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Control of fabric pests with heat dispersed insecticides.

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CONTROL OF FABRIC PESTS WITH HEAT DISPERSED INSECTICIDES

The destruction of furs, feathers, clothing and other fabrics by insect pests has persisted for many centuries. It is only within recent years that the efficient control of these insects has become possible. Crude methods were formerly used to destroy fabric pests, but recently efficient and economical procedures have become available.

There are, however, certain aspects of industry which do not lend themselves readily to the conventional control methods practiced against these pests. Outstanding in this field is the storage of wool, in all of its forms, from raw to the finished products. Although much research has been done on the prevention of damage to processed wool such as garments, yarns and partially processed fibers, relatively little work has taken place to prevent damage and destruction to raw and unprocessed wools which are stored in large warehouses. It is in this type of concealed situation that many pests which infest large quantities of stored raw wool, of which the webbing clothes moth, Tineola bisselliella Hum., the black carpet beetle, Attagenus piceus (Olivier) and the furniture carpet beetle, Anthrenus vorax Waterhouse, are examples, have been found.

The damage to raw and partially processed materials is not as apparent as is the damage to the more highly processed goods. This type of damage is very costly to the wool processing industry. Heavy infestations of pest insects cut many of the long fibres, and produce a considerable loss in the amount of long staple wool to be obtained. It is long fibre wool that is used for the production of high quality worsted materials. It is, therefore, to the advantage of the industry to prevent any infestation in their raw materials.

Present methods of control of insect infestations in large volume warehouses have many shortcomings which prevent economical control. The introduction into this country in 1947 of a device for control of household insects stimulated this investigation. The device is a thermostatically controlled electrical vaporizer, manufactured by American Aerovap, Inc., of New York City. Earlier, during World War II, this concept of application was developed in England. The idea was then brought to the United States for use in dispersing insecticides. The unique feature of this device is the automatic and continuous vaporization or application of insecticides. Application of insecticides at very low concentrations by this method does not interfere with normal activities of man within buildings. The presence of a thermostat on these devices permits heavier applications if desired. Having already been tested and used successfully against many flying insects, it was evident that this method might be successful for control and prevention of infestations of fabric pests. The following project was therefore sponsored and supported by the American Aerovap, Inc.

The methods and procedures to be used in this project fall into two classifications. I -- Laboratory investigations and II - Field work in warehouses.

REVIEW OF LITERATURE

The literature pertaining to clothes moths and carpet beetles is of rather large volume. It is not, therefore, the intention of the writer to include a complete list of publications in the literature review. However, this review covers the contents of important papers on the biology and methods of control of fabric pests.

The literature dealing with the control of clothes moths and carpet beetles may divided into four chronological periods. The first of these, relating to early work, dealt primarily with household practices. The second dealt with fumigants, and the third, rather recent developments, were concerned with the mothproofing of materials. The fourth, covering investigations since World War II, is primarily related to the use and investigation of new synthetic organic contact insecticides.

Biology

Carpet Beetles. According to Griswold and Greenwald (1941), the life histories of the different carpet beetles are similar. In general the duration of the egg stage is from 10-15 days. The black carpet beetle, Attagenus piceus (Olivier), the varied carpet beetle, Anthrenus verbasci (Linne) and the furniture carpet beetle, Anthrenus vorax Waterhouse, usually spend at least eight months in the larval stage, but the larval stage of the common carpet beetle, Anthrenus scrophulariae (Linne) may be passed in 78 and may extend up to 400 days. It is this stage that is of economic importance, since the food of the larvae consists of animal material such as furs, feathers, hair, silk and wool. The pupal stage of all four species occupies 9 to 12 days. The adults are generally short lived, with a duration of 15-40 days except for Anthrenus vorax which may live 50-250 days (Back & Cotton, 1938; Back, 1938; Griswold & Greenwald, 1941).

Clothes Moth - Tineola bisselliella Hum. Griswold (1944) states that this insect is probably of African origin and has been "artificially spread." It is now a cosmopolitan insect occurring in almost every part of the world. A related species, Tinea pellinella Linne, the case-bearing clothes moth, has approximately the same habits as Tineola bisselliella Hummel, the webbing clothes moth, but apparently is not as prevelent in northeastern United States.

Clothes moths, like carpet beetles, are serious pests of furs, feathers, hair, felt and woolen material, but are not injurious to silk and cloth of vegetable origin such as cotton and linen. The larva is the injurious form which feeds upon the above types of materials (McDaniel, 1926; Back, 1923).

Biological studies on the webbing clothes moth by Griswold (1944) indicate that the length of the egg stage may be from 5 to 20 days, depending on the temperature. The length of larval life depends primarily upon nutrition and physical factors. The larval period was observed to vary from 35 days to two years. The pupal stage varied from 10 to 50 days depending on the temperature. Adult life varied from 5 to 16 days. A diet of fish meal was superior to a number of other foods, and produced uniform and short developmental periods in the life cycle of the webbing clothes moths (Billings, 1936; Back, 1940; Griswold and Crowell, 1936; Griswold, 1944).

Control

I. Earliest Controls. Before the advent of chemicals for control, early methods practiced by householders consisted of thorough brushing and exposure to the sun. These procedures resulted in brushing eggs and larvae off of the clothes. Other practices such as frequent laundering and cleaning, wrapping tightly in paper and storage in tight containers all contributed to subsequent control (Back, 1923; McDanield, 1927; Comstock & Comstock, 1895).

Back (1923) summarized the early methods as follows:

1. Constant watchfulness for insects.
2. Thorough brushing, beating and sunning treatments.
3. Careful wrapping.
4. Naphthalene in closets, trunks and tight chests.
5. PDB in closets, trunks and tight chests.
6. Camphor, but this is not as efficient as Naphthalene and PDB.
7. Pyrethrum powder.
8. Cold storage.
9. Dry heat.
10. Hot water.
11. Soap solution.
12. Gasoline, benzene and kerosene.
13. Dry cleaning.

The practical methods of combating fabric pests in the home are discussed in detail by Flint and McCauley (1937). Prevention of injury to clothing, blankets and other fabrics susceptible to insect injury begins with cleanliness. Drawers, chests, closets and cracks about the home should be clean and free from lint and other substances that can serve as foods for these pests.

The early methods of control are still as effective as they were and following those precautions recommended enhances the control of fabric pests.

II. Fumigants. Fumigants used in enclosed boxes or tight trunks were recommended by McDaniel and Back. Oil of red cedarwood, tar paper, naphthalene, camphor and PDB have been either recommended in the construction of, or allowed to vaporize in the tightly closed containers. Unless these quite volatile compounds are used in tight containers where a strong vapor concentration can be maintained, they are useless (Back, 1923 and McDaniel, 1927).

Bottimer (1929), investigating the effectiveness of paradichlorobenzene and naphthalene as repellents on clothes moth larvae, came to the conclusion that neither material was of value in ventilated rooms. He found that neither PDB nor naphthalene had any effect on the feeding or apparent well being of the larvae.

Observations on the repellent action of PDB, naphthalene and cedar oils against the adults of clothes moths were carried out by Billings (1934). The methods employed were to observe oviposition on cloth, a part of which was the cover for a bottle filled with the above materials. In all cases eggs were evenly deposited over the whole under surface of the cloth which indicates that the cedar oils, naphthalene and PDB are inefficient as repellents for adult clothes moths.

Herrick (1934) criticized the conclusions stated by Billings in the preceding paper. Herrick maintains that if moths did not lay eggs over the mouth of the bottle, then there was some repelling effect. He also states that, since larvae of the clothes moths never went toward, but always from PDB and naphthalene in Bottimer's experiment (1929), there was repellent action. Herrick's stand is one of a critic. He proposes that some experiments should be devised to demonstrate whether or not the chemicals under consideration possess any repellent properties to clothes moths.

Further work by Abbott and Billings (1935) was carried on with PDB, naphthalene and cedar oils used as repellents for clothes moths. Liberated clothes moths were observed to enter treated closets as readily as they did checks, proving that none of the above mentioned materials appear to give repellent action for clothes moths.

Frey (1939) made extensive studies on the effectiveness of naphthalene, paradichlorobenzene and hexachloroethane on clothes moths. At the rate of 15 oz./100 cu. ft. used in air tight containers, PDB gave 100 per cent mortality of larvae, adults, and eggs, after four days' exposure. After 15 days' exposure mortality of larvae for naphthalene and hexachloroethane was 40 and 0 per cent respectively. Both PDB and hexachloroethane gave 100 per cent mortality of adults in one day, but it took 5 days to obtain the same results with naphthalene. At 15 oz./100 cu. ft. and an exposure period of 4 days, PDB gave 100, naphthalene gave 99.6 and hexachloroethane gave 37.9 per cent mortality of eggs. After 8 days, all three produced complete mortality.

Colman (1940) presented information on the effects of PDB during the feeding of black carpet beetle larvae. Cages simulating closets were employed within which PDB was allowed to vaporize. Smaller cages containing wool and larvae were placed within the larger "closets." Determination of the amount of feeding was made by periodic weighing of the wool material. It was found that after the first week, feeding stopped completely for at least 4-6 weeks depending on the concentration of the PDB vapor. After all the PDB had dissipated, resumption of feeding took place.

Observations in a University of Massachusetts dormitory clearly demonstrated that paradichlorobenzene had no effect on the clothes moths, as ordinarily used by hanging a cake of PDB in the closets. Fifty-one rooms were infested, 26 of which had PDB in the closets.

Infestations of fabric pests may become so heavy and unrestricted that usual measures of prevention are not able to cope with certain situations. McDaniel (1927) recommends fumigation in such instances with hydrocyanic acid gas, sulfur fumes, carbon disulphide or carbon tetrachloride. McDaniel states that although hydrocyanic acid gas is very toxic to humans, results are probably better than any of the others and is safe to use if the necessary precautions are taken. The precautions consist of vacating the building completely, insisting that no one enter the building while fumigation is proceeding, sealing the building tightly and starting the fumigation procedure on the top floor, for HCN is lighter than air and rises. Fumigation with sulfur is likely to injure wall paper, fabrics and metals. Carbon disulphide has an odor that clings to clothing and other material. Danger of fire is also encountered when using this material. Carbon tetrachloride is safer but expensive and not adaptable to large areas. It is, however, excellent for tight containers such as trunks and sealed closets.

Cotton and Roark (1927) introduced a new fumigant consisting of three parts by volume of ethylene dichloride and one part carbon tetrachloride. It proved very effective against stored product pests and is not explosive.

Fumigation tests on fabric pests were encouraging.

Herrick and Griswold (1932) continued the study of the effectiveness of ethylene dichloride and carbon tetrachloride on immature carpet beetles and clothes moths. Their results were exceedingly encouraging. They obtained 100 per cent mortality on larvae of both pests in a trunk with a capacity of 5 cu. ft. using 2 oz. of the mixture. The authors state, "The liquid is clean, has a pleasant odor, keeps indefinitely in a tight container and promises to be a suitable household fumigant."

Colman (1934) described hydrogenated naphthalene (1,2,3,4, tetra-hydro naphthalene) as showing considerable promise as a fumigant against the clothes moth, Tineola bisselliella Hum. This material, more volatile and more rapid in action than flake naphthalene, is useful in situations where repeated fumigation is not possible.

Further investigation was carried on by Colman (1936) with tetra-hydro naphthalene and ethylene dichloride. Three fumigation cabinets were used in which clothes moth larvae were placed. Two were used for each of the fumigants and one was used as a control. Results obtained from simultaneous tests with equal amounts of the fumigant showed that tetra-hydro naphthalene was more effective than ethylene dichloride.

Fumigation in tight trunks and closets is a very efficient way of combating infestations. However, today there are safer and more economical means of eliminating infestations in whole buildings.

III. Moth Deterrents. The history of mothproofing, according to Moncrieff (1950), is embodied in the tale, "that materials dyed green never become moth eaten." Like most tales it was frequently disproved and held to ridicule. However, Meckback (1921) set up tests with many different dyes and proved that fabric dyed with Martius Yellow, a constituent of green dyes, was not damaged. The material dyed with this dye (dinitro alpha naphthol) was the only one of hundreds that resisted moth damage. From this early work a great industry, that of mothproofing, arose. Combinations of Martius Yellow were employed in other colors to produce resistance to moth damage.

Present techniques of moth proofing woolen materials, as enumerated by Moncrieff (1950) consist of treatments with:

1. Colored dyestuffs.
2. Fluorides.
3. Colorless dyestuffs of the Triphenylmethane series.

4. Mitin FF, a watersoluble colorless dyestuff.
5. Mystox series which employ pentachlorophenol as the active mothproofing agent.
6. DDT.
7. Eulan series. Phospherium compounds.
8. Formaldehyde - treating wool with formaldehyde.
9. Modification of the wool molecules - breakdown of protein crosslinkages which pests cannot digest.

Many of these methods of mothproofing can be applied during the process of dry cleaning. Certain mothproofing agents such as Mitin FF, Eulan CN Extra, Lanoc CN and a modification of the wool method, which resist the action of dry cleaning, do not have to be replaced. Back (1938) describes the procedures and results of tests on two mothproofing solutions. The first, a solution of penta-chloro-dioxy-triphenal methane-sulphonic acid, proved to be an effective mothproofer, even after six dry cleanings, six washings with neutral soap or weathering for 30 days. One test fabric which was washed in caustic soap six times, was the only piece showing damage, and then only to the nap. The control cloth was thoroughly riddled with holes. The second solution tested was an arsenical, advertised commercially, which proved to be useless, in protecting woolen goods.

Billings (1938) of the United States Department of Agriculture, Food and Drug Administration, describes the methods used by the department to examine and test large amounts of preparations sold as mothproofers. The procedures used in these tests consisted of placing test materials in friction type cans with eggs of the clothes moth. Controls of untreated material were also made. The effectiveness of the moth proofers was determined by the amount of damage produced on the wool by methods later described by Neal (1943).

Hase (1933, 1936) working on the lasting effects of mothproofing materials showed successful results with Eulan, a series of complex fluorides. The formulations of Eulan consisted of "Eulan NK", "Eulan W Extra" and "Eulan new." In 1936 Hase, using "Eulan LW" had successful results at the rate of 3% by weight of the material. The materials were proofed against infestation even after 30 washings with Lux soap. The same treatment proved effective against carpet beetles, (Anthrenus sp.).

Roark (1931) indexed all patented mothproofing materials, excluding fumigants. This list makes known to research workers the materials that have been proposed as mothproofing agents. Roark states that if a compound is a good mothproofing agent, many times it may find application against other insect pests. Such was the case with fluoride and fluosilicate compounds.

Jackson and Wassel (Roark, 1931) gave the following criteria of excellence for a mothproofing material:

1. Be inodorous;
2. Adhere evenly to the fiber treated, like a dyestuff;
3. Be unrecognizable on the fiber;
4. Not dust off;
5. Not affect adversely the physical properties of the textile fibers;
6. Be soluble in inexpensive organic solvents, such as petroleum naphtha, as well as in water;
7. Have no untoward physiological action; that is, be non-toxic to human beings;
8. Repel clothes moths;
9. Be reasonable in price from the industrial standpoint.

Fletcher and Kenaga (1942) described mothproofing procedures and tests for determining resistance of fabrics to black carpet beetle larvae. The following is a summary of the results and conclusions.

1. Botany style No. 315, 100% wool was selected as the best test fabric.
2. A low open type metal or glass cage for testing

3. Ten insects per test
4. Larvae 4.5-6.5 mg. are ideal
5. Two inch squares of wool ideal for tests
6. 63-83% of larvae were under, 12 to 15% on, and 4 to 25% were off the wool during the four week period.
7. Evaluation of damage was made by both the indirect method of weighing frass which is not affected by humidity, and the direct method of weighing cloth which is affected by humidity
8. A two-week test period is sufficient for determination of damage but a four-week period is necessary in regard to determining mortality.
9. 1.6 mg. of frass produced by 10 larvae was established as starvation checks.
10. Evaluation of damage by visual observation, frass weight and fabric weight loss, was found to agree quite closely (Fletcher, 1943).

Mothproofing materials, although of some value, have their limitations. Feeding of insect pests is not prevented in any way. The insects must do some feeding before the effect of the material takes place. This fact shows that damage will occur and if enough insects are present appreciable damage will occur.

IV. Modern Residuals. Since the advent of the new organic insecticides, there have been many workers investigating the possible use of these organic substances in fabric pest control. The greater residual value of the new insecticides pointed to a more convenient and economical control of these pests. Doner and Thomssen (1943) maintained that best control then was still based on old practices. Clothing to be stored should first be dry cleaned or washed and stored in mothproof containers charged with PDB or napthalene. In case of infestations control can be obtained by using proper sprays, or fumigation with carbon disulfide and other fumigants. Where infestations are heavy and building wide, competent pest control men should be hired for HCN fumigation.

In 1944, Stellwaag, testing DDT for use against clothes moths, obtained encouraging results. Young clothes moth larvae all died after 24 hours when allowed to crawl on cloth dusted with DDT. He also found that eggs were not affected but adults were rapidly killed by contact with DDT. It soon came into widespread use.

The insecticide DDT is an excellent mothproofer, impregnated at the rate of 0.1 per cent of the clothing weight. It is completely effective at .05 per cent, however, and remains invisible on the clothing up to .75

per cent of clothing weight. It has been impregnated from solutions, emulsions, suspensions and dusts. It may also be incorporated with carbon tetrachloride or trichloroethylene and used in the continuous-flow dry cleaning process. In this process the solution of DDT is forced through clothing, returned to the storage tank, filtered and reused (Smith, 1947).

DDT is not strongly absorbed by wool but does become quite resistant to washing when the residue has been reduced to 0.1 per cent of the cloth weight. It is not as permanent as Eulan CN, or Mitin FF. Other insecticides such as toxaphene, chlordane and BHC, although more toxic to carpet beetles than DDT, are more volatile and therefore less permanent.

Slade (1945), found that the gamma isomer of BHC was the most toxic to insects of all isomers. Its effectiveness on the webbing clothes moth, <u>Tineola bisselliella</u> (Hum.) was exemplified, as was its high toxicity to a host of other insect pests. Slade mentions the fact that gammexane was exceptionally stable at high temperatures and could be applied as an aerosol by volatilization from hot plates or other heating methods.

The use therefore, of Lindane vaporized continuously from an electric device [1] seemed logical, and applicable.

[1] Aerovap, which is used for the automatic and continuous vaporization of insecticides.

Its toxicity to clothes moths made it even more suitable for experimental research on clothes moths and carpet beetles, with which topic this thesis is concerned.

Collins and Glasgow (1946), experimented with DDT thermal fogs against clothes moths in a wool storage warehouse. A heavily infested five story warehouse was treated with several DDT formulations, including combinations with pyrethrins. The thermal fog generator applied approximately 1 lb. of DDT per 160,000 cubic feet of space (1 floor). The results obtained for each floor and for each formulation was 100 per cent kill of moths and the mortality of some larvae. In the control operation it was necessary, because of hazards, to stop all activity in the building and close the building tightly in order to allow as little escape of the aerosol as possible. No data on the lasting effect of such treatment have been reported.

The effectiveness of six chlorinated hydrocarbon insecticides for resistance to washing and dry cleaning was tested by Laudani and Marzke (1949). The procedure was to impregnate the wool material with the insecticide, wash or dry clean the wool, and expose it to carpet beetle larvae. DDT proved to be the best insecticide and was able to withstand at least one washing or one dry cleaning. Of the six insecticides tested, greatest protection to wool cloth was obtained with DDT, dichlorodiphenyldichloroethane (DDD), chlordane, methoxychlor, toxaphene and benzene hexachloride in the order named.

METHOD AND PROCEDURE

Experimental work under laboratory conditions comprised a major portion of the investigations on the effect of vaporized insecticides on fabric pests. This work was primarily directed toward obtaining information pertaining to the feasibility of using vaporization for the control of infestations by fabric pests, especially in warehouses of large volume. Its secondary purpose was to obtain information regarding the relative toxicity of Lindane and DDT to the fabric pests.

In the laboratory, investigations were conducted with several pests: Tineola bisselliella Hum., Attagenus piceus (Olivier) and Anthrenus vorax Waterhouse. Adults, larvae, pupae and eggs were subjected to vaporized insecticides. In addition, an attempt was made to determine the depth of effective penetration of the evolved aerosols into wool.

Rearing of Insects. The three pests, the webbing clothes moth, the black carpet beetle and the furniture carpet beetle were reared on a ground Gaines dog food to which about five per cent by weight of dried yeast was added. Kerr preservative jars, were used as rearing cages. Circular pieces of paper towel which replaced the original metal discs, were held in place by the threaded metal ring of the original top (Figure 1). The paper tops permitted an exchange of water vapor and other gases to take place.

Approximately one inch of food was placed into the jars and 25-30 adults of the desired species were introduced for reproductive purposes. More food was added as needed. Cultures of each species were started monthly to insure a constant supply of various stages of insects of known ages.

The rearing jars were kept in a temperature-humidity chamber maintained at 30° C. and 80 per cent relative humidity, which is near optimum physical conditions for these species (Griswold and Crowell, 1936). As tests were carried out insects were transferred from the rearing cages to the cages used for experimental work.

Testing Cages. Cages used for testing the effectiveness of vaporized insecticides must have certain qualifications. They must be so constructed as to permit passage of vaporized insecticides as well as to retain the insects.

A satisfactory testing cage for the adults of the clothes moth and carpet beetles and pupae of the clothes moth was a disposable fabric cage made of tarlatan cloth (Spear, 1951). This cage is a rectangular bag, 6.5 x 6.5 x 14 inches, to which is attached a cardboard end with a friction door (Figure 2).

Figure 1. Cage used for rearing both carpet beetles and clothes moths.

Figure 2. Cages used for testing effectiveness of insecticides against adults of beetles and moths.

Larvae and pupae of the carpet beetles were placed in open petri dishes in tests for effectiveness of the insecticides (Figure 3). It was found that clothes moth larvae disturbed during the transference to the petri dishes could not be retained without a cover. These covers were made of fine mesh copper screen discs fastened to the petri dish with masking tape. These cages (Figure 4) proved very successful in retaining the clothes moth larvae. Ground dog food was sprinkled lightly in all cages containing larvae, and wool was placed in those containing pupae.

In addition to tests designed to demonstrate the effectiveness of vaporized insecticides on fabric pests in the open, experiments were carried on to determine the depth to which the vaporized insecticides effectively penetrated into baled or bagged wool. The cages were located at different levels within the wool, in such a manner that they could be observed without disturbing them. A wire basket with glass sides filled with wool served to simulate bagged wool. Small 1 x 1 x 0.75 inch perforated plastic cages were used to retain adult clothes moths within the wool (Figure 5). These cages were placed along the glass side at 1 inch intervals to a depth of 3 inches in order to allow inspection and observation of moth mortality.

Figure 3. Cage for testing insecticides against carpet beetle larvae and pupae.

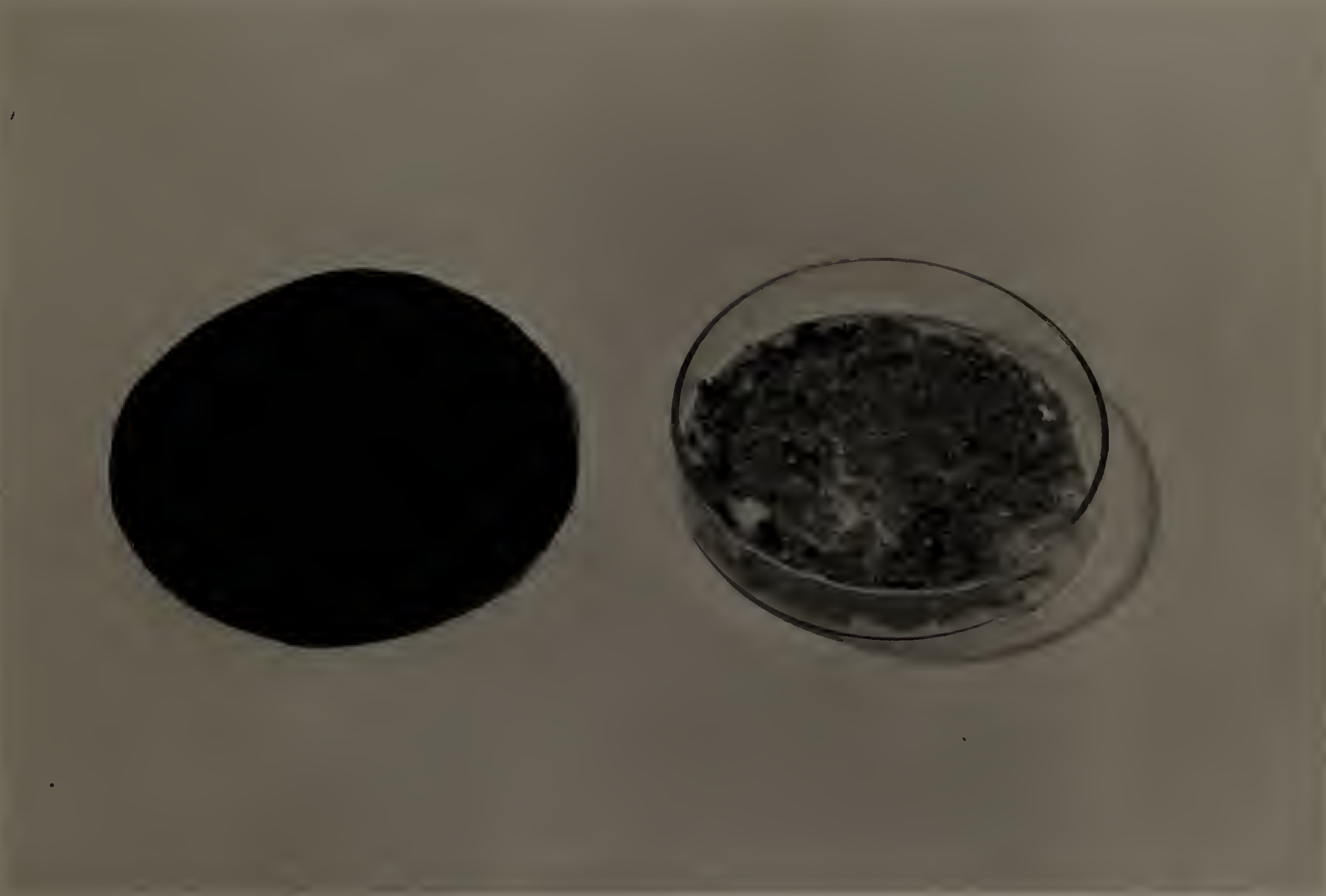

Figure 4. Cage used to test insecticides against clothes moth larvae.

Figure 5. Cages and equipment used to determine depth of penetration of vaporized insecticides.

Laboratory Experimental Room. The tests to determine the effectiveness of vaporized Lindane and DDT were conducted in a room of 16,000 cubic feet capacity. The Aerovap was set to vaporize one gram per 24 hours, which is within the recommended commercial concentration of one gram per 15,000 to 20,000 cu. ft. per 24 hours. Most tests on insects were duplicated with both DDT and Lindane.

The caged insects were introduced into the insecticidal atmosphere and mortality recorded at the end of each 24 hours. Four tests replicated three times were used in each observation.

Controls were maintained for all tests. The control insects were kept in a room with the physical conditions similar to those of the room for vaporizing the insecticides. Mortality was recorded at corresponding time intervals.

Description of the Warehouse. The warehouse was a three-story brick building with two large rooms on each floor. The rooms were connected by a vestibule at either end of which was a large fire-proof door. The dimensions of the rooms were 100 x 74 x 13 feet for the smaller and 146 x 70 x 13 feet for the larger. Corresponding rooms on each floor had the same dimensions. The cubic capacity of the rooms was approximately 96,000 and 133,000 cubic feet.

The interior of the building, except for the brick walls, was of wood construction. Floors were of regular matched hard wood flooring. The building was of rather tight construction and windows were in good condition. Doors were open only during times of shipping or receiving wool storage material.

Material stored in this warehouse consisted solely of raw and partially processed wool. All the wool was baled or bagged in burlap containers. The types of wool consisted of "raw wool," "scoured wool," "noil" and "top." Raw wool consists of the wool just as it is shorn from sheep and contains grease, dirt and debris. Scoured wool has been washed with an alkali or soap in order to remove greases, oil and as many other impurities as possible. Noil is the short fibre wool with some debris which has been extracted from the clean long fibres during the combing process. Top is the extracted long fibre wool which has been scoured, combed and twisted. This "top" wool is very valuable and is ready to be used in the manufacture of high quality worsted materials.

Warehouse Testing. The availability of six warehouse rooms, all of which were infested with clothes moths, and parts of which were lightly infested with carpet beetles, provided an excellent opportunity to test vaporization in the field. The clothes moth infestations had built up to enormous proportions in two rooms. In other rooms the moth infestation was moderate, while infestations of carpet beetles were light in four of the rooms.

The vaporization rates used in five or the rooms ranged from 1 gram per 15,000 cu. ft. per 24 hours to 1 gram per 48,000 cu. ft. per 24 hours (Table 9). The sixth room was used as a control. Lindane was used since it is safer for man but more rapid in action than DDT against wool pests.

The vaporization units were attached to wooden support columns located at frequent intervals about the rooms. The units were located so as to produce an even distribution of insecticide. Before installation, a study of the air currents and their distribution were made by observing the movement of smoke.

The six rooms of the warehouse were designated by letters A to F (Table 9). Room A, the larger room of the first floor, was reserved as a check or control room where no insecticides were to be used. Room B, the smaller room of the first floor, had seven Aerovaps which vaporized lindane at the rate of 1 gram per 15,000 cu. ft. per 24 hours. In Room C, on the first floor, lindane was vaporized at the rate of 1 gram per 26,000 cu. ft. per 24 hours by four Aerovaps. In room D, the larger room of the second floor, lindane was vaporized at the rate of 1 gram per 28,000 cu. ft. per 24 hours by five Aerovaps. Room E, on the third floor, had three Aerovaps which vaporized lindane at the rate of 1 gram per 36,000 cu. ft. per 24 hours. In room F, which was the larger of the third floor rooms, three Aerovaps were used to vaporize lindane at the rate of 1 gram per 48,000 cu. ft. per 24 hours.

Before the Aerovaps were put into operation, a thorough investigation was made of the infestation. Insect numbers were based on an average of six five-minute counts per room per week (Table 9). Observations were made at stations chosen at random.

EFFECTIVENESS OF THE VAPORIZED INSECTICIDES DDT AND LINDANE

Clothes Moth, *Tineola bisselliella* Hum.

Adults. Clothes moths were transferred from rearing jars to tarlatan cloth cages for testing the effectiveness of DDT and lindane. Four cages containing ten moths each were used in each test which was replicated three times. Effectiveness was determined by observations on the mortality of the moths every 24 hours. The average mortality of clothes moths exposed to the insecticides is presented in Table 1.

Table 1. The mortality of adult clothes moths exposed to DDT and lindane vaporized at the rate of 1 gram per 16,000 cu. ft. per 24 hours.

Insecticide	No. of Days	Per Cent Mortality	
		Exposed	Control
DDT	1	81	0
	2	100	0
	3	--	1
	4	--	1
Lindane	1	100	0
	2	--	3
	3	--	8
	4	--	20

All of the moths exposed to DDT were killed within 48 hours. In comparison, none of the control insects died during the same interval. Lindane produced 100 per cent mortality within 24 hours. Careful examination of small bits of wool cloth placed in the cages to stimulate oviposition, revealed no eggs. It is apparent that the immediate effect of lindane on the moths prevented them from ovipositing even though there were gravid females present.

Effect on Eggs. Eggs deposited in an atmosphere containing DDT failed to hatch. In penetration experiments (see pp. 45,46), moth mortality was not as rapid as with fully exposed moths, thus allowing time for oviposition on bits of wool in the cages. These cages were then allowed to remain in the room fully exposed to vaporized insecticides after all the adults had died.

It was found that of an average of 50-60 eggs per cage, none hatched in either a DDT or a lindane atmosphere. It is apparent that both insecticides have a very severe effect on clothes moth eggs. Shriveling and drying of the eggs was noticed soon after exposure. In comparison, those eggs deposited in an insecticide-free atmosphere hatched and larvae developed normally.

Larvae. As larvae of the clothes moth, *Tineola bisselliella* Hummel were needed for tests, the food mixture and larvae were emptied from the breeding jar into a shallow porcelain pan. A lamp was then brought to within 6" above the pan, so that the heat generated by the bulb would activate the larvae in the silken webs and cause them to emerge. They were then easily transferred to cages for toxicity tests.

In order to determine if the insecticides penetrated the screen mesh covering of the petri dishes used to retain the larvae, moths were tested in these same cages. The mortality of the adults in 24 hours with lindane equaled that obtained in the more open cages.

Ten larvae were introduced into each petri dish, and subjected to vaporized insecticides. Vaporized DDT was slow in killing the larvae (Table 2). The first deaths occurred on the tenth day and some larvae survived nearly 60 days. Eighteen per cent pupated and emerged as adults during the test. Similar tests were made with vaporized lindane.

Lindane was somewhat more effective than DDT against the well-developed larvae. Three per cent were killed on the fifth day and 90 per cent by the 60th day. Ten per cent pupated during the 60 days and some successfully emerged as adults.

Table 2. The mortality of nearly mature clothes moths larvae exposed to DDT and lindane vaporized at the rate of 1 gram per 16,000 cu. ft. per 24 hours.

Insecticide	No. of Days	Per cent Mortality	
		Exposed	Control
DDT	1	0	0
	5	0	0
	10	8	0
	15	20	0
	30	50	0
	40	60	0
	50	68	0
	60	82	0
Lindane	5	3	0
	10	12	0
	30	65	0
	40	78	0
	60	90	0

Effect on Pupae. Pupae of the clothes moth were placed in tarlatan cloth cages and exposed to both vaporized lindane and DDT. All of the pupae transformed into adults and some emerged successfully. In many cases, however, the adults died when partially emerged from the pupal case. In other instances the adults died in close proximity to the pupal case. This quick kill of adults suggests that the vaporized insecticides may have had some effect on the pupae, although not actually killing them. The rapid mortality of these adults indicates that copulation and oviposition could not occur. In no instance were any eggs deposited by the moths.

Black Carpet Beetle - *Attagenus piceus* (Olivier)

Adults. The insecticides were tested against adult carpet beetles in the same manner in which they were employed against the clothes moths. The beetles were placed in tarlatan cloth cages and exposed to an atmosphere containing the vaporized insecticide. The mortality of the beetles was recorded daily. One hundred per cent mortality occurred with DDT in less than 10 days and with lindane in 4 days (Table 3).

Table 3. The percentage of mortality of black carpet beetle adults exposed to DDT and lindane vaporized at the rate of 1 gram per 16,000 cu. ft. per 24 hours.

Insecticide	No. of Days	Per cent Mortality	
		Exposed	Control
DDT	1	10	0
	2	43	0
	3	88	5
	4	97	12
	5	98	15
	10	100	40
	15	--	84
	20	--	99
Lindane	1	40	0
	2	60	0
	3	99.5	4
	4	100	12
	5	--	18
	10	--	36
	15	--	85
	20	--	100

The beetles were unable to maintain coordinated activity in the DDT atmosphere after 2 days, and after 6-10 hours in the lindane atmosphere. These facts are very significant for it is obvious that mating and oviposition could not occur among beetles that emerged in the insecticidal atmospheres. It is probable that gravid beetles entering a building that is undergoing treatment would be affected before oviposition occurred.

Larvae. Larvae of several different ages were exposed in both lindane and DDT atmospheres. The larvae were confined in petri dishes with a small amount of food for exposure. Four cages containing ten larvae each were replicated three times.

The older larvae were not affected by either insecticide after an exposure of 3-4 months (Table 4). Younger larvae, especially those newly hatched, were quite susceptible to the insecticides. Some larvae, two weeks old when exposed to a DDT atmosphere, were dead after 15 days' exposure. One hundred per cent of these larvae were dead after 50 days. In the lindane atmosphere death among the young larvae started on the tenth day and continued for 45-50 days.

Table 4. The mortality of different ages of black carpet beetle larvae to DDT and lindane vaporized at the rate of 1 gram per 16,000 cu. ft. per 24 hours.

No. of Days	Per Cent Mortality: Exposed Larvae, 3-5 Months	Exposed Larvae, 2 Weeks	Control Larvae, 3-5 Months	Control Larvae, 2 Weeks
DDT				
14	0	0	0	0
15	0	5	0	0
20	0	20	0	0
30	0	53	0	0
35	0	85	0	0
40	0	92	0	0
50	0	100	0	0
Lindane				
9	0	0	0	0
10	0	6	0	0
20	0	25	0	0
30	0	65	0	0
40	0	96	0	0
50	0	100	0	0

It is evident from the above data that young black carpet beetles are susceptible to both vaporized lindane and DDT.

Pupae. The pupae were placed in open petri dishes and exposed to lindane. Ten pupae were exposed in each petri dish with a piece of suitable wool fabric to stimulate oviposition of adults after emergence. All of the adults died within three days after emergence, without ovipositing (Table 5). The control pupae produced long-lived adults, which deposited eggs three days after the emergence from pupae. By the 15th day, eggs began to hatch and by the 35th day, 50-60 larvae were on the square inch piece of wool fabric.

Table 5. The effect of lindane against pupae and newly emerged black carpet beetles vaporized at the rate of 1 gram per 16,000 cu. ft. per 24 hours.

No. of Days	Exposed: Adults Emerged from Pupae		Control: Adults Emerged from Pupae	
	No. Emerged	No. Dead	No. Emerged	No. Dead
1	0	0	0	0
2	0	0	1	0
3	2	0	1	0
4	2	0	4	0
5	3	1	2	0
6	1	2	0	0
7	0	3	1	0
8	0	0	1	0
9	2	2	-	0
10	-	0	-	0
11	-	2	-	0

Beetles lost their ability to coordinate, 2 to 4 hours after emergence. Lack of coordination was evidenced by the frantic movements of the adults in trying to right themselves. If assistance was provided, the beetles remained on their feet for brief periods only. The beetles did not mate and no eggs were deposited. These experiments indicate that control is absolute for any black carpet beetle adults emerging in a lindane atmosphere vaporized at the rate of 1 gram per 16,000 cu. ft.

Furniture Carpet Beetle, Anthrenus vorax, Waterhouse

Adults. Lindane was the only insecticide used in tests with the furniture carpet beetle. Fifteen adults of variable age were placed in each of four tarlatan cloth cages, a test which was replicated three times. In the vaporized lindane atmosphere, toxic effects were apparent after one day. The adults showed signs of lack of coordination by losing their sense of balance. After two days, death was observed. In the control tests no death occurred until the fifth day.

Since adults of unknown age were used, death occurred early in the exposed and control tests (Table 6). Forty per cent of the exposed beetles and nine per cent of the control insects were dead at the end of eight days. Twenty per cent of the control beetles survived the experiment, but 100 per cent of the exposed beetles were dead by the 30th day (Table 6).

Table 6. Mortality of adults of the furniture carpet beetle exposed to vaporized lindane at the rate of 1 gram per 16,000 cu. ft. per 24 hours.

No. of Days	Per Cent Mortality	
	Exposed	Control
1	0	0
2	7	0
3	17	0
8	40	9
12	55	17
20	80	47
25	94	60
30	100	80

It is evident that since coordination is affected one day after exposure, normal processes of life are not continued. No reproduction or oviposition was observed in exposed insects while control insects reproduced normally.

Larvae. Young and old larvae were placed in petri dishes, with a light sprinkling of the food mixture and exposed to vaporized lindane. The young larvae were more susceptible but two-thirds of them survived an exposure of 150 days (Table 7). None of the control larvae died.

Table 7. Mortality of larvae of the furniture carpet beetle exposed to lindane vaporized at the rate of 1 gram per 16,000 cu. ft. per 24 hours.

No. of Days	Per Cent Mortality		
	Exposed Larvae Age		Control
	Less than 1 mo.	3 mo. or more	
15	1	0	0
24	6.7	0	0
45	15.4	0*	0
65	18.0	0*	0
150	33.3	3.4*	0

* Some larvae pupated and transformed into adults.

During the exposure period growth of the larvae was very slow. Some even appeared to decrease in size. It is probable that the insecticide affected feeding to some extent. It is apparent, however, that damage by these insects could take place before control could be obtained.

Some of the older larvae pupated and transformed into adults during exposure in the lindane atmosphere. These adults lost coordination within an hour or two, some immediately after emergence. This sudden effect on the adults suggests that mating and reproduction by adults emerging from pupae in a lindane atmosphere would be a remote possibility. In effect, control of the furniture carpet beetle over a long period of time appears feasible, since the adults are susceptible to vaporized insecticides.

Insecticidal Penetration Into Wool

Fabric pests in their natural habitats are not always found in the open. Usually they are hidden among the fabrics and raw material that they infest. It was therefore desirable to determine how far vaporized insecticides would effectively penetrate. These tests were focused on depth of effective penetration into raw wool.

Plastic cages containing clothes moths were placed at various depths in wool (Fig. 5). Twenty-four moths were used in each of three cages replicated three times. Mortality of moths indicated the depth to which vaporized insecticides effectively penetrated the wool (Table 8).

Table 8. Penetration of DDT and lindane into wool, as indicated by the mortality of clothes moths.

No. of Days	Per Cent Mortality				
	Test				Control
	Depth				
	0"	1"	2"	3"	
			DDT		
1	50	22	15	0	0
2	100	33.3	24	6	3
3	---	82.3	43	18	9
4	---	100.0	58	40	18
5	---	---	71	68	42
6	---	---	100	87	67
7	---	---	---	96	83
8	---	---	---	100	97
			Lindane		
1	100	40	10	1	0
2	---	61	40	8	3
3	---	100	58	20	8
4	---	---	71	40	16
5	---	---	100	68	40
6	---	---	---	87	63
7	---	---	---	97	96

The results indicate that effective penetration was limited with lindane and DDT. At the one inch level it required four days with DDT and three days with lindane to accomplish 100 per cent kill of the moths. Penetration to the two inch level was evident but it is doubtful if either insecticide effectively penetrated to three inches.

COMMERCIAL WAREHOUSE EXPERIMENTS

Experimental investigations on the effectiveness of insecticides cannot wholly be confined to laboratory research. There are certain influencing factors in the field which either cannot be duplicated in the laboratory, or are overlooked as being of little importance. These factors have been known to disqualify the use of insecticides which in the laboratory appeared to have had very promising results.

It was, therefore, necessary to test the use of continuous vaporization under field conditions. Since the automatic and continuous vaporization of insecticides by heat had never been used in wool warehouses, first attempts to introduce this method were looked upon with skepticism. However, permission was obtained to carry on experimental work in Gilbertville, Massachusetts.

Infestations of clothes moths, Tineola bisselliella Hum. were very heavy in certain parts of this warehouse, while that of carpet beetles was light. Attempts by the company to control this infestation by conventional methods had failed, and the introduction of a new method was warmly accepted.

An interesting correlation between the type of wool and the intensity of the infestation was observed. Rooms B and D, in which raw wool was stored in by far the greater quantity, had heavy infestations. In all other rooms, raw wool was either absent or in small amounts and infestations were much lighter. Apparently there is something quite attractive to moths in raw wool. Whether it is grease, odors, or dried debris and manure which is usually present on parts of each fleece, has not been determined. However, raw wool appears to be more attractive to moths than are other types of wool (Billings, 1936).

Populations of the black carpet beetle, furniture carpet beetle and the common carpet beetle were so low that one five-minute general survey of each room was used. Carpet beetles were in four rooms, A, C, D and E.

The rates of vaporization for each room listed in Table 9 were derived from the total number of grams of insecticide evolved. Individual units were set at approximately 110° C. to vaporize approximately 1 gram per 24 hours. However, temperatures did not remain uniform, but varied 2° - 4° C. among the units, thus producing the rates shown.

Effectiveness on Clothes Moths

Table 9. The cubic capacity, rates of vaporization, types of wool and original population of adult moths in the experimental rooms. July 1, 1950.

Room and Cubic Capacity	Total Rate of Vaporization gm./cu.ft./24 hrs.	Type of Wool	Average No. of Moths Observed in Five Minutes
A 133,000	None (Control)	Noil, Scoured and Raw	8
B 96,000	1/15,000	Top, Noil, Scoured, Raw & sweepings in open kegs	100's
C 96,000	1/26,000	Tops and Noil	8
D 133,000	1/28,000	Raw and Noil	100's
E 96,000	1/36,000	Scoured and Noil	4
F 133,000	1/48,000	Top, Noil, Scoured and Raw	7

The Aerovaps were in operation from early in July to November 1st, 1950. Effects on the populations of clothes moths are presented in Table 10.

Table 10. The effectiveness of various amounts of vaporized lindane against clothes moth populations in wool warehouses, 1950.

Room	Rate of Vaporization gm./cu./ft./ 24 hrs.	Av. No. of Live Moths Observed in 5 Min. Weeks of Treatment					
		Original	1	4	6	8	12
A	Control	8	8	8	5	6	5
B	1/15,000	100's	45	12	0*	0*	0
C	1/26,000	8	*	*	0	0	0
D	1/28,000	100's	24	8	0*	0*	0
E	1/36,000	4	*	*	0	0	0
F	1/48,000	7	4	4	5	4	5

*Occasional moth observed.

There was a definite reduction in the population of clothes moths when lindane was vaporized at rates from 1 gram per 15,000 cu. ft. per 24 hours to 1 gram per 36,000 cu. ft. per 24 hours. In comparison vaporization in other rooms appeared to give excellent control. In rooms B and D immediate results were observed. After the first week the adult population was reduced from one literally swarming, to one in which individuals could easily be counted. The number of adults continued to be reduced and after the sixth week only occasional moths could be found. Adults were apparently killed soon after emerging and before reproduction could take place. Data obtained in laboratory experiments corroborates the results in the warehouse. This would mean that the emergence of adults would be possible only as long as the supply of larvae and pupae were present. The infestation would be eliminated as soon as the immature stages completed development.

Effectiveness of vaporized lindane on clothes moth infestations in other rooms was as evident as that described in room B. In rooms C and E, the original population was reduced to a point at which occasional moths were seen after the first week. These results appear quite logical since the original population was lighter and fewer larvae were present which could eventually become adults.

A totally different result was obtained in room F where lindane was vaporized at the rate of 1 gram per 48,000 cu. ft. per 24 hours. Although the original infestation was relatively light, little or no effect was apparent on the adult moth population throughout the summer. The population appeared static and did not decrease in any significant amounts. In comparison to other concentrations of vaporized lindane, it is assumed that at 1 gram per 48,000 cu. ft. per 24 hours, the concentration of lindane in the air was not great enough to produce death of the moths. In room A where no insecticides were used, the infestation also remained relatively constant throughout the summer.

The Aerovaps were taken out of operation early in November because the storage space of the warehouse was not heated and temperatures were such that insects, if present, were inactive. However, no moths had been seen in rooms B and D after the latter part of September, and none in rooms C and E after the latter part of August. The Aerovaps were left in place in anticipation of continuing tests the following summer.

Early in the spring of 1951, observations were made to determine populations or signs of any moths. Rooms A and F, as expected, showed signs of moth activity by the first of May. In late June, occasional moths were observed in rooms B, C, and D. It is possible that these moths could have been introduced on incoming wool or from rooms A and F. The infestation having been definitely established, Aerovaps were again put into operation at the same rates of vaporization as the preceding summer (Table 11).

Table 11. The effectiveness of various amounts of vaporized lindane against clothes moth populations in wool warehouse, 1951.

Room	Rate of Vapori-zation gm./cu.ft./ 24 hrs.	Av. No. of Live Moths Observed in 5 Min. Weeks of Treatment				
		July 1st	1	4	6	8
A	Control	6	6	6	7	5
B	1/15,000	5	2	0*	0	0
C	1/26,000	3	0*	0	0	0
D	1/28,000	4	1	0*	0	0
E	(Discontinued)					
F	1/48,000	5	4	6	6	5

*Occasional moths observed.

Results obtained during the summer of 1951 closely corroborate those recorded in 1950. Infestations in rooms B, C, and D were apparently eliminated after four weeks of treatment. Room E was discontinued as a storage room and was used for weaving of cotton material. At 1 gram per 48,000 cu. ft. per 24 hours, no control was apparent, and the infestation continued as it did through the previous summer. The control room also showed a rather static infestation.

Carpet Beetles

The carpet beetle infestation was very light. The three species involved, Attagenus piceus (Olivier), Anthrenus vorax Waterhouse and Anthrenus scrophulariae (Linne), were therefore observed and data recorded for carpet beetles as a group instead of by single species.

The methods employed for treatment and observation of these pests were the same as that for clothes moths. However, the infestation of carpet beetles was so light that a general five-minute count was sufficient to cover the whole room. The rooms that contained infestations great enough to be measured were A, C, D, and E. Favorite congregating places were carefully observed.

Outstanding among the places most frequented by adults are windows (Back, 1923). The window sills were carefully cleaned by brushing all loose debris away after each count so that any adults that might be present could readily be counted the following week. This method also permitted close observation on the number that died on the window sills.

The results (Table 12) of the treatments of the warehouse with vaporized lindane shows that this method is quite effective against carpet beetles.

Table 12. The effectiveness of various amounts of vaporized lindane against carpet beetle populations in wool warehouses, 1950.

Room	Rate of Vaporization gm./cu.ft./ 24 hrs.	Ave. No. of Live Adult Carpet Beetles Observed in 5 Min.				
		Weeks of Treatment				
		Original	1	4	6	8
A	Control	5	5	3	4	4
C	1/26,000	4	3	2	0*	0*
D	1/28,000	6	4	1	0*	0*
E	1/36,000	4	5	5	4	6

*Occasional beetles observed.

Treatment of the warehouse appeared to eliminate the infestation of carpet beetles in rooms where lindane was vaporized at 1 gram or more per 28,000 cu. ft. per 24 hours. It was evident that in room E where lindane was vaporized at the rate of 1 gram per 36,000 cu. ft. per 24 hours, no control was obtained and the infestation continued through the summer. However, in rooms C and D, a definite reduction in the population of adults was observed. After the fourth week of treatment, adults were observed only as occasional individuals. These occasional individuals were observed at the windows to which they were attracted; some were still alive but many were dead. Presumably these beetles had entered the building from out-of-doors since they were on the wing outdoors during this period (Back, 1923).

The infestations reappeared the following summer, 1951, with the same abundance. Occasional individuals were observed but the infestation in the control room and room E were at a moderate level.

Caged Insects

A further study with caged insects was made during the treatment of the warehouse in the summer of 1950 and 1951. Clothes moths, Tineola bisselliella (Hum.) and black carpet beetles, Attagenus piceus (Olivier) were introduced into rooms C and D in cages. The cages were pint cans having fine mesh screen windows. Adults and larvae of the insects were placed in separate cans; five adults and ten larvae were used. Adults were freshly emerged and larvae were quite mature. Raw wool was placed in the cans so that conditions were normal. These cages were distributed at random in rooms C and D and observations of mortality made weekly (Table 13).

Table 13. The effectiveness of vaporized lindane against caged adults and larvae of clothes moths and black carpet beetles under warehouse conditions.

Insects	Number of Living Insects					
	Original	1 wk.	2 wks.	3 wks.	4 wks.	6 wks.
	Room C - 1 gm./26,000 cu.ft./24 hrs.					
Moths						
Adults	5	0	-	-	-	-
Larvae	10	10	10	10	8*	8*
(Carpet) beetles						
Adults	5	2	0	-	-	-
Larvae	10	10	10	10	9*	9*
	Room D - 1 gm./28,000 cu.ft./24 hrs.					
Moths						
Adults	5	0	-	-	-	-
Larvae	10	10	10	10	10	10
(Carpet) beetles						
Adults	5	3	-	-	-	-
Larvae	10	10	10	10	9*	9*
	Control					
Moths						
Adults	5	5	3	-	-	-
Larvae	10	10	9*	9*	8*	8*
Beetles						
Adults	5	5	4	3	-	-
Larvae	10	9*	9	8*	8	8

*Larvae transformed into adults.

Adults of caged moths and carpet beetles in rooms C and D were killed much sooner than were those in control tests. The adults are quite susceptible to lindane vapor as shown in laboratory studies. The black carpet beetles appeared to be somewhat more difficult to kill than the moths. The well-developed larvae were unaffected by the vaporized lindane. However, some pupated and emerged as adults, which were killed quite readily.

CONCLUSIONS

The effectiveness of DDT and lindane on various stages of clothes moths and carpet beetles was determined in the laboratory. The laboratory experiments were carried on with a vaporization rate of 1 gram per 24 hours per 16,000 cu. ft.

Clothes moth adults were more readily killed by lindane than by DDT. All adults in the lindane atmosphere were killed in one day while those in DDT required two days for 100 per cent mortality.

Larvae of clothes moths were quite resistant to both lindane and DDT.

The adults of the black carpet beetle were killed by lindane in four days while it took ten days to achieve 100 per cent mortality with DDT. Adults emerging in both lindane and DDT atmospheres developed a complete lack of coordination in two to four hours.

Mature larvae of the black carpet beetle apparently were not affected by vaporized insecticides. However, larvae two weeks old or less when exposed were all dead after 50 days in atmospheres of both DDT and lindane.

Pupae of the black carpet beetle apparently were not affected by the insecticides, since all transformed to adults.

The furniture carpet beetle was apparently more tolerant than the black carpet beetle to vaporized lindane. However, adults which emerged in a lindane atmosphere completely lacked coordination after 24 hours.

Mature larvae were apparently not affected by lindane and even 66 per cent of those larvae under one month of age survived 150 days of exposure.

Vaporized insecticides did not penetrate effectively more than two inches into wool.

Data taken in a commercial wool warehouse indicated that effective control of clothes moths could be obtained in 4 to 6 weeks with concentrations ranging from 1 gram per 24 hours per 15,000 cu. ft. to 1 gram per 24 hours per 36,000 cu. ft. Effective control of carpet beetles could be obtained in four to six weeks with concentrations of 1 gram per 24 hours per 15,000 cu. ft. to 1 gram per 24 hours per 28,000 cu. ft.

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