing is handled, to insure safety.

SECTION IV

DISINFESTING OF CLOTHING AND EQUIPMENT

10. Chamber Method. The fumigation chamber consists of six to ten sections and should be assembled with care. It has a capacity of approximately 330 cubic feet.

11. Assembly. a. A solid and level foundation should be provided for the chamber.

b. All joints other than those of the meeting edges of the door openings should be carefully caulked with the caulking compound provided. (Note: Do not use mastic for this purpose when operating in freezing temperatures.)

c. After the chambers are assembled and the gasoline engines have been properly attached for operating the blowers, it is important that the halide leak detector be ready for use. The chambers should be checked for possible leaks as soon as the gas is introduced.

12. Operating Procedure. a. The amount of methyl bromide and the time for exposure are to be adjusted according to temperatures as indicated in Table VI.

TABLE VI

Standard Chambers (330 Cu.Ft. Capacity)	Other Chambers	Time Exposed to Full Concentration	Temperature Degrees Fahrenheit
3 lbs.	9 lbs/1000 cu ft	½ hour	60 or over
3 lbs.	9 lbs/1000 cu ft	1 hour	50 to 59
3 lbs.	9 lbs/1000 cu ft	1½ hours	40 to 49
3 lbs.	9 lbs/1000 cu ft	2 hours	-9 to 39
4 lbs.	12 lbs/1000 cu ft	½ hour	-9 to 59

b. The men whose effects are to be disinfected bring with them to the fumigation and bath area all items of individual clothing and equipment including blankets and shelter halves.

c. As the men enter station number one, which is the undressing tent, they will be issued a number tag, together with a valuables bag and a salvage barracks bag bearing the same number. All clothing and equipment, including that worn by the individual, blankets, shelter halves, leather goods, shoes, valuables and helmets, are placed in the barracks bag. The tag is placed around the man's neck, and as he proceeds past station number two (fumigation chamber) he will deposit his barracks bag as instructed in the location designated for it.

d. The closed barracks bags are placed in the chamber on poles or trays by the fumigation operators and their assistants.

e. When the chamber is completely loaded (it normally holds about sixty-four barracks bags), the vault doors and all other openings are tightly closed, and the chamber is ready for operation.

f. The engine has been started before the chambers are loaded and the blower is kept in constant operation until the last charge of methyl bromide has been fully exhausted and the last load of bags removed.

g. At a signal from the fumigation foreman (assistant) in charge, the operator stationed at the rear of the fumigation chambers will immediately place the first one pound can of methyl bromide in the device provided for injecting this substance into the chamber, and will throw the lever which punctures the can. He will hold this lever in its clamped position for a sufficient period of time to assure complete injection of the can's contents. This procedure will be repeated with each additional can of the required charge. The damper in the exhaust vent should be slightly cracked while the contents of the first two cans are being injected.

h. The timer is set for thirty minutes and started when the last can of methyl bromide has been injected into the chamber. When the timer signals the end of the thirty minute interval, the damper in the exhaust duct is opened and the fan is allowed to exhaust for ten minutes. Simultaneously with the opening of the exhaust duct, the inlet vent in the front of the cabinet is likewise opened for a period of five minutes. At the end of five minutes, the large door is opened a crack and allowed to remain so for the last five minute period of the ten minute interval.

i. The barracks bags are now removed from the vault and transported to the dressing station where they are identified and returned to their owners.

j. The operation and maintenance of the small gasoline engine which drives the blower in each chamber will be carried out in accordance with the manufacturer's operating and maintenance manual. (See TM 10-1615)

13. Bag Method. a. This method of fumigation should be used only out of doors or in a structure without side walls A special impervious bag (Bag, delousing, QM 27-B-208) with an inner pocket for a methyl bromide ampule (QM 51-M-888), and provision for tying shut the folded end is used in the bag method for fumigation of individual clothing and other equipment. A different time schedule is required for fumigation in bags and the following table will apply:

Time-Temperature Schedule for Methyl Bromide Bag Fumigation

Time Exposed to 1 Ampule of Methyl Bromide	Temperature Degrees Fahrenheit
3/4 hour	60 or over
1-1/4 hours	50 to 60
1-3/4 hours	40 to 49
2-1/4 hours	-9 to 39

b. Procedure for bag fumigation.

(1) A numbered fumigating bag and correspondingly numbered tag for identification are issued to each man.

(2) The clothing and equipment to be deloused are placed inside the fumigating bag.

(3) The operator inserts an ampule of methyl bromide and closes the bag.

(4) The men to be deloused proceed as in Section V, "Disinfesting of Personnel."

(5) The ampule of methyl bromide within the closed bag is broken and the bag allowed to lie on its side for 3/4 hour or longer. (See Time-Temperature Schedule above).

(6) The bags of fumigated clothing are opened in the presence of the owner and emptied onto the ground, the operator standing to windward.

(7) After airing five minutes, the clothing may be worn, each garment being shaken out thoroughly.

SECTION V

DISINFESTING OF PERSONNEL

14. The Bath Unit. a. Equipment. The bath unit consists of the boiler, the shower heads (two sets of twelve each), and the gasoline-driven booster pump for supplying water.

b. Personnel required for operation of the unit.

(1) The engineer is in direct charge of the boiler and will follow the manufacturer's directions concerning its operation.

(2) The engineer is assisted by the fireman, who is specifically trained to operate and service the fire unit or oil burner.

(3) One processor is assigned to act as foreman in the showers.

c. Operation. The shower consists of twenty-four heads of a gross capacity of three gallons of water each and with an actual volume flow of about 1.8 gallons per minute per head. Men in groups of twenty-four will be ushered under the shower, and the processor in charge will set his timer for the interval which has been designated as the proper time for the men to remain under the showers. When the group has completed the bath, they move on and will be followed by another group and so on.

15. The Drying and Spraying Operation. a. As the men move from the showers to the drying station they will receive (usually) a paper towel for the purpose of drying themselves and their hair. They will then move into the spraying tent, where two processors are provided to manipulate the hand sprayers, using the delousing spray provided for the purpose. This spray will be applied as follows: Spray is applied to all hairy parts of the body. The eyes should be closed and covered with the horizontally placed fingers when the eyebrows are sprayed. More effective coverage of the head is obtained if the operator stands on a sixteen-inch platform as the individual being sprayed turns slowly about. Chest hair, if heavy, should be sprayed as well as the hair of the axillary, pubic and anal areas. Unnecessary wetting of the skin with the spray should be avoided. A slow manipulation of the sprayer will allow the mist to settle into the hair and not be diffused into the air.

b. In theaters of operation it is contemplated that a medical officer will be provided by the organization being served and that he will inspect the men immediately after they are sprayed. Following the inspection the men will immediately proceed to the supply station where they will receive such new clothing as has been assigned for issue to them. At or near this point they will receive the barracks bags containing the effects which have just been fumigated.

SECTION VI

FURTHER CONSIDERATIONS

16. In order to afford protection to the men in case of inclement weather, additional ridge poles and upright poles have been provided for the flies which are issued with the tents. They will make it possible for a corridor of tent flies to be set up between the supply station and the final exit station if necessary.

17. It is recommended by The Surgeon General's Office that the men be kept on sanitary canvas strips from the time they enter the showers until they put on their shoes at the exit station. This canvas can be kept disinfected by using a chlorine solution made as follows: HTH * Grade A 70%. Use one-half teaspoonful of this item to five gallons of water and apply to the canvas with a garden sprinkling can or a pail and broom approximately every two hours. It is further recommended that the canvas be hung out to sun and air when it is not in use.

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* High Test Hypochlorite

18. It is suggested that salvage barracks bags be requisitioned for use in fumigating the effects of the personnel being disinfested. It is further recommended that immediately on receipt of these bags, each one be stenciled with a number to correspond with a similar number on the tag and the valuables bag with which it will be used.

19. A substitute for spray during the training period can be provided by using a solution of water containing 35 to 50 per cent ethyl alcohol.

6. Control in Returning Troops

The control of lice, and thus typhus, extends not only to preventing or eliminating lousiness among troops while overseas but the prevention of entry of any lousy individual whether military or civilian until such person and his effects have been completely deloused. To accomplish this end requires close cooperation between military, naval and public health services.

Since all army transports, navy transports, and other passenger-carrying vessels and freighters operate under the supervision of their respective home ports, they may be controlled in their movement by such ports. At all the major ports of embarkation (debarkation for arrivals) there is assigned to the Port Surgeon's Office an entomologist to advise on methods of preventing the entry of insects of medical importance. The writer has this position at the San Francisco Port of Embarkation.

The first step in prevention of the entry of lice and consequent spread of typhus must necessarily be aboard the vessel transporting troops or other persons. When the writer was first assigned to the Port Surgeon's Office at San Francisco the following instructions were drafted for issuance to the transport surgeons at that port:

Delousing

"1. General Provisions. A recent directive from the War Department states, in substance, that all prisoners of war will be disinfested upon entering the United States regardless of whether lice are found. An existing agreement with the Canddian Government states that all Australian and New Zealand troops will be disinfested upon entering the United States and before their entrance into Canada. It is the responsibility of the transport surgeon, therefore, to thoroughly examine for lice the persons, clothing, and baggage of any troops belonging to the above categories. In addition, the same examination will be necessary in the case of all American military personnel returning to the United States.

"2. Identification of Lice. Lice are small, flattened, wingless, insect ecto-parasites with sucking mouthparts, hard outerbody shells, narrow heads, and three pairs of legs with the feet adapted for grasping hairs or fibers. The three most important species of lice attacking men are differentiated both on the basis of habit and appearance. They are the head louse, Pediculus humanus humanus; the body louse, Pediculus humanus coporis; and the pubic or crab louse, Phthirius pubis.

a. The head louse is small, whitish, with faint dark markings on the sides, narrowly oval and flat in shape, and will range from one-eighth to one-quarter of an inch in size. Although it may wander to other parts of the body its preferred habitat is in the fine hair on the head and chiefly in the areas behind the ears and on the nape of the neck. The nits, or eggs, are greyish white, a little less than one-sixteenth of an inch long and are attached to the individual hairs by a cement-like exudate.

b. The body louse is presumably a close evolutionary product of the head louse since there is little structural difference between the two. It inhabits the clothing rather than the hair of the host, although a few may be usually seen clinging to the hairs of the pubic region or under the arms where they have travelled for a meal. Due to their dirty whitish appearance they are frequently called "grey-backs" and, during the last war, "cooties." Color is not always a distinguishing characteristic since lice some times change their color with their hosts and may be white, brown, red, grey or black. The body, or more properly the "clothing louse," will be found in the clothing next to the skin of the host and more particularly in the seams and bands. The body louse may be somewhat larger than the head louse. The nits or eggs are attached to fibers of cloth usually in the region of seams. Occasionally eggs may be found on crossed hairs on the host. Except for being slightly larger in size, they closely resemble the eggs of the head louse.

c. The pubic louse has the appearance of a miniature crab with the same general flattened shape, stocky oval contour, and well-developed claws. The color range is from white to red and the individuals may range in size from a grain of sand to the size of the head of a large pin. The crab louse prefers the pubic area but may be found from head to ankles on the host. The nits are usually very small, darkish, and glued to individual hairs near the surface of the body of the host.

"3. Dissemination of Lice. All three primary species spread by physical contact with infested inviduals, scattering of egg-infested hairs, promiscuous use of combs and brushes, exchange of wearing apparel, use of infested towels, blankets, mattresses, etc.; contrary to popular conception, this is also true of the crab louse. Head lice and body lice move rapidly, migrate with astounding ease, and attack cleanly persons just as readily as slovenly persons. Pubic lice move more slowly but, in the relatively restricted areas of a ship, may spread easily from one person to another. Lice become agitated when body temperature increases and may leave a fever patient for a normal individual. This peculiarity is important in the spread of disease. Occasionally lice will infest the entire living quarters and control measures, other than on persons, clothing, etc., will have to be invoked. Prevention of lousiness depends primarily upon personal cleanliness. However, no amount of personal hygiene will prevent dissemination of lice where there are careless and unclean companions.

"4. Symptoms and Detection of Lice. The transport surgeon may easily detect lice when they are present by a thorough examination of men, clothing, and equipment. Body lice will not, as a general rule, be found in low tropical areas since the heat, profuse perspiration and excessive humidity between skin and clothing offer them unsuitable breeding conditions. Head lice are more common in those areas. However, both head and body lice are found in all geographical areas where men in any number exist. The same is true of crab lice. The bites of lice produce an irritation varying with the sensitivity of the person involved. Usually there is little local irritation. However, it is usually sufficient to induce scratching with corresponding wheals and pustules, oozing blood and serum, brownish scabs, or mottled bronze skin areas. Arny or all of these may indicate lousiness. Occasionally in an individual badly infested with head lice, the hair will become matted with a carapace, or trichoma shield, under which lice and fungus growths abound. This condition is typified by a fetid odor. An infested individual will sometimes refrain from mentioning his condition. He thereby almost certainly infests other persons with whom he comes in contact. The transpott surgeon should not only examine the men and their equipment but request cooperation of the pharmacy. Most persons have had some experience with lice and even relatively uninformed individuals may appear at the pharmacy asking for camphor, larkspur, kerosene, etc. A cursory inspection will often entirely miss the presence of nits, immature lice, and local irritation. A thorough examination is therefore necessary and will embrace troops, personal belongings, clothing, blankets, and mattresses, joints in bunk rails, cracks and junctures in decks or floors, store closets, latrines, etc.

"5. Control Measures. Effective control implies complete disinfestation not only of the individual, but also of the unit, and all of their personal belongings, and also any blankets, mattresses, etc., which *may* have become infested. All the nits, larvae, and adult lice must be killed else the control measures are unsatisfactory. Vigilance, prompt treatment, and effective follow-up measures are necessary. Without becoming involved in complicated life histories, all three types of lice hatch under normal conditions in about one week after the eggs are laid. Therefore, *it is necessary to repeat treatment about six or seven days after the first treatment*. Ordinary soap and hot water showers and shampoos are of little avail once lice become firmly established. More stringent measures are necessary. Lice and their eggs and larvae are all subject to excessive heat or any penetrating substance. Frequently the transport surgeon will have to exercise his own ingenuity. Dry heat at a temperature of 155° F. for one minute or at 131° F. for five minutes will kill lice and eggs. Immersion of fabrics for a few moments in boiling water will accomplish the same result. Heat will injure leather and shrink woolens. A number of alternative controls are listed below. Some are applicable to all three types of lice, others to only one particular kind. Some of the materials listed may be unvailable and it will be necessary to improvise. One or more alternatives given below may be combined. Thoroughness and repeat treatment (after six or seven days) are imperative.

a. Head Lice.

(1) Closely clip hair.

(2) Dust hair with 3% derris or cube powder.

(3) Fine tooth comb and hot vinegar. Apply in solution; then wrap head in a hot wet towel for an hour. Comb and repeat.

(4) Commercial sheep dip or mange cure.

(5) Equal parts of kerosene and olive oil, rubbed in well, secured by a warm towel and washed out the following morning.

Ethyl acetate in a 5 to 10 cc. quantity may be added.

(6) A 10% solution of larkspur.

b. Body Lice.

(1) Any of the remedies listed under paragraph 5a will prove sufficient as a body treatment. Usually a thorough application of tincture of green soap and a long hot shower with particular attention to hairy areas will suffice.

(2) Clothing will have to be treated separately by application of a hot iron to seams or by thorough pressing, boiling, a 5% cresol solution along seams, etc.

c. Pubic Lice. Use any of the remedies suggested under paragraph 5a. Eggs must be destroyed or removed by application of hot vinegar to loosen them from the hairs, by close clipping, shaving and/or by application of acetone in kerosene and olive oil. Usually some eggs will survive almost any treatment and a repeat is necessary. Where typhus is suspected, all doctors, nurses, and medical corpsmen should be particularly careful not to become infested or get lice fecal material in skin abrasions or cuts.

Tightly fitting garments, long rubber gloves, etc., are helpful.

"6. Records and Activities. The transport surgeon is responsible for the detection, controlling, and reporting to the Port Surgeon of the presence of lice upon persons, apparel, belongings, or unit equipment aboard the vessel to which he is assigned. He will consult with the transport commander, unit commanders, and unit surgeons and then proceed to thoroughly examine the persons, apparel, belongings, unit equipment, sleeping quarters, latrines, etc., of any and all who are aboard the vessel for the purpose of entering the United States.

a. Personnel to be considered are:

(1) Australian and New Zealand military personnel

(2) Any other British Empire or Allied military personnel

(3) American military personnel

(4) Civilian personnel whether passengers or crew

(5) Prisoners of war

b. The transport surgeon will report the results of his examination to the transport commander and then if lice or lousiness has been detected proceed with active control measures.

c. At the conclusion of his investigation and/or control measures, the transport surgeon will prepare a certificate in quadruplicate for his signature and for the signature of the transport commander. This certificate will embrace the following points:

(1) Name of vessel

(2) Date of inspection

(3) Results of inspection

(4) Personnel examined (designate units)

(5) Number (if any) of personnel infested, quarters or materials infested

(6) Control measures invoked

(7) Results of control measures

(8) A definite statement that lousiness either <u>does</u> or <u>does</u> <u>not</u> exist on any persons, materials, or quarters aboard the vessel.

(9) Said certificate to embrace the signatures of both transport commander and transport surgeon.

d. When and if the vessel breaks radio silence upon approaching the United States, the transport surgeon will advise the Port Surgeon that lousiness <u>does</u> or <u>does</u> <u>not</u> exist aboard the vessel.

e. If the Port Surgeon is advised that lousiness exists aboard the vessel, medical inspectors (entomologists) will board the vessel in the stream and before it docks, to consult with the transport surgeon regarding further procedures. Should lousiness exist and the medical inspectors have not been able to board the vessel before it docks, the transport surgeon, through the transport commander, will not permit any ship personnel to leave the vessel until representatives of the Port Surgeon's Office arrive.

f. The transport surgeon is specifically enjoined to observe and comply with all points stated in paragraph 6 and will be held strictly responsible and liable therefore."

Since the above instructinns were written, many revisions have been made. As more effective lousicides were developed, the transport surgeon was advised.

At the present time, all transports carry an ample supply of both the DDT louse powder and spray and all surgeons are fully instructed in their use. Fumigation, of course, is not feasible aboard ships at sea.

Inasmuch as any disinfestation performed at sea is not likely to eliminate all the lice, a regular delousing procedure is accomplished after the debarkation if the surgeon reports the finding of any lice (except pubic) at any time during the return voyage. Furthermore, as above indicated, certain categories of persons arriving are routinely processed through the disinfestation plant.

The details of delousing at ports of embarkation are essentially the same as that described for overseas fumigation and bath companies. If it is deemed necessary to disinfest the ship itself, and it usually is, this is accomplished by HCN. When infested individuals have been kept sufficiently isolated only individual compartments may need treatment. This may be treated by using Dupont "Safety Gas" (methyl formate 15%, carbon dioxide 85%) or by generous dusting with 10 per cent DDT powder. In using the latter a rotary type Paris Green duster has been found quite satisfactory. Sufficient powder is used so as to create a light dust cloud, which, upon settling, will leave a perceptible coating on all surfaces. The compartment is then kept closed for one hour to permit settling of the dust and the dust then remains undisturbed for at least eight hours.

SUMMARY

Inasmuch as typhus fever is essentially a war-borne disease and whereas the infecting rickettsiae are spread primarily by the louse, a reinitiation and accleration of control and prophylaxis research have been instituted.

After considerable laboratory and field testing, new lousicides and application methods have been developed that permits of individual treatment, or entire populations may be disinfested in a very short time.

For individual treatment a number of dusting powders may be used, of which 10 per cent DDT (2,2-bis-(p-chloro-phenyl)-1,1,1-trichlorethane) has proved most effective. By dusting the underwear all nymphs and adults are killed within a few hours and the wearer is protected against re-infestation for two weeks or longer provided the underwear is not washed. Although DDT is not an ovicide, its persistence of effectiveness extends beyond the incubation period of the egg stage.

Underwear may be treaed with DDT in an emulsion or solution and the killing power for lice is completely effective for several weeks. Subsequent washing of the underwear diminishes this effectiveness only slightly. The greater the

concentration of DDT, the longer lasting the effect. Using a 5 per cent solution and assuming that the underwear will absorb 2 per cent of its weight in solution, two sets of impregnated underwear should protect the wearer against lousiness for the entire winter, the season of greatest incidence of infestation.

It is frequently necessary, as in the case of troops or other groups moving from an infested area into an uninfested area, to completely eliminate lice in a very short time. Sprays have been developed that contain both a lousicide and an ovicide that give a complete kill in a single application. The most effective of these contains DDT as the primary lousicide and benzocaine as the ovicide with benzyl benzoate added as a scabicide. For treatment of the clothing and bedding, fumigation with methyl bromide at the rate of nine pounds per thousand cubic feet for a period of thirty minutes at ordinary temperatures gives a complete kill of lice and eggs. For emergency fumigation on a small scale, a gas-impervious bag has been developed that uses methyl bromide ampules.

In overseas theaters of war, disinfestation is accomplished not only by the individual soldier's use of a louse powder, but also by mobile fumigation and bath units. By the use of demountable fumigation vaults for clothing and other effects and a body spray, an entire army division may be deloused in a comparatively short time.

Disinfestation aboard ships at sea is most easily accomplished by usage of powder. Delousing at ports of embarkation is merely a modification of methods employed by overseas fumigation and bath units.

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