Circular No. 635

May 1942 • Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE

Control of Insects Attacking Stored Tobacco and Tobacco Products

By W. D. Reed, *associate entomologist*, and J. P. Vinzant,[1] *junior entomologist, Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine*[2]

CONTENTS

INTRODUCTION

A LARGE INDUSTRY concerned with the curing, fermentation, and manufacturing of tobacco has grown up in the United States. This industry, in common with many others, is beset by insect enemies which take a large toll each year. The principal pests of stored tobacco are the tobacco moth (*Ephestia elutella* (Hbn.)) and the cigarette beetle (*Lasioderma serricorne* (F.)). It should not be inferred, however, that tobacco products from the factories of American manufacturers are likely to be insect-infested or that these products were made from infested tobaccos. Precautions are taken at all times to eliminate insects from tobacco warehouses and factories, and a constant effort is being made by the industry to keep its stocks free of insects.

[1] Resigned September 15, 1940.

[2] The writers are indebted to E. M. Livingstone and A. W. Morrill, Jr., of the Bureau of Entomology and Plant Quarantine, for their assistance in working out some of the information contained in this bulletin.

Most tobaccos must be held in storage for 2 years or longer so that a slow fermentation, or aging, can be induced with natural conditions of temperature and moisture. Therefore, manufacturers must carry in storage large stocks of tobaccos in order to fulfill trade and manufacturing requirements. On January 1, 1941, for example, there was in storage in the United States and Puerto Rico a total of 2,988,187,000 pounds of unmanufactured leaf tobacco, for which millions of cubic feet of warehouses were required.

These valuable stocks of tobacco are subject to attack by the cigarette beetle and the tobacco moth, and unless they are properly protected large losses may result. This circular was prepared to provide the tobacco industry with the most up-to-date information regarding the pests of cured tobacco and recommendations for their control.

CLASSES AND TYPES OF TOBACCO

The various tobaccos stored in this country are grouped into the following classes: Flue-cured, fire-cured, air-cured, cigar filler, cigar binder, cigar wrapper, miscellaneous domestic, foreign-grown cigar, and foreign-grown cigarette. These groups comprise 35 or more domestic and foreign types, the latter being represented especially by the cigar types produced in Cuba, Sumatra, Java, and the Philippine Islands and the cigarette types produced in countries of southeastern Europe and the Near East. Most of the tobacco used in domestic manufacture is held in storage during the aging period near the manufacturing centers, and stocks of American tobaccos intended for export are largely stored in warehouses at ports along the Atlantic coast. The distribution of the tobacco districts, together with types produced, is shown in figure 1.

HISTORY OF STORED-TOBACCO INSECTS

The cultivation and use of tobacco by American natives was mentioned in historical documents as early as 1503. The first cultivation of tobacco on a commercial scale by the English-speaking colonists in America was at Jamestown, Va., in 1612.

No mention was made of the attacks of stored pests in the early records on tobacco, and this is unusual, since the cigarette beetle has been generally conceded to be a native American insect. This insect was first described in France in 1792 from specimens collected in America.

The oldest record of the occurrence of the cigarette beetle comes from Egypt, from the tomb of Tutankhamen (Alfieri, A., 1931 [3]):

> Insects found in alabaster vases in the tomb of Tutankhamen were *Lasioderma serricorne* F., *Sitodrepa panicea* L., and the ptinid *Gibbium psylloides* Czemp., generally embedded in some substance such as dried resin. These beetles are therefore probably indigenous to Egypt and have scarcely altered morphologically in the 3,500 years that have elapsed.

The earliest record of the occurence of this insect in stored tobacco in the United States was in North Carolina in 1886, and additional

[3] ALFIERI, A. LES INSECTES DE LA TOMBE DE TOUTANKHAMON. Soc. Roy. Ent. d'Égytpe, Bul. 1931 (3–4): 188–189. 1931. [Abstract in Rev. Appl. Ent., Ser. A, 20: 107. 1932.]

published records on the habits and occurrence of this insect in South Carolina appeared in 1889.

The tobacco moth was first recorded in France in 1737 as infesting chocolate products. It was first reported in the United States in 1897,

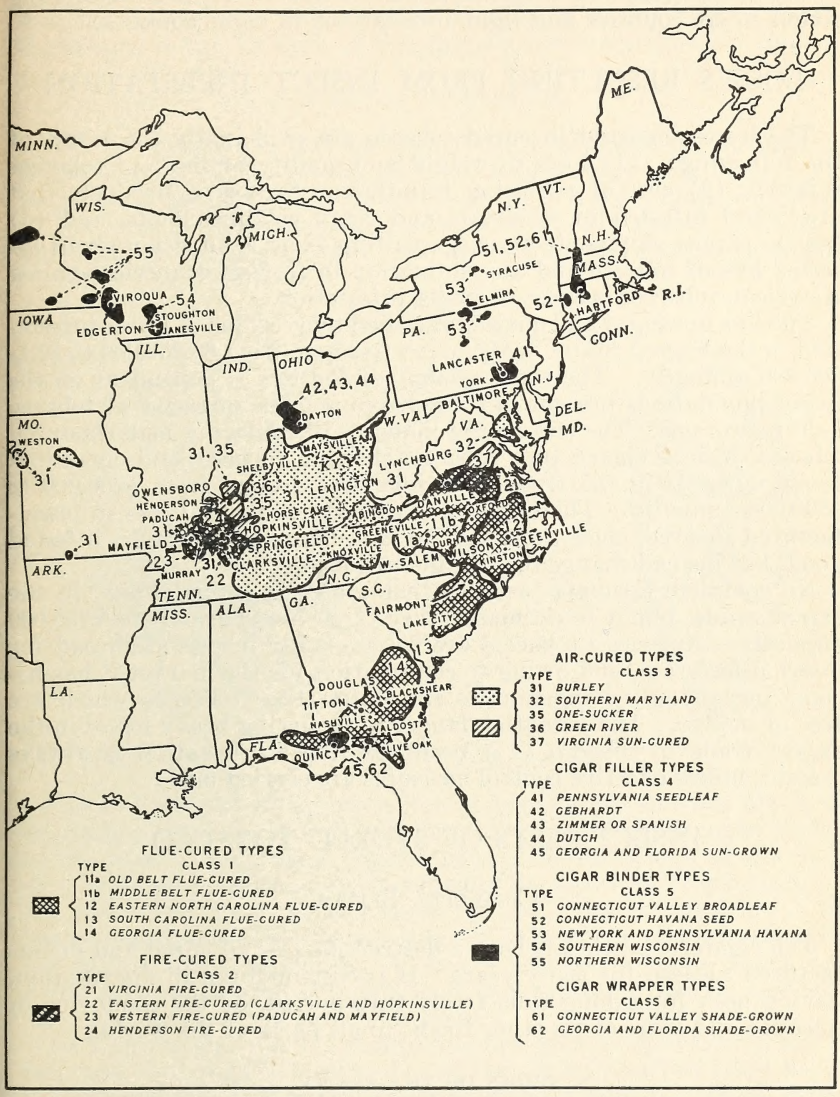

FIGURE 1.—Tobacco-growing districts.

but it is likely that the insect was brought into North America in early colonial times in cacao beans, dried fruits, or other foods.

The tobacco moth was first reported infesting cigarette tobacco in Europe about 1909 and was first found infesting tobacco in the United States in 1930. Since 1930 the moth has greatly increased its popula-

tions in warehouses of domestic flue-cured and imported cigarette tobaccos. In 1937 records of infestation in tobacco stored in growers' pack houses on the farm were obtained from two localities in North Carolina. In 1938 an outbreak occurred in pack houses on the farm in North Carolina and Virginia, moderate to severe infestations being found in six counties and light infestations in eight counties.

LOSSES RESULTING FROM INSECT INFESTATION

The losses incurred in cured tobacco are principally the result of the following: (1) Loss in weight and quality of the leaf tobaccos infested, (2) cost of replacing manufactured tobacco products that are found infested in wholesale and retail establishments, and (3) loss on export shipments abroad resulting from arbitration about infested lots of tobacco and discrimination in foreign countries against American tobaccos because of insect infestation.

The loss in weight and quality of stored tobacco due to insect infestation in the United States is estimated to range from $3,250,000 to $10,000,000 annually. The total amount of the loss is dependent on the insect populations present in the tobacco and the quantity of tobacco held in storage. The cost to the industry of replacing manufactured tobacco, such as cigars, pipe tobacco, chewing tobacco, and cigarettes, found infested in the trade is estimated to range from $200,000 to $500,000 annually. There is a much greater potential loss in manufactured tobacco, since thousands of consumers never return infested goods but instead change their brand of tobacco.

No complete estimates are obtainable on the annual losses in the export trade, but it is estimated that these losses are about $250,000 annually. American tobaccos are being closely inspected abroad for insect infestation, and owing to competition for the market it has become increasingly important to ship only those tobaccos which are free of insects. The potential danger of incurring heavy losses in the export trade in tobacco as a result of insect infestation is always present, unless effective control measures are carried out.

INSECT PESTS OF STORED TOBACCO

Cigarette Beetle

The cigarette beetle has been a destructive pest of cured and manufactured tobacco for many years. It is cosmopolitan in distribution, having been for a long time freely transported, by the commerce in tobaccos and some of its other foods, to all parts of the world.

STAGES OF THE BEETLE

The adult is a small, brownish-red beetle less than one-eighth of an inch long (2.2 to 3 mm.). When at rest the head is somewhat retracted under the front part of the body and the insect appears lifeless. The egg is pearly white, elongate, and measures about 0.019 inch in length. Under summer conditions the eggs hatch in 6 to 8 days. The larvae, or grubs, are very small when hatched, but in

tobacco they may reach their full size (about three-sixteenths of an inch long) in around 35 days during warm weather. The mature larva is grayish white and covered thinly with fine brown hairs. When growth is complete, the larva transforms into the inactive pupal stage and emerges a fully developed beetle in about 7 days in summer and in 14 to 18 days in the cooler weather of spring and fall. The four stages in the life cycle of the cigarette beetle are shown in figure 2.

SEASONAL OCCURRENCE

A wide variation in seasonal occurrence is exhibited by the cigarette beetle because of the variety of conditions under which tobacco and its products are handled, and because of the diverse climatic conditions of the localities in which the beetle is commonly found. In heated buildings or in the subtropical climate of southern Florida there may

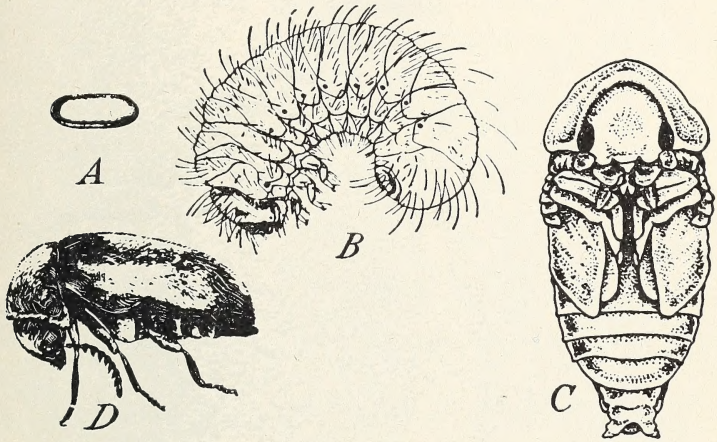

FIGURE 2.—Stages of the cigarette beetle: *A*, Egg; *B*, full-grown larva; *C*, pupa; and *D*, adult. Eleven times natural size.

be no well-defined hibernation period but a mere slowing up of development in the egg, larval, and pupal stages during the cooler periods of the year. Under these conditions each of the stages of the insect may be found at almost any time during the year. In North Carolina, Tennessee, and States farther north the beetle passes the winter in unheated buildings in the larval stage in tobacco or other foods. The low temperatures prevailing in severe winters in these States may materially reduce the population of overwintering larvae, especially those that are younger and less mature.

In Virginia and North Carolina the full-grown overwintered larvae, or grubs, start pupation in April and the spring brood of adult beetles begins to emerge in tobacco warehouses about May 15. There is considerable overlapping of the generations, but there occur rather sharply defined peaks of emergence of the broods of adults, which can be gaged by suction light traps. The peak of emergence (presence of the largest numbers) of the spring brood from 1933 to 1936 occurred in Richmond, Va., during the weeks ending as follows: 1933, June 23; 1934, June 29; 1935, July 5; and 1936, June 19.

The major portion of a generation of cigarette beetles completes development during warm weather in about 50 to 60 days, and ordinarily two generations and a partial third generation occur annually in the tobacco storages of Virginia and North Carolina. This seasonal occurrence of stages of the insect is illustrated in figure 3. Normally there is a peak number of adult beetles during the latter part of June, another about the middle of August, and a third but smaller peak about October 1. When unusually warm weather occurs late in the fall, this third brood may be large. The populations of cigarette beetles found in tobacco warehouses depend upon a number of factors, the most important of which are temperature, relative humidity, and the types, grades, and quantities of tobacco stored.

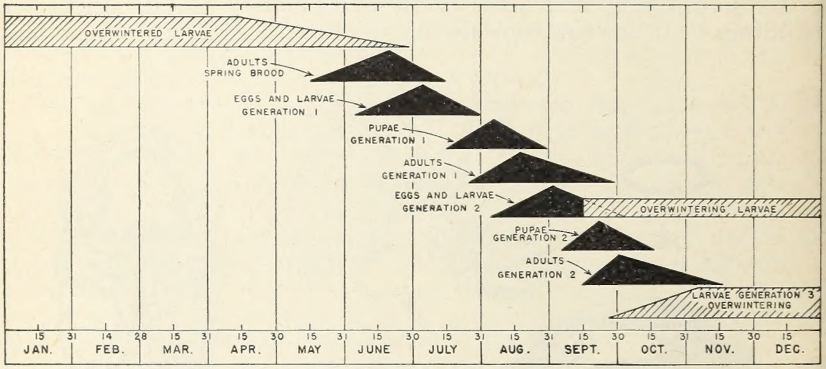

FIGURE 3.—Seasonal occurrence of the stages of the cigarette beetle in Virginia and North Carolina, based on laboratory life-history studies and trap records obtained in tobacco warehouses from 1933 to 1939.

CHARACTER OF INJURY AND FOOD HABITS

Nearly all the injury inflicted by the cigarette beetle is caused by the larvae. Food is not necessary to the normal life of the adults, and all the damage caused by them is done as a means of escape from the commodity in which they have pupated. Ordinarily it is necessary for the adults to get out of the tobacco where they may fly about and mate before the females lay their eggs. The beetle attacks all the principal types of cigar, snuff, and cigarette tobaccos except burley and Maryland. Infestations in the latter are very rare. It also attacks most of the manufactured products such as cigars, cigarettes, and smoking and chewing tobacco. The grub burrows through the commodity, leaving behind it a fine powder of excrement. Cigars and cigarettes are thus rendered unfit for use, and infested smoking and chewing tobaccos are generally objectionable to the consumer. The greatest losses from this insect, however, occur in unmanufactured tobacco. Injury to flue-cured cigarette tobacco is shown in figure 4.

Although tobacco is undoubtedly the most important single food of the cigarette beetle in the United States, the insect also commonly infests cottonseed meal, chili powder, curry powder, ginger, dry yeast, and cayenne pepper. In addition the beetle has been reported from

FIGURE 4.—Leaves of flue-cured cigarette tobacco showing result of feeding by larvae of the cigarette beetle.

various parts of the world as infesting opium, red pepper, rice, paprika, turmeric, saffron, spices, licorice, pyrethrum powder, bran, belladonna, raisins, dried figs, and corn meal.

Tobacco Moth

The tobacco moth is widely distributed throughout the Temperate and Tropical Zones of the world. It is at present the most serious pest of flue-cured and imported cigarette tobaccos in storage in the United States. Because of its preference for a limited number of tobacco types, however, it is not of such universal concern to the tobacco trade as is the cigarette beetle.

STAGES OF THE MOTH

The adult is a small, grayish moth, somewhat variable in color, some adults being distinctly gray and others brownish gray. It measures

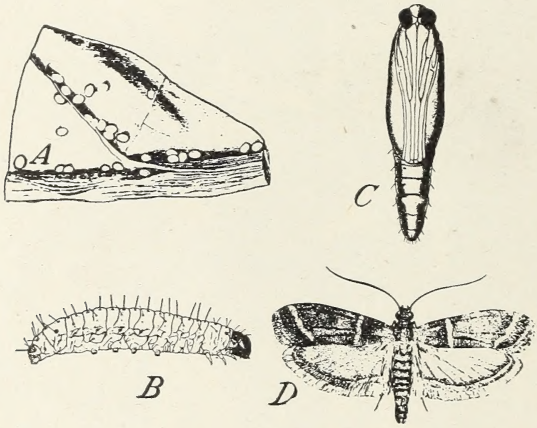

FIGURE 5.—Stages of the tobacco moth: *A*, Eggs attached to tobacco leaf; *B*, full-grown larva; *C*, pupa; *D*, adult. *A* 10 times, *B* 6 times, *C* 9 times, and *D* 7 times natural size.

about three-eighths of an inch from head to tips of the folded wings and has a wing spread of about five-eighths of an inch. The average longevity of adults is about 8 days in summer and about 14 days in the cooler weather of spring and fall. Mating and egg laying may begin within 24 hours after emergence. The maximum number of eggs laid by 1 female is about 275.

The eggs are grayish white when laid, turning brown or red during incubation. They are about one-fortieth to one-fiftieth of an inch long and, though visible to the naked eye, are not easily found on tobacco. They are laid singly, sometimes grouped closely, on or as near to the tobacco as possible. The incubation period is 4 to 5 days in summer and ranges from 6 to 17 days in cooler weather.

The larva of the tobacco moth is usually tinged with pink, although there is considerable variation in color, some larvae being creamy white or brownish. The head is reddish brown and the body has rows of small brown spots along the back. When full-grown the larvae measure about three-eighths to one-half inch in length. They ex-

hibit a wide variation in rate of development during the warm months of the year, and this is the only stage of the insect that passes the winter in hibernation. Under favorable conditions of growth the larval period in tobacco averages about 35 days during the summer months.

At the completion of growth the larvae seek a sheltered place for pupation, near the surface of the tobacco or in some other location in the storage house. They spin loose cocoons and transform into light brown pupae. The length of this stage is about 10 days in summer and about 17 days in spring and fall. The four stages of the tobacco moth are shown in figure 5.

SEASONAL OCCURRENCE

The tobacco moth passes the winter as a larva in hibernation. The overwintering larvae range in size from one-fourth to full grown, and in the fall many of the mature individuals migrate from the tobacco to sheltered places about the building, where they spin

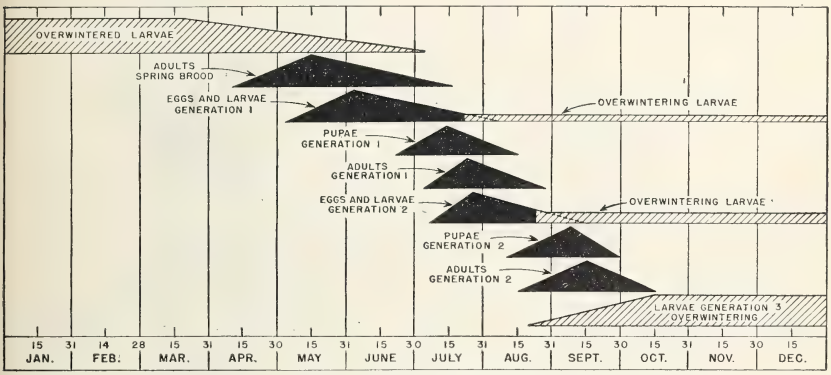

FIGURE 6.—Seasonal occurrence of the stages of the tobacco moth in Virginia and North Carolina, based on laboratory life-history studies and on observations made in tobacco warehouses from 1932 to 1934.

loose cocoons of silk, in which they hibernate. The immature larvae as a rule remain in the tobacco in an inactive condition during the winter, and their populations are not reduced materially by the winter temperatures prevailing in Virginia and North Carolina. The full-grown larvae start pupating in March, and the moths usually begin to appear in small numbers during the latter part of April. This spring brood of adults may be expected to reach the peak of emergence around May 15 in Virginia and the Carolinas. On account of the large proportion of small larvae overwintering, emergence of the spring brood is delayed and continues until early in July. At this time the population of adult moths is usually at a very low point.

The extended emergence of the spring brood results in considerable overlapping in later emergence; however, well-defined peaks usually occur late in July or early in August and again during the latter part of September. During the season when moths are active a generation may be completed in about 60 days in stored tobacco. The seasonal occurrence of the stages of the tobacco moth in Virginia and North Carolina is shown in figure 6.

422451°—42——2

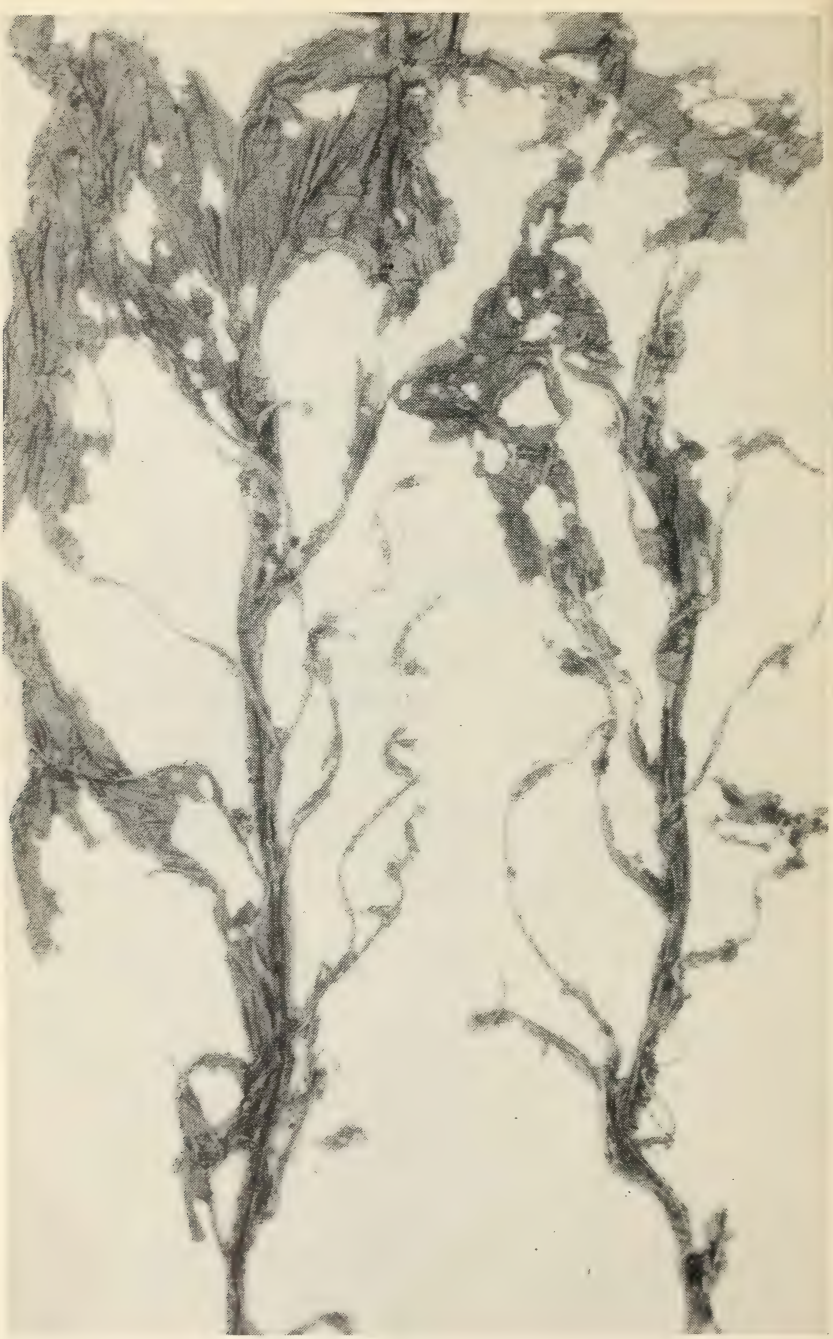

FIGURE 7.—Leaves of flue-cured cigarette tobacco showing result of feeding by larvae of the tobacco moth.

CHARACTER OF INJURY AND FOOD HABITS

The larva is the only stage of the tobacco moth that feeds. In tobacco its injury is confined almost exclusively to unmanufactured flue-cured and imported cigarette tobaccos. Infestations in other types of tobacco and in manufactured tobaccos are practically unknown, even though several other types may be stored in the same building with infested flue-cured tobacco. Among the types attacked the insect has shown a particular fondness for the grades highest in sugar content.

Feeding injury by larvae of the tobacco moth in flue-cured cigarette tobacco is shown in figure 7. The larvae usually feed from the stem end toward the tip, but they may attack the leaves at any point between the midrib and the larger veins, leaving behind them strands of webbing, to which black pellets of larval excrement adhere. In addition to the absence of large areas of the leaves, in some instances all except the midrib and veins, the webbing and accumulations of excrement are objectionable to buyers and manufacturers.

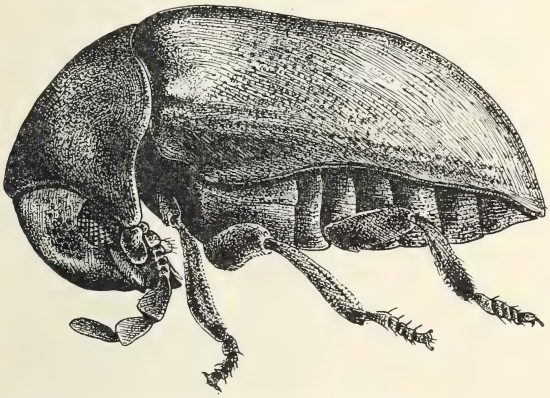

FIGURE 8.—The larger tobacco beetle, a pest of stored tobacco in the Tropics. It is also reported from Florida. Approximately 10 times natural size. (From Runner.)

The tobacco moth may feed on a variety of stored products as well as on tobacco. In the United States it has been reported as feeding on dried fruits. In the course of investigations at Richmond the insect was reared on corn meal, cottonseed meal, rolled oats, peanut meal, wheat "red dog" (low-grade flour), laying mash, and sweetened mixed feed (horse feed). From this and other countries the larvae have been recorded as feeding upon cacao beans, chocolate, various shelled nuts, linseed and flaxseed meals, coffee, chicory, ship's biscuits, cottonseed cake, cayenne pepper, rice, pearl barley, and other seeds.

UNIMPORTANT SPECIES

In addition to the cigarette beetle and the tobacco moth, other species of insects are occasionally collected in cured tobacco and tobacco products, and some are known to feed on the tobacco. Prominent among these occasional pests is the larger tobacco beetle (*Catorama tabaci* Guérin), found in the Tropics and reported from Florida. This insect (fig. 8) attacks cured tobacco and tobacco seed in much the same manner as does the cigarette beetle.

The phycitid moth *Tlascala finitella* (Walk.) was first collected in 1932 from hogsheads of flue-cured tobacco in Richmond. Occasional specimens have been observed since that date in warehouses of cigarette tobacco.

A number of other species of insects have been found in stored tobacco, none of which are considered to be of appreciable economic importance. The larva of the moth *Aglossa* sp. (presumably *cuprealis* (Hbn.)) feeds on tobacco in a molded and partly decayed condition and is sometimes found in warehouses. The following species, listed about in the order of their abundance, have been found in tobacco: *Tribolium confusum* Duv., *Henoticus serratus* (Gyll.), *Ahasversus advena* (Waltl), *Typhaea stercorea* (L.), *Anthrenus verbasci* (L.), *Lepisma saccharina* L., *Ptinus brunneus* Duft., *Attagenus piceus* (Oliv.), and *Trogoderma* sp. Some of these insects probably act as scavengers, eating the dead bodies of the cigarette beetle and the tobacco moth, whereas others use the tobacco as a temporary shelter.

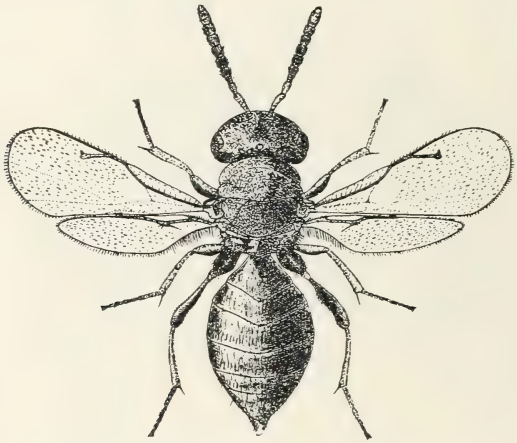

FIGURE 9.—The chalcid *Aplastomorpha calandrae*, a parasite of cigarette beetle larvae. Greatly enlarged. (From Cotton.)

NATURAL ENEMIES OF STORED-TOBACCO INSECTS

The cigarette beetle and the tobacco moth have a number of important natural enemies. The little chalcid wasp *Aplastomorpha calandrae* (How.) (fig. 9), which is a parasite of the larval stage of the cigarette beetle, is often found in abundance in connection with large populations of the beetles. Several factors make it unlikely that this parasite is an important factor in controlling infestations of the cigarette beetle. In tightly packed tobacco the adult females find it difficult to enter feeding tunnels of larvae. The parasites are very vulnerable to fumigants and other methods of control of the beetle and to low temperatures in winter.

The predacious mite *Pediculoides ventricosus* Newp. has been found attacking cigarette beetle larvae in tobacco warehouses, but its importance in controlling this insect is not known.

The adult and larval stages of the clerid beetle *Thaneroclerus girodi* Chev. (fig. 10) are found in stored tobacco in Florida preying on larvae and pupae of the cigarette beetle. This insect has been found in Virginia also, in stocks of tobacco received from Cuba and Puerto Rico.

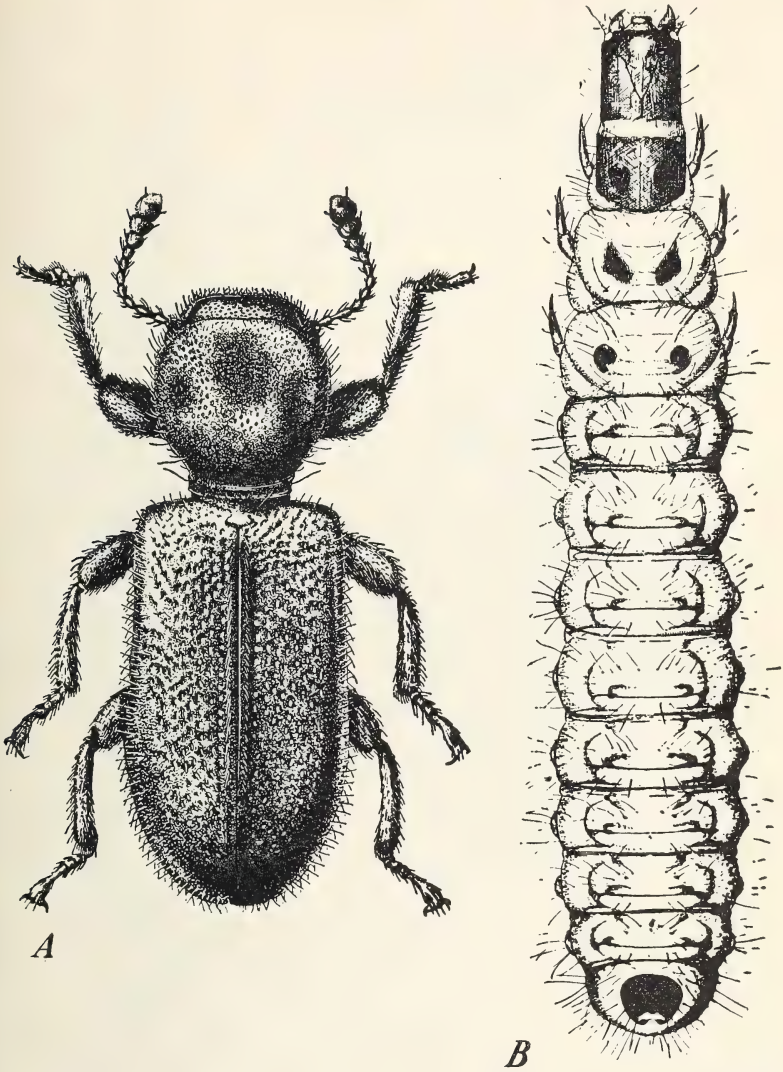

FIGURE 10.—Adult (*A*) and larvae (*B*) of the clerid beetle *Thaneroclerus girodi*, a predacious enemy of larvae and pupae of the cigarette beetle. Greatly enlarged.

The tobacco moth also is attacked by several natural enemies, some of which help to reduce the populations. The braconid parasite *Microbracon hebetor* (Say) preys on well-grown larvae of the moth, but it has not been observed in sufficient numbers in tobacco warehouses to be

regarded as an important natural control. The adult parasite (fig. 11) is seldom found in large numbers until near the end of the summer, an indication that it survives the winter conditions of storage in comparatively small numbers. The adults and pupae of this parasite overwinter at or near the surfaces of hogsheads and bales of tobacco and in cracks of walls or ceilings. Since these locations expose the insect to the minimum temperatures reached in winter and also to fumigants or other insecticides applied in the warehouses, this is an important factor in reducing the number of parasites in tobacco storage houses.

Other natural enemies of the tobacco moth are mites of the genus *Laelaps*, which prey on adults and eggs, and a spider, *Theridion tepidariorum* Koch, which often constructs considerable webbing, in which many moths are captured and destroyed. These mites and spiders

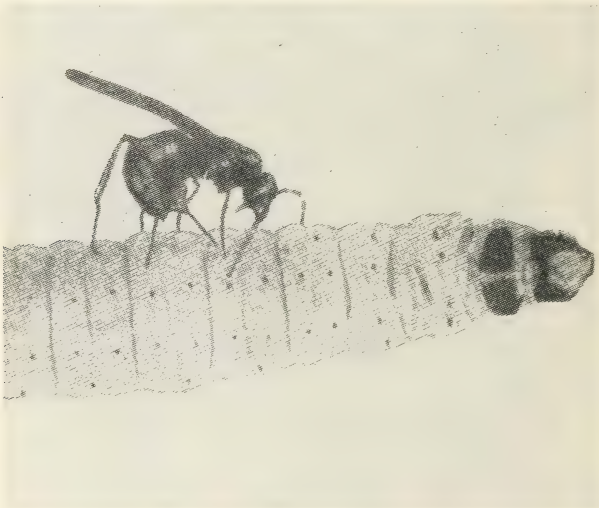

FIGURE 11.—The braconid *Microbracon hebetor*, a larval parasite of the tobacco moth, stinging a larvae of the Mediterranean flour moth (*Ephestia kuehniella*), a moth closely related to the tobacco moth. Ten times natural size. (From Doten, Nev. Agr. Expt. Sta. Tech. Bul. 78.)

have not been observed in sufficient numbers, however, to indicate an important degree of control. The hymenopterous parasite *Mesostenus gracilis* Cress. was collected in many localities in North Carolina and Virginia and is especially abundant in farmers' pack houses.

HOW INSECT INFESTATIONS ORIGINATE IN TOBACCO

Domestic Flue-Cured Cigarette Tobacco

When flue-cured tobacco is packed in hogsheads or cases after being redried, it is free of all living insects. If, however, this tobacco is allowed to remain for even a day or two in any building where tobacco moths or cirgarette beetles are flying, it may become infested. The

adult females lay their eggs on the tobacco exposed in cracks between the staves or on the case itself. When the eggs hatch the tiny larvae crawl inside and begin to feed. Tobacco for export, redried during August and September and held for a week or more in infested storage rooms, is certain to contain some infestation when placed on shipboard unless it is fumigated prior to being loaded on the ship. In its early stages infestation in new-crop tobaccos is not easily detected, and the only insurance against such infestation is careful handling and prompt shipment of redried tobacco or fumigation just before loading in holds of the ship.

In like manner, flue-cured tobacco redried during the warm months and placed in domestic storage where insect infestations are present is likely to be infested during the same season. Storages that have been practically freed of insects by fumigation may be rapidly reinfested by the movement into them of tobaccos that are infested by the cigarette beetle and the tobacco moth.

Imported Cigarette Tobaccos

A survey of the distribution of tobacco insects in Greece and Turkey was made in 1933 by the senior author, and the results showed that both the tobacco moth and the cigarette beetle are distributed throughout these countries. The insects were found in warehouses, in planters' houses and curing yards, and in small village warehouses, tobacco moth infestation being found more prevalent than that of the cigarette beetle. In spite of precautions taken and control measures practiced in the countries of origin, Turkish-type tobaccos are nearly always infested upon arrival at the ports of entry into the United States. If such tobaccos are not fumigated upon arrival and are stored with uninfested tobacco, the whole will likely be infested during the next warm season unless suitable control measures are applied. Conversely, if imported tobaccos are fumigated upon arrival and subsequently stored with infested tobacco, they will be reinfested as soon as adults become active. The adults of the tobacco moth and of the cigarette bettle deposit their eggs on the burlap covering these bales, and when the eggs hatch the young larvae crawl inside.

Cigar and Snuff Tobaccos

In cigar and snuff tobaccos the only pest of economic importance is the cigarette beetle. The domestic tobaccos are infested principally after being packed in hogsheads, bales, or cases and placed in storage. In these types the cigarette beetles gain entrance into the package through small openings or they deposit their eggs on the outside and the young larvae enter. Most of the infestation in cases of this sort is around the outer edges of the tobacco. Imported cigar-filler tobacco may be infested when packed and is sometimes brought into this country from Puerto Rico and Cuba with cigarette beetles in various stages distributed throughout the bales.

Tobacco Products

Practically all tobacco products are subject to attack by the cigarette beetle, and there are many points at which such infestation may occur. Constant vigilance and the exercise of certain definite precautions are necessary to prevent infestation in factories, particularly during the summer months. The possibilities of infestation in the factory vary widely according to the products manufactured, whether cigarettes, cigars, smoking tobacco, or chewing tobacco, and according to methods of handling the products before shipment to distributors.

The high-temperature and other processes used in preparing tobacco for manufacture usually eliminate all insect life in the leaf tobacco; but after the tobacco is blended, cut, and bulked, it may remain in the factory for various periods before and after manufac-

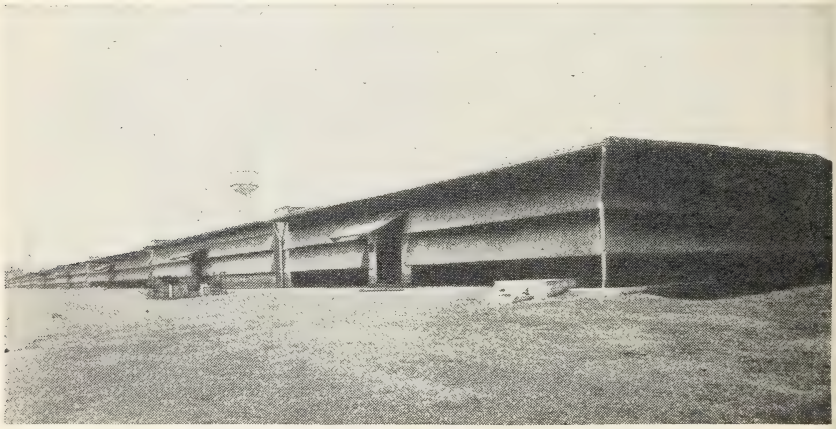

Figure 12.—Open tobacco warehouses with louvers along the sides to provide the maximum ventilation, each section having inside dimensions of 142 by 103 by 15½ feet and a volume of about 226,700 cubic feet.

ture. During this time it is subject to infestation by the active stages of the insects present in the factory, and the final processes of manufacture and packaging do not assure the destruction of infestation in the commodity. For example, in cigarette manufacture, if rigid controls are not maintained, cigarette beetles may deposit eggs on the shredded tobacco in the cut-storage rooms just prior to the making of the tobacco into cigarettes. Most of the infestation occurring at this stage of the processing would be carried through to the finished product. If the packaged cigarettes are held too long in shipping rooms, cigarette beetles may fly in during the warm months and infest the commodity in the cartons. Manufactured cigars are often held for aging in open trays or in boxes for as long as 5 weeks, and during this time they are subject to infestation if adult cigarette beetles are present. If steps are not taken to eradicate it, any infestation occurring after the filler, binder, and wrappers are cut will probably appear in the packaged cigars.

Even though the products may leave the factory free of all insect infestation, they may subsequently become infested in wholesale distributors' warehouses, on retailers' shelves, or in the hands of the consumer. With the exception of hermetically sealed containers, an insectproof package is practically nonexistent. Most packages may be entered by the young cigarette beetle larvae that hatch from eggs deposited on the wrapper by adult beetles.

CONTROL OF STORED-TOBACCO INSECTS

Control in Open Warehouses

The open type of tobacco warehouse usually consists of a wooden framework supporting sheet-metal walls and a composition roof. The floors may be of concrete, wood, or a foundation of crushed rock covered with cinders. As shown in figure 12, there are large louvers running the entire length of the warehouse sections, and an additional screened opening without louvers is left near the eaves and gables. Until 1939 these openings were almost always screened with hardware cloth of four to eight meshes to the inch. This type of construction permits a free circulation of air through the building, which, while an aid to the rapid aging of tobacco, is a serious handicap in the matter of insect control. The size of warehouse sections varies somewhat, the average being 150 by 103 by 15½ feet. A single section may contain from 800 to 2,000 hogsheads of tobacco, depending upon its size. This enormous poundage of tobacco is open to attack by both the cigarette beetle and the tobacco moth, which may readily enter or leave through coarse screens. It is desirable that a practical method of fumigation be developed for this type of tobacco storage, and research work is under way toward this end.

INSECT TRAPS

The suction light trap is a useful device for combating the cigarette beetle in open warehouses. The trap (fig. 13) consists of a barrel of galvanized sheet metal, a flange of block tin, and a cone of 20-mesh brass screen wire. To the small end of the cone the lid of a fruit jar is soldered, and into this lid is screwed a jar of suitable size for retaining the insects caught. A 40-watt light bulb is suspended from the flange, and suction is provided by a fan operated by a $\frac{1}{20}$-horsepower motor, which is mounted on a cross bar within the barrel. The motor and light bulb together consume about 1 kilowatt of electrical energy each 24 hours, making the cost of operation low.

One or two traps should be suspended in each storage section, depending upon its volume, and in order to obtain the best results the traps should be operated continuously, night and day, during the season when moths and beetles are flying. In Richmond records were kept for 6 consecutive years of the numbers of cigarette beetles caught in 10 traps operating in 5 open warehouse sections containing imported cigarette tobaccos. The traps were operated in identical locations each year and for the entire period of activity of the adult

422451°—42——3

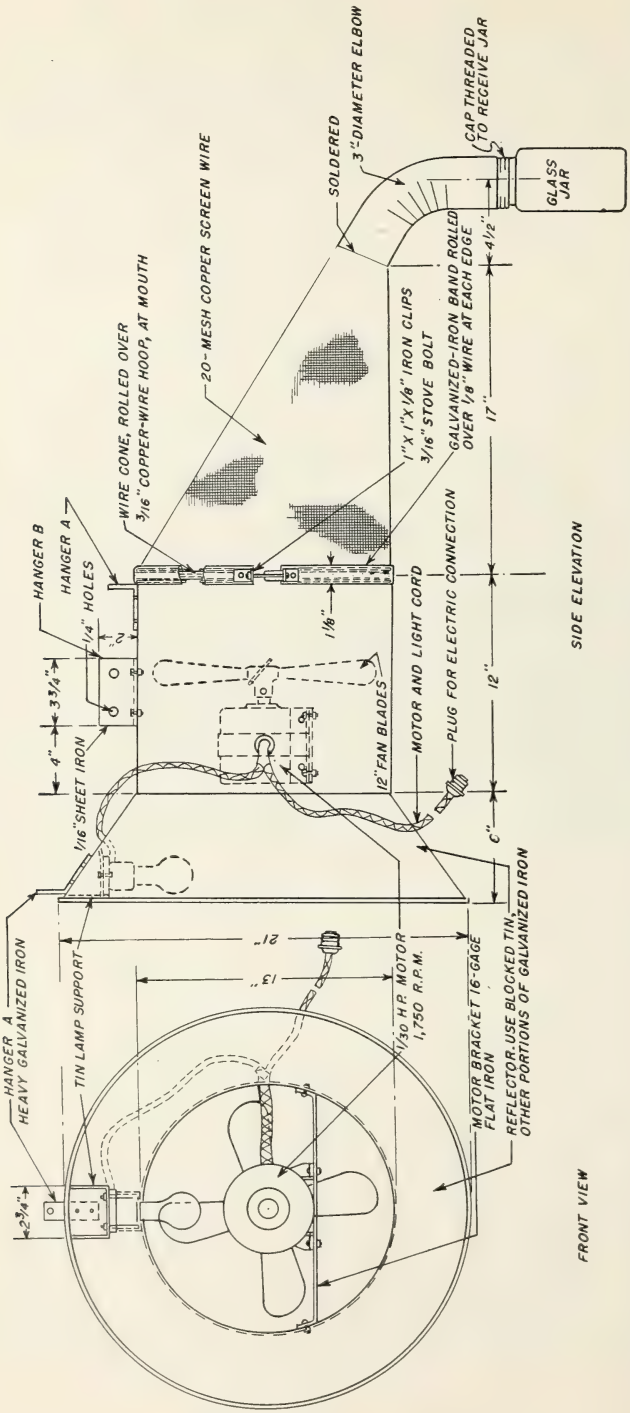

FIGURE 13.—Working diagram of the suction light trap used for reducing cigarette beetle populations and for determining the emergence of broods of the tobacco moth.

beetles. A large reduction was shown in the numbers caught during the last 5 years as compared with the first year (fig. 14).

The tobacco moth is not strongly attracted to lights, and therefore the traps are not effective in reducing the populations of this insect. The trap catches, however, are a satisfactory sample of the population and thus furnish an invaluable aid in showing the beginning, rise, and fall of moth emergence during the season and in estimating the effectiveness of control measures applied.

PYRETHRUM POWDER

Materials that affect the taste or aroma of tobacco or create a fire hazard cannot be used as insecticides in warehouses. The insecticide

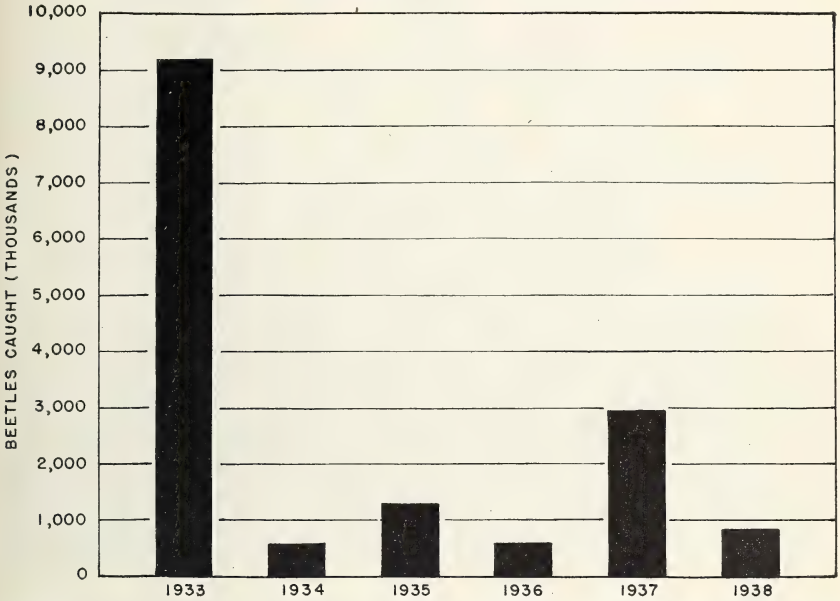

FIGURE 14.—Total catches of cigarette beetle adults made with 10 suction light traps during the 6-year period 1933–38. (Totals are approximate and calculated from volume of beetles caught on basis of 3 cubic centimeters equals 1,000.)

must be one that kills the insects by contact, since at present there is no method of applying materials directly to the tobacco upon which the pests feed. These limitations greatly reduce the number of insecticides suitable for use as dusts or sprays against stored-tobacco pests. Pyrethrum powder, although not a perfect control measure, will not damage stored tobacco and is effective in reducing populations of tobacco moth adults. It is not effective against the cigarette beetle and should not be used as a substitute for trapping or fumigation. **Men operating the duster or entering the warehouse for any purpose while dusting is in progress, or soon after it is completed, should wear approved respirators. (See figs. 15 and 16.)**

This insecticide is made from the flowers of one or more species of chrysanthemum, which are imported and ground into a fine powder.

To obtain the best results, the pyrethrum powder should be milled to such a fineness that most of it will pass through a 200-mesh sieve, and it should contain a minimum of about 0.80 percent of total pyrethrins.

The powder should be applied at the rate of 3 ounces for each 1,000 cubic feet of space not occupied by tobacco. For example, the poundage of pyrethrum powder required for one application in an open storage section having a total volume of 237,312 cubic feet and a storage capacity of 1,728 hogsheads would be calculated as follows: Allowing 54 cubic feet as the volume of an average hogshead of flue-cured tobacco, the space occupied by tobacco would be 54 times 1,728, or

FIGURE 15.—Power duster for applying pyrethrum powder, with operating crew and equipment for dusting open warehouses.

93,312 cubic feet. The space unoccupied by tobacco then equals 237,312 less 93,312, or 144,000 cubic feet. Multiplying 144 by 3, the weight required is 432 ounces, or 27 pounds.

A power duster suitable for applying pyrethrum powder in tobacco warehouses (figs. 15 and 16) is equipped with a fan 20 inches in diameter turned at a speed of 3,450 or 3,600 revolutions per minute by a 3-horsepower motor operated from a suitable electric connection in the warehouse. The diameter of the delivery hose at its outlet is 3½ inches, and the air velocity at this point is approximately 15,000 feet per minute. The short delivery hose with the proper diameter at the outlet is more efficient than a longer one. The hopper has a capacity for about 40 pounds of pyrethrum powder (fig. 15).

The recommendations of the Southeastern Underwriters' Association for a duster which meets satisfactorily the fire hazards in tobacco warehouses are the following:

1. All electrical equipment of an electrically operated dusting machine, including motor, switches, and attachment plug, should be of the type approved for dust-laden atmospheres, and the frame of the dusting machine and discharge nozzle should be effectively grounded to prevent static electricity accumulation. Fan blades of the blower should be constructed of a nonferrous metal.

2. During dusting operations all electrical equipment other than that directly connected to the dusting machine should be disconnected and no open flames or other sources of ignition should be allowed in the building.

3. No internal-combustion engine furnishing power for an insecticide duster should be used or stored inside any principal building or additions thereto.

Wind movement in excess of 5 to 7 miles per hour seriously interferes with dusting in open warehouses, both by hindering the proper distribution of the insecticide and by carrying it outside; there-

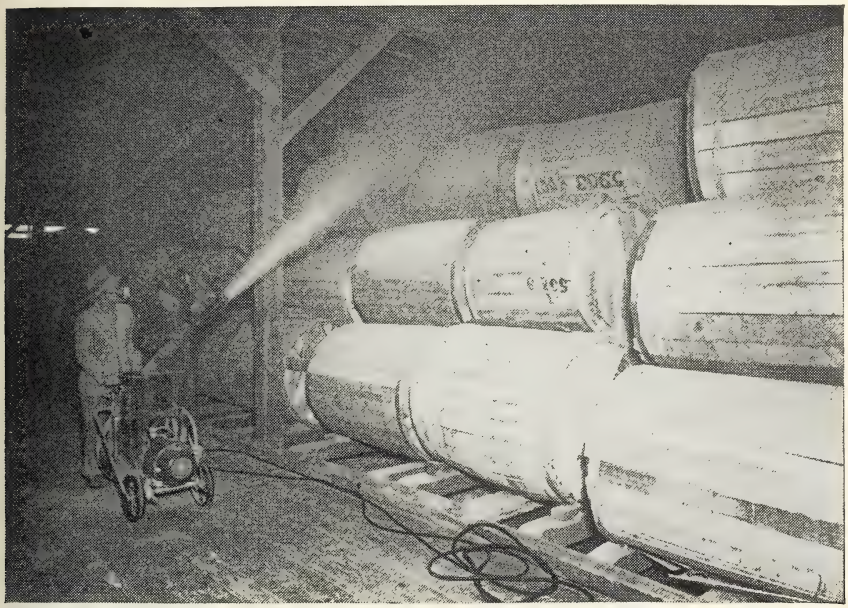

FIGURE 16.—The power duster and operating crew applying pyrethrum powder to a section of an open warehouse.

fore, applications should be made when conditions are as calm as possible. Rainy weather does not interfere provided the dust is not allowed to get wet. Pyrethrum powder is effective only against adult tobacco moths, and for this reason applications should be made when moths are present in the storages. Suction-light-trap catches serve as a satisfactory gage of moth abundance. Operation of the traps should start in April, the time depending on the temperature, and the dust should be applied weekly as long as the average catch of tobacco moths per trap exceeds about 25 per week.

The use of pyrethrum powder in open warehouses has the following objectionable features: (1) After a season of dusting a coating of the pyrethrum powder covers the containers of tobacco, and this residue is undesirable, and (2) the rate of reduction in population is slow, permitting considerable damage each year in open warehouses. Efforts are being made to develop a more satisfactory control measure.

SCREENING

The doors, ventilators, and all other openings of the warehouse should be effectively calked and screened to prevent the cigarette beetle and the tobacco moth from moving into or dispersing from the building. A screen satisfactory for this purpose is one containing 18 meshes per inch, made of wire 0.011 inch in diameter. It is desirable to have two extra coatings of electrogalvanizing to enlarge the diameter of the wire and to make the openings smaller. Because of corrosion resulting from exposure, the galvanized steel wire will have to be replaced about every 3 to 5 years. It is recommended that the

FIGURE 17.—Closed tobacco warehouse, which can be sealed and fumigated effectively when outbreaks of the tobacco moth and the cigarette beetle occur.

wire receive a coating of enamel at the time of manufacture to prevent rust and thereby extend for several years the period of effectiveness of the wire.

The screening of open warehouses serves two main purposes, as follows: (1) It materially reduces insect flight in and around storage warehouses, and (2) it prevents insects from escaping when dust or other insecticides are applied in the warehouse.

CONTROL IN CLOSED WAREHOUSES

When the cigarette beetle and the tobacco moth appear in closed warehouses, steps should be taken at once to reduce or eliminate the infestation. The prompt use of control measures will prevent serious outbreaks and avoid heavy losses. The control of these insects in

all storage centers is of much importance to the entire tobacco industry. The adults disperse from infested warehouses in large numbers and reinfest fumigated tobacco or often invade nearby manufacturing plants. One heavily infested warehouse in a storage center such as Richmond, Va., or Durham, N. C., might serve to spread infestation throughout the locality. Unless prompt measures are taken to control infestations, the population of the insects will increase manyfold the following season.

The closed type of tobacco warehouse (fig. 17) is constructed of wood, brick, or reinforced concrete, and usually the roof is of tar and gravel. In some instances the floors consist of a foundation of crushed rock covered with soil and a layer of coal cinders. In many closed warehouses, however, the floors are constructed of concrete or closely fitted wooden boards. The buildings may be one or several stories high with enough ventilators through the walls and roof to provide the proper aeration for the fermenting tobaccos. Wooden supports 6 by 6 inches are usually placed along the floor, upon which the hogsheads and cases of leaf tobacco are stacked during the aging period. The volume of these warehouses varies greatly, some containing not more than 25,000 cubic feet and others more than 400,000 cubic feet per section. Many units of closed storage consist of 20 to 25 sections of warehouses separated by fire walls, with a total volume of several million cubic feet. Tobacco warehouses of this size frequently store more than 50 million pounds of tobacco at a time. Since it has not proved feasible to move these large stocks of tobacco through special fumigating apparatus, the most practical and economical method of control thus far developed has been periodic fumigation with hydrocyanic acid gas. **This gas is poisonous, and pages 39 and 40 should be read before attempt is made to use it as a fumigant.**

PERIODIC FUMIGATION

When catches from traps indicate that the insects have increased to a point where control measures are advisable, the main dependence should be placed on periodic fumigation of the warehouse. The tendency is sometimes prevalent to postpone the application of direct control measures and place too much reliance on low winter temperatures or other natural controls. If a satisfactory dosage of fumigant is applied promptly upon the appearance of insects in the warehouse, the population can be held to a low level or sometimes eliminated in buildings of tight construction. Results of the periodic application of hydrocyanic acid gas for control of the tobacco moth are shown in figure 18.

SEALING OF WAREHOUSES

To obtain effective results in the control of insects, warehouses must be sealed properly prior to fumigation. This sealing makes possible the retention of the maximum concentration of gas. Materials for this purpose include several commercial grades of waterproof paper, tar paper, durable cardboard for ventilators, and elastic roofing cement. All openings in the walls and ceiling, such as ventilators, eaves, windows, elevator shafts, skylights, and doors, should be made gas-tight prior to the application of the fumigant. Paperhangers' paste, mixed

cold, is satisfactory for attaching the cardboard and paper to the walls. The doors can be sealed with gummed paper. For sliding doors it is recommended that a mixture of 4 parts of asbestos and 1 part of calcium chloride with water, worked into a stiff dough, be used. Cracks in the walls, ceiling, and floors, sometimes caused by weather changes, natural decay, or sinking of fundations, should be filled with the elastic roofing cement (fig. 19).

PIPING OF WAREHOUSES

For best results from fumigation with hydrocyanic acid gas the warehouse should be equipped with ⅜-inch copper tubing and one small spray nozzle installed for each 15,000 to 25,000 cubic feet. The nozzles should be distributed about the building so as to provide the proper dispersion of the gas. The piping system should be arranged so that the gas pressure is about the same on all nozzles. Large tobacco warehouses containing several floors require branch

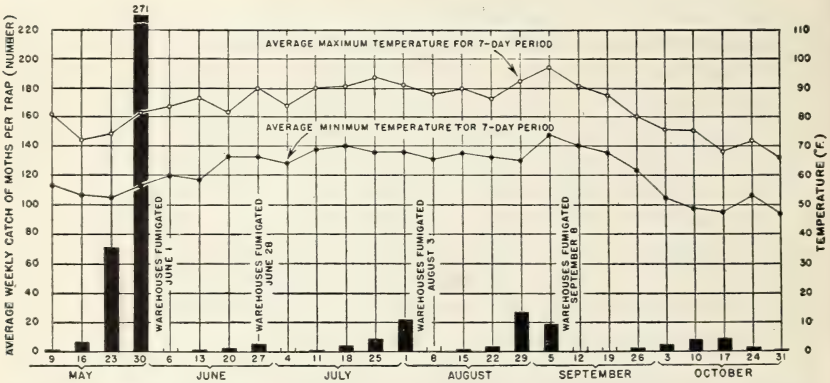

FIGURE 18.—Weekly catches of tobacco moths following periodic fumigations with hydrocyanic acid gas in tobacco warehouses having a total capacity of 3,318,000 cubic feet, Richmond, Va., 1932.

lines with separate risers. From 10 to 18 nozzles may be used to a riser with satisfactory results. Detailed plans for piping warehouses can be obtained from the fumigating company after a survey of the building and its contents has been made (fig. 20).

When it is not advisable to pipe the warehouse to be fumigated, a supply of rubber hose and nozzles can be obtained for use in introducing the hydrocyanic acid. This hose for temporary use can be rented from the fumigating company.

APPLICATION OF HYDROCYANIC ACID

Liquid hydrocyanic acid is shipped in steel cylinders equipped with an inlet and an outlet valve. A small compressor is used to pump air into the cylinder through the intake valve until a pressure of about 100 pounds is obtained. **Before connecting gas to piping, one should be certain that all human beings and animals are out of the warehouse. Read pages 39 and 40.** The cylinder of hydrocyanic acid is then joined to the piping system leading into the warehouse, after which the outlet valve is opened. The pressure of about

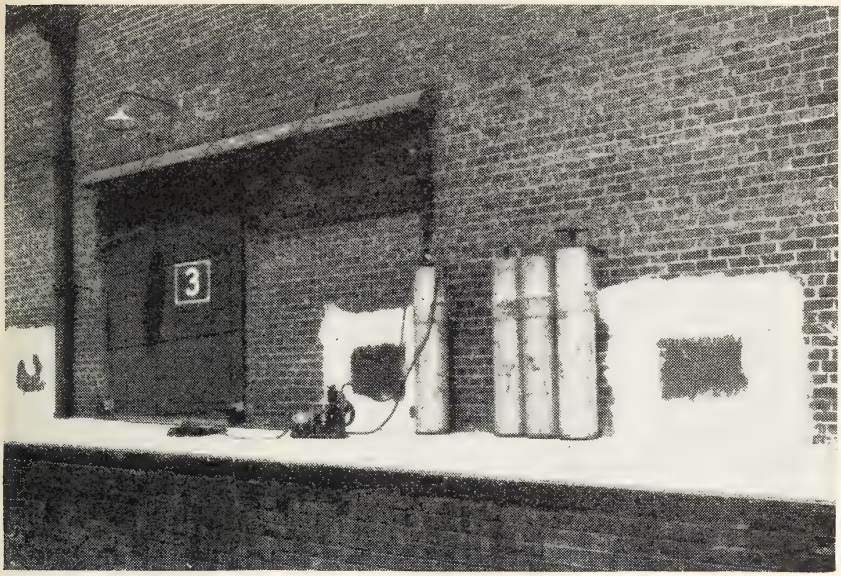

FIGURE 19.—Tobacco warehouse sealed prior to fumigation and cylinders of hydrocyanic acid and air compressor used in fumigation.

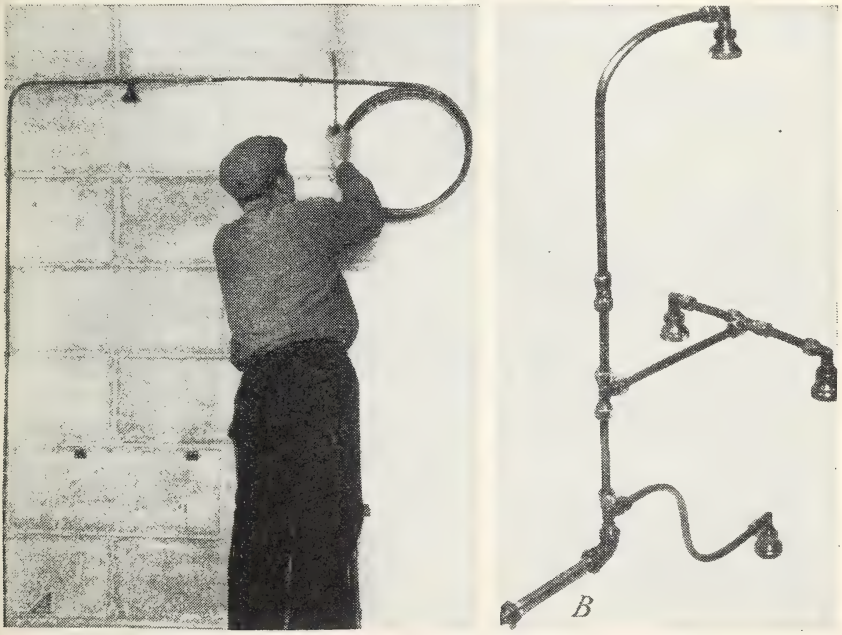

FIGURE 20.—Installation of ⅜-inch copper piping for use in the application of liquid hydrocyanic acid. The piping is flexible and can be run along walls or rafters to any desired point. *A*, Man installing pipes and nozzles; *B*, the different attachments for spray nozzles used for applying hydrocyanic acid in warehouses. If piping has been used recently, it should be blown out thoroughly to eliminate pockets of gas, which might be forced out in the face of the workman installing it.

100 pounds on the hydrocyanic acid in the cylinder forces it through the piping system and sprays it through nozzles into the warehouse. When less than one cylinder of hydrocyanic acid is required, the amount needed should be weighed from the cylinder on portable platform scales. **When the required dosage has been admitted, the valves on the cylinder should be closed and the piping system blown clear of hydrocyanic acid gas. The inlet pipe entering the warehouse should be capped after the pipes and nozzles are blown clear of gas.**

The most satisfactory dosage for closed warehouses is 10 ounces of hydrocyanic acid per 1,000 cubic feet with an exposure of 72 hours, repeated at intervals of 20 to 45 days, depending upon the degree of infestation. It is recommended that in most warehouses a minimum of two and a maximum of four fumigations be planned for each year in order to keep the populations of insects under control. When trap records indicate that a heavy infestation is present, the dosage should be increased to 16 ounces per 1,000 cubic feet. Owing to the leakage of gas, even from well-sealed warehouses, it is rarely economical to apply a dosage greater than 16 ounces in these periodic fumigations.

FACTORS AFFECTING CONTROL

DOSAGE, TEMPERATURE, AND EXPOSURE

If satisfactory results are to be obtained in the periodic fumigation of tobacco warehouses, careful attention must be paid to a number of details. The dosage of hydrocyanic acid, the temperature, and the period of exposure are all of importance. It is concluded after several years of work on the problem that dosages higher than about 16 ounces of hydrocyanic acid per 1,000 cubic feet are rarely economical owing to the loss by leakage. In many instances a dosage of 10 ounces of hydrocyanic acid per 1,000 cubic feet was the most efficient and economical, provided the application was repeated at proper intervals. The temperature of the tobacco should be 70° F. or above, which requires that the control program be carried out during the period from about June 1 to October 31.

Whenever possible the period of exposure should be 72 hours. The concentration of hydrocyanic acid gas will vary with the different types of warehouses treated, and often much of the gas has leaked out after the first 8 to 10 hours have elapsed. Nevertheless the results are uniformly more satisfactory with a 72-hour exposure than with an exposure of 24 or 48 hours.

TYPES OF BUILDINGS

The type of construction of tobacco warehouses affects materially the results obtained from periodic fumigations. Those having floors of coal cinders on a foundation of earth and crushed rock gave less effective results than storages with floors of concrete or wood. The thickness of walls and the general tightness of the warehouse at such locations as eaves, ventilators, skylights, windows, elevator shafts, and doors all affect the results obtained. In warehouses of good construction and where all openings are sealed properly, two fumigations for the season are usually satisfactory, whereas in warehouses of poor construction or improper sealing four and sometimes five fumigations are required to obtain control.

MOVEMENT OF TOBACCO

From most large warehouses there is normally a constant movement of aged tobaccos into channels of manufacture or into the export trade and of the new-crop tobaccos into storage from redrying plants. Sometimes lots of partly aged tobacco are transferred from one warehouse to another or from small warehouses into the large storage centers. Records from one large closed warehouse in Richmond show that in 3,318,000 cubic feet of space 3,024 hogsheads of flue-cured tobacco, each weighing about 1,000 pounds, which had been stored for 1 year or longer in other localities, were moved in over a period of 6 months. These old tobaccos as a rule are not segregated but are stored in the various warehouse sections according to grade. This movement of tobaccos often reinfests the warehouse, and it is an important factor in determining the number of periodic fumigations required during the season for the most satisfactory control.

SCREENING OF WAREHOUSES

The installation of an 18-mesh steel or copper screen over all openings in the warehouse prevents the dispersal of adults of the cigarette beetle and the tobacco moth during the emergence of broods. This is a most important factor in preventing the reinfestation of closed warehouses that have been freed from insects. Great variation exists in the insect populations in different sections of the same storage, and unless the warehouses are protected by screens the insects disperse into all sections and the cost of control is increased. The screened warehouses are protected also from migrating insects which originate in foods of these pests other than tobacco. These foods are listed on pages 6, 8, and 11 of this circular.

Control by Chamber Fumigation

ATMOSPHERIC CHAMBERS

Small chambers equipped for the fumigation of tobacco at atmospheric pressure are used satisfactorily in many tobacco warehouses and factories. This equipment may be constructed in several sizes and types to fit the individual need and may be built of wood and tar paper, metal, or brick. For the most efficient service the chamber should be made tight by equipping it with refrigerator-type doors and covering it inside with a good grade of cement or two coats of paint. Several fumigants have given satisfactory results in chambers of this type. **All fumigants are more or less poisonous. The characteristics of the kind to be used should be known and all necessary precautions against this fumigant should be taken. See pages 30 and 31.** Chambers such as these should be installed in tobacco-storage warehouses for the fumigation of infested tobacco en route to the factory or of incoming lots of infested tobacco for storage.

HYDROCYANIC ACID GAS

From Liquid Hydrocyanic Acid

Liquid hydrocyanic acid can be used satisfactorily in small chambers. If chambers are located inside a warehouse, all workers around the

operation should protect themselves against possible gas pockets by wearing approved gas masks. The liquid hydrocyanic acid is applied through a piping system similar in design to that described above for closed warehouses. Slats should be placed between the stacked bales of tobacco for the duration of the fumigation period so that the maximum penetration may be obtained. Dosages below 16 ounces per 1,000 cubic feet are not recommended for gastight chambers. When tobacco is heavily infested and several inches of penetration is desired, a dosage of 24 ounces should be applied. The exposure should be 72 hours for all types of unmanufactured tobacco, and the best results are obtained when the temperature of the tobacco is 70° F. or above.

From Sodium Cyanide and Sulfuric Acid

Hydrocyanic acid gas can also be generated from sodium cyanide and sulfuric acid by the barrel or pot method. For mixing the materials the most satisfactory formula is as follows: Sodium cyanide (96 to 98 percent) 1 pound, sulfuric acid (commercial grade, 66° Baumé) 1½ pints, and water 3 pints.

The required quantity of water should be placed in the barrel or crock first, after which the sulfuric acid should be poured into the water with care. The charge of sodium cyanide for each container should be placed in double thicknesses of paper bags and put beside the container before the fumigation is begun. When sealing is complete and the chamber vacated, the bags of cyanide are placed in the acid-water mixture. **The operator should wear a gas mask with suitable canister for protection against hydrocyanic acid gas and should leave the fumigated space and immediately seal the exit from the outside. All entrances to the warehouses should be securely locked to prevent the entry of persons who may not know of the danger.** (See figure 21.)

In crocks not more than 4 pounds of sodium cyanide is used for each fumigation and in barrels (fig. 21) not over 30 pounds. Sodium cyanide in 1-ounce egg-shaped balls is equivalent to about 53 percent of hydrocyanic acid, but this figure may be reduced as much as 10 percent because of the retention of a portion of the gas by the acid residue. Under practical conditions, therefore, the yield of hydrocyanic acid gas is only about 43 percent of the weight of sodium cyanide used, and the dosage should be calculated on the basis that 2½ pounds of sodium cyanide will yield the equivalent of 1 pound of commercial liquid hydrocyanic acid. The volume of space to be fumigated should be computed in cubic feet and a sufficient number of generators placed to accommodate the sodium cyanide required for the fumigation.

When the fumigation is completed and the chamber thoroughly ventilated, the liquid residue in the barrels or crocks must be disposed of promptly. When the generator is moved and the liquid residue shaken about, a small amount of hydrocyanic acid gas may be given off, and it is necessary for operators to avoid breathing this gas. The liquid residue should be buried beneath

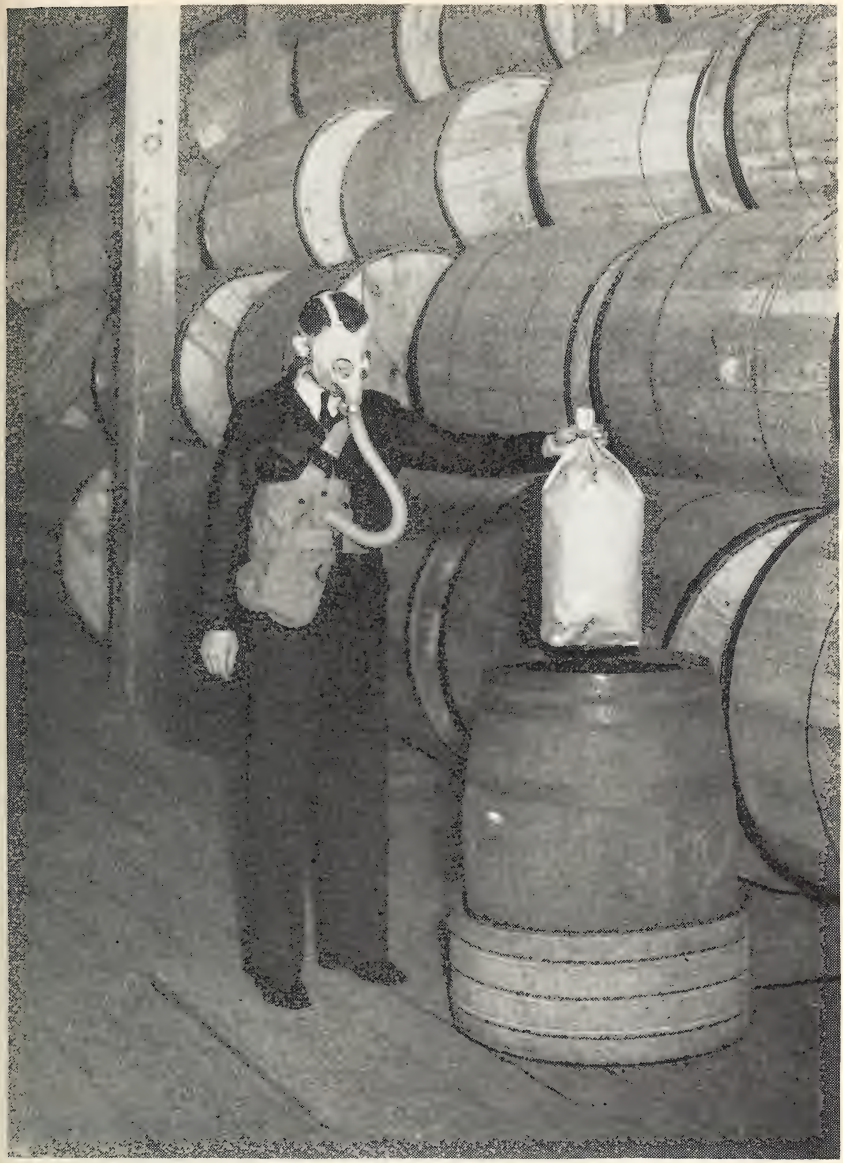

FIGURE 21.—Fifty-gallon wooden barrel and other apparatus used with sodium cyanide for generating hydrocyanic acid gas. The man, equipped with a gas mask, is resting the bag of sodium cyanide on the edge of the barrel before lowering it carefully into the acid-water mixture.

several feet of soil or dumped into sewer drains when these practices do not conflict with public health regulations. This residue should not be dumped indiscriminately, and a permit should be obtained from the proper public health authorities for disposing of it.

Chemical tests have indicated that a 1–1½–2 formula (i. e., 1 pound of sodium cyanide, 1½ pints of sulfuric acid, and 2 pints of water) yields somewhat more hydrocyanic acid gas than the 1–1½–3 formula, but the larger quantity of water in the latter avoids danger of crystallization of the residue in the containers and is the most practical for general use.

From Calcium Cyanide

Calcium cyanide is a granulated material packed in tin containers of various sizes. When exposed to the air the granules absorb moisture and a chemical reaction takes place which liberates hydrocyanic acid gas. Strips of paper should be placed on the floor of the chamber to be fumigated and on this the calcium cyanide should be spread, about 9 square feet of floor space being allowed for each pound of the material to be scattered. **After the material is properly distributed, hydrocyanic acid gas is evolved rather rapidly, and the operator must wear a suitable gas mask at all times when applying it.**

The highest grade of calcium cyanide is reported to be equivalent to 50 to 55 percent of hydrocyanic acid and the lower grades equivalent to 23 to 29 percent. In practical fumigation work some of the hydrocyanic acid may be retained in the residue. For example, if the high-grade material is equivalent to 50 percent of hydrocyanic acid, then 16 ounces would be required to produce a concentration of gas equivalent to that of 8 ounces of liquid hydrocyanic acid. For the best results the exposure should be 72 hours and the temperature of the tobacco 70° F. or above.

CARBON DISULFIDE

Carbon disulfide is a colorless, volatile liquid, which evaporates upon exposure to the air, forming a heavy gas toxic to stored tobacco insects and human beings. Owing to the fire risk involved, its use is greatly restricted in chamber fumigation. Approved gas masks should be worn by operators of fumigation chambers in which this gas is used.

In the fumigation of tobacco the liquid carbon disulfide is poured into shallow metal pans suspended from the ceiling of the fumigation chamber. The dosage recommended for stored tobacco is 10 pounds of the liquid per 1,000 cubic feet of space, with an exposure of 72 hours. The temperature of the tobacco should be 70° F. or above for the best results. **The vapors of carbon disulfide are highly inflammable and explosive, and this gas should not be used except in accordance with the regulations of fire insurance underwriters.**

The following permit for the use of carbon disulfide as a fumigant is endorsed by the Southeastern Underwriters' Association and the Virginia Insurance Rating Bureau:

In consideration of the following warranties, permission is hereby granted for the keeping on premises and for the use of carbon disulfide as a fumigant or insecticide.

Warranted by the assured:

1. That not exceeding 1 pound of carbon disulfide for each 100 cubic feet, interior space, will be used in the fumigation of any building or compartment.
2. That all carbon disulfide, on storage, will be kept in metal, preferably zinc lined and sealed receptacles; and that these receptacles will be kept detached at least 50 feet from all main buildings, or buildings where open fires or lights are maintained.
3. That no open fires or lights will be allowed in any building subject to fumigation with carbon disulfide.
4. That all electric and telephone wires entering any building subject to fumigation with carbon disulfide will be equipped with outside control switches, enclosed with lock boxes, and that these switches will be opened and locked during the entire period of fumigation.
5. That no artificial heat of any description will be allowed in any building or compartment subject to fumigation during the period of fumigation.
6. That any or all buildings or compartments which are under fumigation will remain closed for a period of at least 24 hours, and when opened, following fumigation, will be thoroughly ventilated for a period of at least three hours before being used.
7. That when a building or compartment is fumigated all doors shall be locked and the keys turned over to one reliable and responsible person in charge.

VACUUM CHAMBERS

The fumigation of tobacco at a pressure below that of the atmosphere for the elimination of all stages of the cigarette beetle and the tobacco moth was first introduced into the tobacco industry several years ago. The apparatus has been modified and adapted for tobacco fumigation, and during the past few years many improvements have been made. The fumigation of tobacco in partial vacuum is the most efficient method known of applying the gases available for use on tobacco. Vacuum chambers should be installed in tobacco warehouses for the fumigation of incoming lots of infested tobacco, both imported and domestic types, for storage and also for the fumigation of tobaccos en route to the factory.

APPARATUS AND PROCEDURE

The apparatus required consists of a steel cylinder of sufficient strength to withstand the pressure when a partial vacuum is produced inside. Attached to the cylinder is a pump of suitable size, a volatilizer for the gas, and the necessary recording gages. A part of the equipment consists of loading platforms and conveyors built especially to accommodate the containers of tobacco to be fumigated. The chambers are made in both cylindrical and rectangular shapes and are capable of holding various quantities of tobacco up to one or more carload lots.

The tobacco to be fumigated is placed in the steel chamber, the doors are closed, and the pressure is reduced by pumping out the air until a vacuum of 28 to 29 inches is registered on a standard vacuum gage. The total amount of vacuum produced depends upon the barometric pressure outside. The proper dosage of fumigant is then applied by weighing it into the vacuum tank. At the end of the exposure the gas should be pumped out of the tank and the pressure restored to normal by breaking the vacuum with air. This is called "air washing" and may be repeated one or more times if desirable. The manufacturers of vacuum chambers can supply estimates and specifications to meet the needs of individual factories and warehouses (fig. 22).

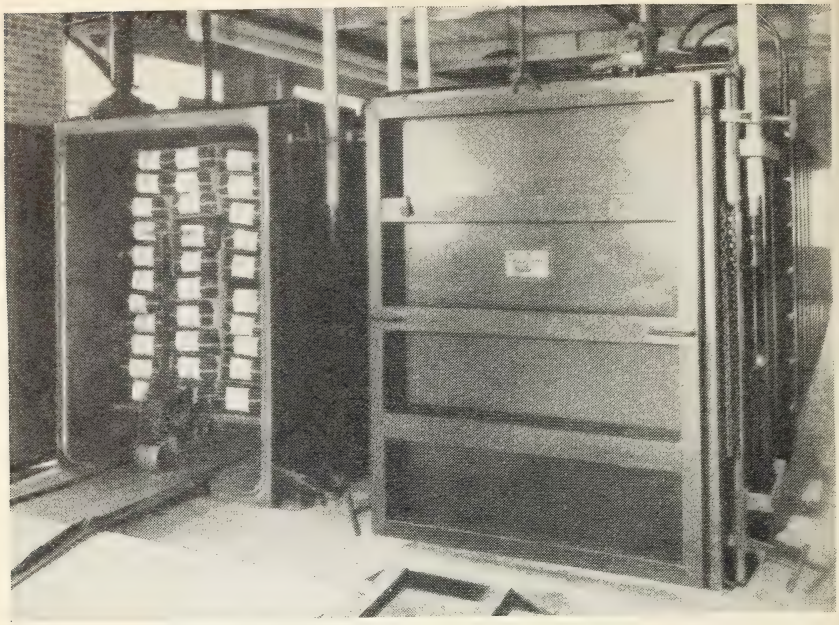

FIGURE 22.—Rectangular steel chambers used in the fumigation of tobacco in vacuum, each chamber being 37 by 6½ by 4⅝ feet and having a volume of 1,162 cubic feet. These tanks were installed for treating imported cigarette tobacco and each has a capacity of about 17,500 pounds of tobacco.

DOSAGES AND EXPOSURE OF AVAILABLE FUMIGANTS

The most widely used gases for the fumigation of tobacco in vacuum are hydrocyanic acid and a mixture of 1 part of ethylene oxide and 9 parts of carbon dioxide. A mixture of 15 percent of methyl formate and 85 percent of carbon dioxide has given good results in the fumigation in vacuum of bales of tobacco of low density. In bales closely packed the results have been unsatisfactory with the methyl formate-carbon dioxide mixture.

The dosages and exposures recommended for the fumigation of tobacco in vacuum when the temperature of the tobacco is 70° F. or above are given in table 1.

TABLE 1.—*Dosages of various gases recommended for the fumigation of different types of tobacco in vacuum chambers at a temperature of 70° F. or above*

Fumigant	Tobacco	Dosage per 1,000 cubic feet	
		4-hour exposure	15-hour exposure (overnight)
		Pounds	*Pounds*
Hydrocyanic acid	Cigarette	5	4
	Cigar filler	4	3
	Cigar wrapper	5	4
Ethylene oxide and carbon dioxide	Cigarette	60	55
	Cigar filler	55	50
	Cigar wrapper	65	60
	Manufactured cigars	45	
Methyl formate and carbon dioxide	Cigarette	65	60
	Cigar filler	60	55
	Manufactured cigars	50	

Much of the fumigation of tobacco in vacuum takes place during the fall, winter, and spring months, when the temperature of the tobacco is below 70° F. The recommendations for dosage and exposure in table 1 are likely to be revised when more information is available on the effectiveness of the fumigants at low temperatures.

Control in Tobacco Factories

STATEMENT OF PROBLEM

Tobacco factories are usually located near large storage warehouses. The buildings vary in size and may range from one to six stories high, depending upon the capacity of the factory. It is necessary to have the maximum amount of daylight for the various processes of manufacture, such as stemming, blending, bulking, heating, and making the finished products. The factory contains many windows, doors, elevator shafts, and other openings. The greatest danger of factory infestation lies in bringing the cigarette beetle and the tobacco moth into the factory in leaf tobacco from storage. Another important source of contamination in the factory is the migration of adults from storage warehouses through the unscreened openings in the building.

ELIMINATION OF INSECTS IN LEAF TOBACCO

Since infested leaf tobacco is probably the most important source of insects in the factory, great care should be exercised to eliminate all living insects en route from the storage to the factory. In cigarette tobaccos the hogsheads, cases, or bales are often subjected to a steaming process in the presence of high vacuum for moistening the tobacco prior to manufacturing it. This process, applied before the covering is removed from the packages, raises the temperature in the tobacco to 160° F. or above and kills all insect life present. For packages receiving this treatment no fumigation is required, but precautions should be taken to treat the tobaccos immediately when brought into the factory. All tobaccos not receiving the vacuum-steam treatment should be fumigated in atmospheric or vacuum chambers before being taken from storage. Under no circumstances should infested leaf tobacco be moved into the factory before all living insects have been eliminated.

PROTECTION OF FACTORY AGAINST MIGRATING INSECTS

Adults of the cigarette beetle and the tobacco moth disperse in large numbers from tobacco warehouses and other sources of infestation. Records indicate that these pests may migrate distances ranging from 1 to 15 miles from the point of origin. During the emergence of broods in summer, thousands of the moths and beetles may fly into a factory unless the windows, doors, and other openings are properly screened. These openings should be covered with 20-mesh screen of standard specifications.

In addition to screens, one or more suction light traps (fig. 13) should be installed on each floor of the factory. They should be operated whenever the factory is running. The catches reduce the

number of beetles and moths flying in the factory and also provide a worthwhile check on the effectiveness of the screening.

FUMIGATION OF TOBACCO PRODUCTS

If the safeguards mentioned above are taken, manufactured tobacco products are exposed to little or no insect infestation in the factory. Manufactured cigarettes leaving the factory for the wholesale trade are not fumigated owing to the precautions taken in modern factories to prevent infestation. Lots of infested cigarettes returned to the manufacturers from wholesale and retail establishments should be fumigated before they are received in the factory.

Manufactured cigars should be safeguarded in the factory against infestation by the cigarette beetle from the time they are made until packed and shipped. This interval may in some instances amount to 40 days or longer. All cigars not kept in cool storage or in an insect-proof humidor during this storage period should be fumigated before they are shipped, especially in the warm months, when the cigarette beetle is migrating. Manufactured cigars should be fumigated in a vacuum chamber with the ethylene oxide-carbon dioxide mixture at the rate of 45 pounds per 1,000 cubic feet with an exposure of 4 hours or with the methyl formate-carbon dioxide mixture at the rate of 50 pounds per 1,000 cubic feet with the same exposure period.

Manufactured pipe tobacco and plug tobacco are not fumigated at the time of shipment and must be effectively protected during the storage period in factories if losses are to be averted. All goods returned owing to insect infestation should be fumigated before they are received in the factory.

HEAT TREATMENT AND COLD STORAGE

The first factory process for domestic cigarette types of tobacco, after purchase from the grower, is called redrying. The machines used in this process consist of redriers in which the atmospheric conditions are regulated. The hands of tobacco are transported on sticks by a chain conveyor through these redriers, and the required percentage of moisture is taken from or added to the leaves. In the redriers for cigarette tobacco there are five chambers and the time required for tobacco to pass through them varies for different grades and types of tobacco. A typical operating cycle for flue-cured tobacco and the maximum temperatures reached in each chamber are shown in table 2. All insect infestation present is killed by these high temperatures. Redried tobacco, however, is subject to reinfestation when held in an infested factory or storage warehouse.

TABLE 2.—*Typical operating cycle for redrying flue-cured cigarette tobacco*

Process	Chamber No.	Maximum temperature	Exposure	Process	Chamber No.	Maximum temperature	Exposure
		°F.	*Minutes*			*°F.*	*Minutes*
Heating	1	160	7	Cooling	4	90	7
	2	205	6	Ordering	5	120	16
	3	178	7				

Cold storage is of great value in preventing or holding in check infestation in connection with factory operations. In many instances when flue-cured cigarette tobacco has fermented satisfactorily the hogsheads or cases are held in storage at around 50° F. to prevent loss of color through excessive fermentation. This temperature prevents activity by the tobacco moth and the cigarette beetle and arrests insect development.

Cold storage is widely used in the cigar industry for storing manufactured cigars from the time they are made until they are shipped. The storage chambers vary in size to suit the needs of the individual cigar factory. The temperatures maintained range from about 45° to 55° F., and under these conditions insect infestation is prevented or checked. The cigarette beetle can be killed by exposure to low temperatures. For example, at 36° a 16-day exposure will kill all stages and at 25° a 1-day exposure will produce complete mortality. At a temperature of 40° a 33-day exposure is required to effect complete mortality of the cigarette beetle.

Program of Control

STORAGES

In periodic atmospheric fumigations of closed warehouses containing domestic and imported tobaccos, a penetration deeper than 3 to 6 inches in packed tobacco is rarely obtained. For this reason it is important to keep a check on the population of the insects in all warehouses and to time applications of the fumigant to correspond with the emergence of broods of beetles and moths. Nearly all tobacco moth larvae when full-grown migrate to the surface of packed tobacco or into sheltered places outside the hogsheads and bales. Larvae of the cigarette beetle also migrate to the surface in large numbers. The adults of neither species feed on tobacco but remain on or outside the containers of tobacco for mating and egglaying. Since the eggs are laid at or near the surface of the packed tobacco, no penetration of gas is required to kill adults, eggs, and many larvae. The emergence of broods of the tobacco moth and the cigarette beetle can be determined rather accurately by using a suction light trap (fig. 13) for an indicator. Another indicator, less suitable but inexpensive, consists of a fabricated board 16 inches long, 10 inches wide, and ⅜ inch thick, on which is attached a sheet of sticky flypaper 14 inches long and 8 inches wide (fig. 23).

One of these fabricated-board indicators for each 50,000 to 75,000 cubic feet of tobacco warehouse should be installed by suspending it at an angle of about 45 degrees 6 inches below an electric light. A 40-watt light is recommended for use over each trap, and only the lights located over the traps should be allowed to burn during the night. In many warehouses the suction light traps (fig. 13) are permanently installed, and the catches from them are used for scheduling fumigations.

The question of when to fumigate is a difficult one to answer in terms that will apply under all the varied conditions prevailing in storages housing different types of tobacco and having various degrees of infestation of one or both of the principal pests. In ware-

houses that have not been fumigated or in which control has not been obtained because of improper timing, faulty application, or too few applications, a definite schedule based upon trap catches should be adopted and followed. In such storages, where the tobacco moth and the cigarette beetle are present in injurious numbers, at least four fumigations should be performed during the warm seasons. On the basis of the average emergence dates in North Carolina and Virginia, the first application of gas should be made between May 15

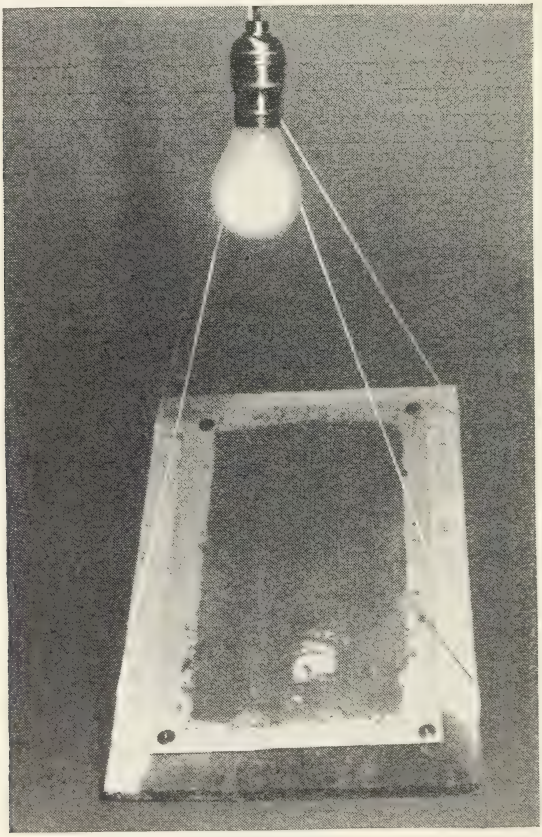

FIGURE 23.—Fabricated-board light trap used to indicate the emergence of broods of stored-tobacco insects.

and 31, depending upon the rate of emergence of the spring brood as indicated by trap catches. The second should be applied between June 25 and July 5, the third between August 10 and 25, and the fourth between September 15 and 30. Spring temperatures and the movement of infested tobacco into or out of storage will cause variations in the dates on which fumigation should be made, and the most advantageous time can be determined only through a knowledge of the insect conditions as shown by trap catches and personal observations. Where fumigation and dusting with pyrethrum powder have reduced the moth population to low levels, the early fumigation (May 15 to

31) may be omitted and the others timed solely for controlling the cigarette beetle. In warehouses storing tobacco primarily for domestic manufacture, where the necessity for daily access to the building in order to withdraw tobacco for manufacture sometimes delays fumigation, two applications properly timed may give satisfactory control.

The following control program is recommended for closed warehouses:

1. Install insect traps in tobacco warehouses prior to the emergence of the spring brood of tobacco moths. (In Virginia and North Carolina this date is about April 15.)
2. Fumigate two to four times annually, as discussed above.
3. For light infestations apply at each fumigation a dosage of 10 ounces of hydrocyanic acid per 1,000 cubic feet and for larger populations use 16 ounces per 1,000 cubic feet, with an exposure of 72 hours.
4. **In the warehouse fumigation of tobacco the gas should be applied by a person trained especially for this work. Tobacco companies should employ the services of a licensed pest-control operator or train an employee especially for handling this important work.**
5. In warehouses containing flue-cured tobacco moth populations should be kept down by supplementing fumigation with weekly applications of pyrethrum powder, as described under Control in Open Warehouses.

In open warehouses weekly applications of pyrethrum powder are recommended for control of the tobacco moth. The powder should be applied with a power duster at the rate of 3 ounces to each 1,000 cubic feet of space not occupied by tobacco, as described under Control in Open Warehouses. Weekly applications should begin as soon as trap catches show that moths are active in the spring, usually early in May, and they should be continued through September. The application of pyrethrum powder does not provide satisfactory control of the cigarette beetle.

VACUUM CHAMBERS

The principal uses of vacuum fumigation in the tobacco industry are in the treatment of tobaccos en route from storage to the manufacturing plant, imported cigarette tobaccos upon their arrival in this country for storage, and hogsheads of flue-cured tobacco at the time of export or when placed in storage.

Infested leaf tobacco is one of the principal sources of infestation in the factory when it is removed from storage for manufacture. If not eliminated the insects will spread over the factory and the adults will lay eggs on the manufactured products. If all flue-cured and imported cigarette tobaccos are fumigated in vacuum before being brought into the factory, the danger of infestation in the finished product is greatly lessened.

The imported cigarette tobaccos brought into this country are grown in the region surrounding the Mediterranean Sea, principally in Greece and Turkey. Infestations of the cigarette beetle and the tobacco moth are not uncommon in these tobaccos, and large populations develop unless checked by fumigation. Infested lots of these tobaccos should be fumigated in vacuum upon arrival in the United States and again when removed from storage for manufacture.

Although it is necessary to safeguard domestic tobaccos for export during the storage period in this country, all lots of hogsheads or cases suspected of containing infestation should be fumigated in vacuum at the port, just prior to being loaded on the ship. This treatment at the recommended dosage and exposure will kill all stages of the insects.

ATMOSPHERIC CHAMBERS

In many tobacco factories it is impracticable to install vacuum-fumigation chambers, and the problems of factory fumigations are handled satisfactorily in small atmospheric chambers. These vary in volume and are constructed of the proper size to accommodate the needs of the individual factory.

Hydrocyanic acid is most often used in these chambers, and it may be applied through copper pipes and nozzles in the same manner as for large warehouses. This fumigant is applied also in the form of sodium cyanide (fig. 21) or by means of discoids. The latter are waferlike disks, made of wood pulp, in which liquid hydrocyanic acid has been absorbed, each containing about one-half ounce of hydrocyanic acid. These disks are packed and sealed in tin cans of various sizes and marketed on the basis of the net contents of hydrocyanic acid.

Carbon disulfide may also be used effectively for the fumigation of tobacco in small chambers. The dosage should be 10 pounds per 1,000 cubic feet of space with an exposure of 72 hours. Exposures shorter than 72 hours are likely to produce unsatisfactory results. The liquid carbon disulfide should be poured into shallow pans and allowed to evaporate in the sealed chamber. **This gas is highly inflammable and explosive in air mixtures and should be used only under permit from fire insurance companies. The permit for the use of this fumigant as endorsed by the Southeastern Underwriters' Association is given on pages 30 and 31 of this circular.**

Calcium cyanide may be applied effectively in small chambers provided enough space is left between the stacked packages of tobacco for spreading of the granular material. As stated on page 30 of this circular, about 9 square feet of floor space are required to spread 1 pound of calcium cyanide properly. The dosage should be the equivalent of 16 ounces of hydrocyanic acid per 1,000 cubic feet with an exposure of 72 hours. This would require the use of 32 ounces of high-grade granular calcium cyanide (50 to 55 percent of hydrocyanic acid) per 1,000 cubic feet.

In the fumigation of tobacco in small chambers the bales should have slats placed between them, and hogsheads and cases should not be too closely stacked. This allows the gas to penetrate the tobacco from all directions shortly after the start of the exposure.

COST OF CONTROL METHODS

Cost figures per unit weight of tobacco treated for insect control are available for cigarette tobaccos only. In the periodic fumigation of closed warehouses with hydrocyanic acid gas the cost varies somewhat according to the type of tobacco, whether flue-cured or Turk-

ish, and according to the difficulties of sealing. However, the cost of this type of atmospheric fumigation averages about 12 to 15 cents per 1,000 pounds for each application. Vacuum-fumigation costs vary from summer to winter, but usually range from 60 to 75 cents per 1,000 pounds, including the cost of the fumigant, labor, electric power, and amortization of equipment.

Treatment of open or closed storages with pyrethrum powder requires an annual outlay of about 15 cents per hogshead. This figure includes cost of powder, labor, and depreciation of dusting equipment used in making about 20 applications.

SAFEGUARDS TO BE EMPLOYED IN FUMIGATION

It is only through well-planned fumigation work that safe procedures can be employed and satisfactory results obtained in the control of tobacco insects. By the exercise of proper care in a definite program of periodic fumigations, heavy losses from insects are averted and the proper protection is given to life and property in the vicinity of tobacco warehouses. Carelessness is responsible for most of the accidents that have been recorded in industrial fumigation.

Only dependable men, preferably licensed pest-control operators, should be employed in warehouse-fumigation work, and they should be in good physical condition at all times. Operators should abstain from the use of intoxicants while on the job.

The following safeguards and precautions should be adhered to closely:

1. All persons and domestic animals must be outside the building when it is sealed and ready for fumigation.

2. Placards containing a warning and stating that a fumigation is being conducted should be posted at prominent places on the building.

3. Guards should be placed around the building to prevent persons or domestic animals from approaching too near it.

4. Gas masks, equipped with satisfactory canisters, should be purchased from the manufacturers of fumigants and worn at all times when the gas is being handled.

5. Local authorities should be notified and the necessary permit obtained for the fumigation. These officials should be notified again when the work has been completed and the building properly ventilated.

FIRST AID FOR PERSONS OVERCOME FROM HYDROCYANIC ACID GAS

Since hydrocyanic acid is widely used in the tobacco industry, it is desirable to include some first-aid information for those who might be overcome by this gas. Detailed information regarding first aid for hydrocyanic acid gas poisoning can be obtained from the United States Public Health Service, the manufacturers of hydrocyanic acid, and many other sources. The directions given in this circular are summarized from this published information.

When persons are working with hydrocyanic acid gas, one or more of the following symptoms may indicate poisoning:

1. Weakness, or palpitation, of the heart.
2. Headache or dizziness.
3. Rushing of blood to the head.
4. Weakness or heavy feeling in the limbs and joints.
5. Nausea and vomiting.
6. Difficulty in breathing and contraction of the chest.
7. Fainting and unconsciousness.

Dangerous quantities of the gas can be obtained by inhaling it in small amounts over an extended period or by absorption through the skin. In the application of the gas and in the ventilation of tobacco warehouses, operators should work in pairs. If one begins to exhibit any of the above symptoms, the coworker should render immediate assistance and remove the patient to the outside. The affected person should be kept warm and in the open air until the help of a physician can be obtained. He should not be allowed to exercise, but should be kept as quiet as possible until the symptoms have passed off. No hypodermic injections should be given and no alcoholic stimulants or liquids should be administered by the mouth until the affected person is fully conscious.

U. S. GOVERNMENT PRINTING OFFICE: 1942