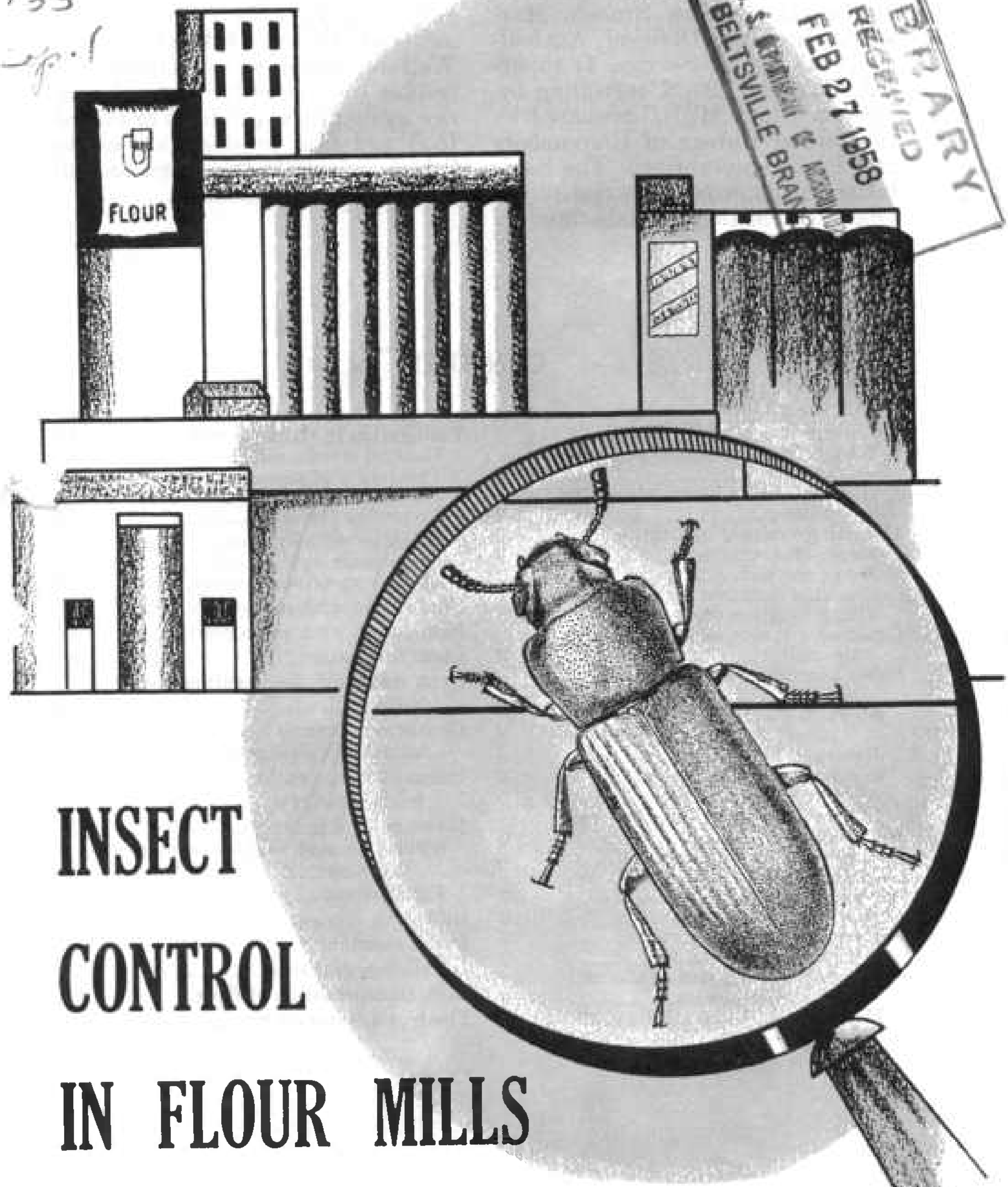
Agriculture Handbook No. 133



INSECT CONTROL IN FLOUR MILLS

U. S. DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Marketing Research Division
Washington, D. C.

This handbook was prepared by the Stored-Product Insects Section, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service. It supersedes Circular 720, "Controlling Insects in Flour Mills," prepared by the former Bureau of Entomology and Plant Quarantine. The Sanitation Committee, Association of Operative Millers, collaborated in planning this handbook, and critically reviewed the text. The Food and Drug Administration, Department of Health, Education, and Welfare, under whose supervision residue tolerances for pesticides on raw agricultural products or milled food and feed products are established, concurs in the insect control procedures recommended.

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Scientific Names of Insects Discussed

Angoumois grain moth	*Sitotroga cerealella* (Oliv.)
Cadelle	*Tenebroides mauritanicus* (L.)
Flat grain beetle	*Laemophloeus minutus* (Oliv.)
Confused flour beetle	*Tribolium confusum* Duv.
Granary weevil	*Sitophilus granarius* (L.)
Lesser grain borer	*Rhyzopertha dominica* (F.)
Mediterranean flour moth	*Anagasta kühniella* (Zell.)
Red flour beetle	*Tribolium castaneum* (Hbst.)
Rice weevil	*Sitophilus oryza* (L.)

INSECT CONTROL IN FLOUR MILLS

By R. T. Cotton

Biological Sciences Branch, Agricultural Marketing Service [1]

Producing flour that will meet high standards of purity and maintaining the flour in that condition until it reaches the consumer is the aim of the milling industry. This handbook suggests procedures and provides information on how to prevent insect infestation in flour mills.

Grain Supply

To produce flour of acceptable quality it is essential to mill only grain that is free from serious contamination by insects and rodents. Cooperative studies between industry and the Food and Drug Administration (Harris *et al.*)[2] have shown that a major source of contamination in flour is the wheat in market channels. The insects that feed within the wheat kernels are of most concern to the miller. Insects that feed externally may destroy grain or cause it to heat, but they are easily removed by the cleaning process prior to milling.

What are the chances of obtaining milling stocks that are free from insects that feed internally in the kernels? The co-operative studies referred to show that slightly over half of the wheat shipments reaching the mills over a 1-year period had some degree of internal insect infestation. The infestation tended to be lower in the West, Northwest, Inter-Mountain, and Northern States—or in areas where the wheat is predominantly hard red spring or white wheat—than in the Central Plains States where hard red winter wheat is predominant. It was highest in the soft red winter wheat from the Midwestern and Eastern States.

Insect infestation in wheat increased as wheat moved from the farm to the terminal elevators. In market wheat the infestation from May to September was low during the marketing of the new crop. The level began to increase in September and continued to do so through the winter.

Wheat coming from the field is practically free from insect infesta-

[1] Dr. Cotton retired March 30, 1957.

[2] Harris, K. L., Nicholson, J. F., Randolph, L. K., and Trawick, J. L. An investigation of insect and rodent contamination of wheat and wheat flour. Assoc. Off. Agr. Chem. Jour. 35 (1) : 115–158. 1952.

tions. These occur later—in storage, transportation, and milling.

Why Infested Wheat Is Unfit for Milling

The grubs, or larvae, of insects such as the rice weevil, granary weevil, lesser grain borer, Angoumois grain moth, flat grain beetle, and occasionally the cadelle or flour beetle burrow inside the wheat kernels, and they and their contamination cannot be entirely removed by any practical known method. The cooperative studies showed that in 16 flour mills the insect fragment count in flour produced in the mills was closely related to the infestation inside the wheat that was milled. The effect of wheat cleaning on the reduction of insect contamination varied from mill to mill. The over-all reduction was about one-third, but in individual mills the reduction varied from none to more than 50 percent.

How To Obtain Clean Wheat for Milling

Wheat at harvest time is usually free from contamination by insects. The ideal procedure for a mill would be to buy a year's supply of wheat at harvest, place it in clean elevator storage, and fumigate the wheat as a precautionary measure. Obviously it is not possible for most mills to follow this plan owing to the limited storage capacity of their elevators. From 4 to 20 times the storage capacity of a mill elevator may be required to supply the wheat needed for keeping the mill in operation. Therefore market wheat being bought should be thoroughly tested to determine whether or not it is sufficiently free from insect and rodent contamination to be fit for milling. Many methods of determining dangerous amounts of internal insect infestation have been developed from time to time. The more important ones are discussed below.

Detecting Internal Infestation

In general it has been found that wheat with more than 0.5 percent of infested kernels is unfit for milling. For domestic flour production some mills will not use wheats for their mill mixes that contain more than 8 internal insects per 100 grams.

Visual Observation

In wheat containing appreciable insect infestation there are usually enough kernels showing emergence holes or insect damage that an experienced grain man can determine the degree of infestation by looking at a sample.

X-Ray Method

The most accurate and widely used method of determining the extent of internal insect infestation in samples of grain is by the use of X-rays.[3] X-ray machines are used to take radiographs of 100-gram samples of wheat that reveal insect forms within the kernels. Manufacturers have now developed X-ray units specifically for this purpose. Although equipment and continuous operation are rather expensive, the method is being used extensively by large milling concerns.

Cracking Flotation Method

Another method of determining the amount of internal insect infestation in grain is the "Cracking

[3] Nicholson, J. F., Milner, M., Munday, W. H., and others. An evaluation of five procedures for the determination of internal insect infestation of wheat. V. The use of X-rays. Assoc. Off. Agr. Chem. Jour. 36 (1): 150–155. 1953.

Flotation Method."[4] Cleaned grain is coarsely ground to release the internal insects and is either soaked in a water-alcohol mixture or in boiling water and then mixed with gasoline or mineral oil. The insects are floated off with the oil layer in a Wildman trap flask and collected on a filter paper and counted. In the process of grinding, some of the insects are broken, but characteristic parts such as the heads can be counted and the number of whole insects reliably estimated.

White Flotation Method

More recent studies by White[5] indicate that a mixture of two solutions of different specific gravities can be used in making a rapid separation of infested from noninfested kernels in a sample of wheat. The mixture consists of a solution of sodium silicate ($Na_2Si_3O_7$) in water with a specific gravity of 1.160, to which is added methyl chloroform adjusted to a specific gravity of 1.30 with refined kerosene. When placed together a definite separation layer is formed between the two liquids, the lighter sodium silicate solution remaining on top. Kernels containing late stages of weevil larvae float on top of the sodium silicate solution; kernels containing early stages of weevil larvae and some noninfested lightweight kernels are buoyed up to the separation level of the two liquids; and noninfested, normal-weight kernels sink to the bottom. A 1,000-kernel sample is placed in a beaker of the mixture and stirred; as the kernels get wet, they quickly separate. If no kernels come to the top, the sample can be considered free from serious infestation. If there are any floaters, the degree of infestation can be estimated by the relation between the number of floaters and the size of the sample.

Grain as a Source of Infestation in the Mill

Of the many sources of insect infestation in the flour mill, the grain stream is usually the most important. Grain coming to the mill is often infested, although the degree of infestation varies with the location of the mill and the source of the grain. Mills in the spring-wheat region and in the Pacific Northwest have fewer insect troubles than mills in the Southwest, where as many as 30 different species of grain-infesting insects have been found in grain arriving at the mills. The fact that many mills find it necessary to draw wheat from many sources to meet their requirements often complicates their insect problem considerably.

Grain-cleaning machinery now in use does not completely remove insects from the incoming grain. Figure 1 shows that samples from the wheat elevator boots, which handled the wheat after it was cleaned, had a high average insect population. As cleaned wheat is not a preferred food for the grain beetles, it is believed that they are introduced into the elevators with the wheat stream. These insects spread all through the mill and are an important source of infestation.

Previous investigations have shown that some insect forms can pass uninjured through the entire system of rolls. Adults of the confused flour beetle have passed unharmed through the first three breaks, and partly grown larvae have survived passage through the first three middling rolls. Eggs of this species are so small that many

[4] See footnote 2, p. 1.

[5] White, G. D. Studies on Separation of Weevil-Infested from Noninfested Wheat by Flotation, AMS-101. 10 pp. March 1956.

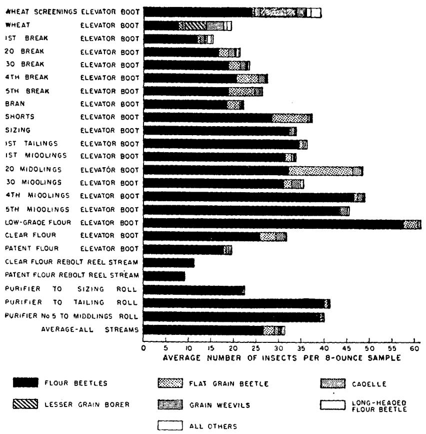

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Figure 1.—Average number of insects per 8-ounce sample and proportions of different species found in 2,367 samples from the different milling streams of 17 flour mills in Kansas, Oklahoma, and Missouri during a 1-year period (1934–35).

of them survive passage through the low-grade flour rolls. When these eggs hatch, infestations may quickly reach serious proportions in all streams of the milling unit.

Figure 1 also shows that wheat screenings from the elevator are usually heavily infested. In many mills the cleaning machinery is placed close to the milling units, and often the screenings are spouted to a collecting sack near the milling machinery or stored finished flour. Any insects crawling from these screenings have easy access to the milling machinery or finished flour.

Grain-cleaning machinery should be segregated in a smut room at one end of the mill, and grain screenings should be disposed of immediately by spouting to a screenings hammer-mill, a centrifugal-force machine, or to a vault where they can be fumigated. If one of these procedures is followed, treated screenings fed into conveyors or transferred to the tail end of the mill will not serve as a source of contamination to the flour-producing section. Grain screenings should never be allowed to accumulate in the mill or in the flour warehouse.

Centrifugal force can be used to advantage in the mill to destroy infestation in both dry and tempered wheat (fig. 2). The machine consists essentially of a rotor with a series of hardened steel impactor posts mounted on it perpendicular to its face. The rotor is mounted directly onto the shaft of an electric motor, and is enclosed in a housing. The grain is introduced near the center of the rotor, which revolves it at a high speed on a horizontal plane, and hurls it by centrifugal force against the impactor posts and the housing. In the operation, free-living insects are killed and some of the infested kernels are broken open so as to expose the internal infestation. A scourer-aspirator removes dirt, debris, and insects dislodged by the impact.

In treating dry wheat a slow-speed unit (1,750 r. p. m.) is located beyond the receiving separator in the cleaning section. This unit destroys and removes most of the external insect life and removes foreign material from the grain. In treating tempered wheat a high-speed unit (3,500 r. p. m.) is located just before the first break rolls and serves as a final cleaning operation. At this speed infested kernels are broken open and the internal infestation largely removed.

Other Sources of Infestation in the Mill

Aside from the grain stream, there are a number of other sources of infestation, such as blending stocks from other mills, returned flours, second-hand machinery, accumulated feed stocks, and nearby elevators.

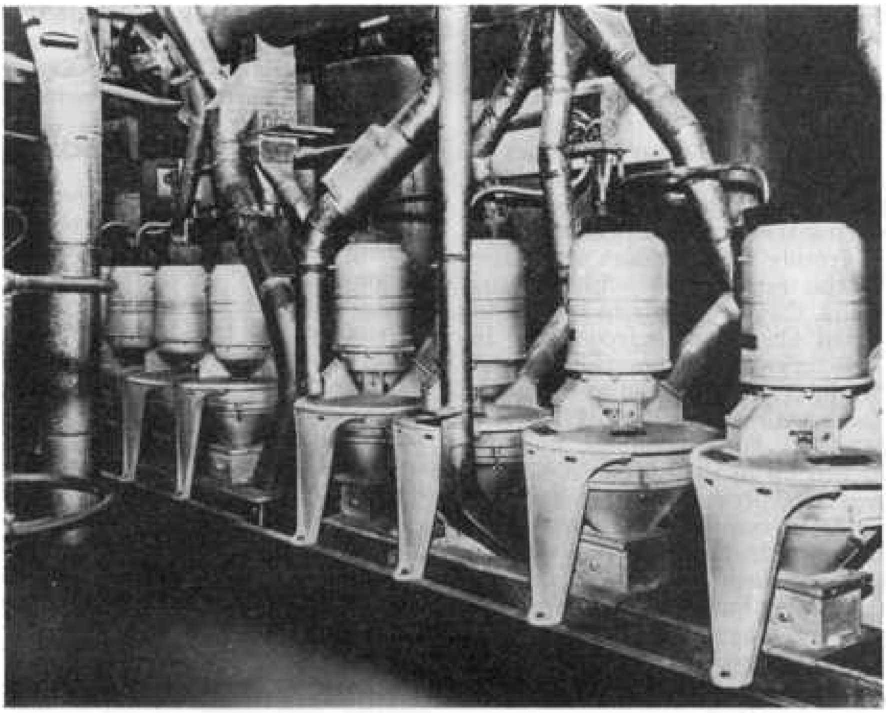

Figure 2.—A mechanical bulk-flour centrifugal machine.

Stock Used for Blending Purposes

The demand for blended flour by large baking concerns necessitates the use of large quantities of clear and low-grade flours that mills may obtain in part from their own warehouses and in part from other mills. Usually these flours have accumulated over a period of time and, since they are highly preferred by the insects, are frequently infested.

Stock intended for blending should first be examined to determine whether it contains insect contamination. Insect excrement in flour cannot be removed by any practical rebolting process, and flour that contains an appreciable infestation of insects is considered unfit for human consumption and should be diverted to feeds.

Flour intended for blending should be run through a sifter clothed with number 10XX bolting cloth and then through a treating machine using centrifugal force, as a precautionary treatment to remove or destroy any insect life that might later start an infestation. The overs should also be treated with centrifugal force before being spouted to feed.

Returned Flours

Returned flours are always a problem to the miller because they invariably constitute a serious source of infestation. Formerly these were fed back into the mill and incorporated into one of the many blends required by modern markets. If, as was usually the case, these flours were infested, the same difficulties were experienced as are described in the preceding section when infested clears are used for blending.

Returned flour that is infested should be sterilized by heat, treated by centrifugal force or by some other accepted method, and diverted to feed immediately. It should never be stored even temporarily in the mill or flour warehouse.

Mills that deliver by truck encounter the problem of providing for the return of infested flours during their regular delivery trips. If freshly milled flours are placed in the same truck with infested flours, they are likely to become infested also. Not infrequently, insects crawling from the infested products are delivered to customers along with fresh stocks of flour. If returned flour products must be picked up in the course of a delivery trip, provide the truck with a separate compartment into which these products can be placed, thoroughly clean the truck between trips, and burn or otherwise treat the sweepings so as to destroy the insects they contain. Feed and flour should never be delivered in the same truck.

Second-Hand Machinery

Used machinery occasionally is purchased from mills that are being dismantled. All milling units are likely to contain some infestation, and machinery that has been lying idle for some time is almost sure to be heavily populated with insects, because they thrive and reproduce rapidly in undisturbed accumulations of milling stock. Unless proper precautions are taken, used machinery may introduce insects into a mill. Infestations of the Mediterranean flour moth are known to have been frequently carried from one mill to another in this way.

If possible, second-hand milling machinery should be fumigated in an atmospheric vault, under a tarpaulin, or in a railway box car before it is set up in its new quarters.

Accumulated Feed Stocks

The practice of storing certain feeds in the mill or flour warehouse during periods when such feeds are accumulated is exceedingly common. It is difficult to produce feed that is entirely free from insect infestation, owing to the impossibility of sifting it through fine enough mesh to remove insect life. If feeds are stored near flour or milling machinery, insects are sure to migrate from the feeds.

Feeds can be treated by centrifugal force in such a manner that all insect life is killed, but unless mills are equipped for this, the feeds should be stored in a separate warehouse as far as possible from the mill and the flour warehouses. Of course, warehouses should be kept sanitary.

Infestation From Nearby Elevators

Many of the insect pests of stored grain and milled cereal products are strong fliers. During grain-cleaning operations it is not uncommon for insects removed in the process to be blown out into the open air. Many of these insects will fly from elevator to flour mill, where they will start infestations in elevator boots or in any milling unit into which they can crawl. The red flour beetle and the flat grain beetle are the two species most likely to come from such sources. Insects removed in grain-cleaning operations should be destroyed immediately.

Insect Population in Flour Mill

The insect population of a flour mill is of vital concern to the miller, because his ability to produce insect-free flour is closely related to the absence of insect population in the milling streams.

Information relative to insect populations in milling machinery at different times of the year, and as affected by different methods of milling and insect sanitation, has been obtained through monthly collections of samples of stock from a number of mills over a period of several years. Of 2,367 8-ounce samples of stock taken from elevator boots or purifier conveyors during 1934–35, 80 percent were found to be infested (fig. 1). In these samples 74,175 insects, representing 30 species, were found. The relative abundance of the 6 species occurring most frequently is shown in figure 3. The flour beetles (*Tribolium* spp.) were predominant. The relative abundance of insects in the various milling streams, as shown in figure 1, is attributed to the relative attractiveness and nutritional value of the various milling fractions. The heaviest populations are found in low-grade flour.

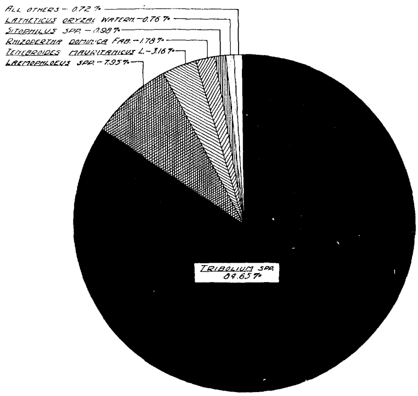

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Figure 3.—Percentage of different species of insects taken in milling streams of 17 flour mills in Kansas, Oklahoma, and Missouri during a 1-year period (1934–35).

The Mediterranean flour moth was formerly the most troublesome pest of flour mills, owing to its abundance and the habit of the larvae, or worms, of spinning silken threads wherever they crawled, webbing and matting the flour particles together and clogging the machinery until operations had to be shut down. Although this insect is no longer a serious pest in mills that fumigate annually, it is still common in some mills.

Any species of insect that attacks grain may be found in a flour mill. These insect pests of stored grain are described and figured in U. S. Department of Agriculture Farmers' Bulletin 1260 (revised 1955), a copy of which may be obtained by writing to the Office of Information, U. S. Department of Agriculture, Washington 25, D. C.

Controlling the Insect Population in Flour Mills

Insects will breed in any location where accumulations of flour, grain, or other milling stock remain undisturbed. The miller must eliminate such accumulations or treat them with fumigants.

Double floors or walls provide harborage for insects making them difficult to eliminate. Poorly designed milling units also create problems. Danger spots are elevator boots; conveyors for flour, grain, or dust; conveyors on reels and purifiers; dead spouts and conveyors; dust-collecting systems in general; and the bottom and idle sections of certain types of sifters. A certain amount of stock remains undisturbed in these milling units.

Redesigning milling equipment or replacing it with more modern machinery will do much toward eliminating insect breeding places. A pneumatic conveying system for mill stock solves many of the problems of keeping a mill clean and sanitary. Pneumatic lifts require far less floor space than elevator legs and can be located alongside the walls. The space formerly taken up by elevator legs can be used for additional machinery.

Conveyors on reels and purifiers should be replaced by hoppers.

Dust-collecting systems require constant attention. Many are poorly designed, quickly become choked-up, and allow infestations in the stock in these systems to crawl back and infest all milling units. Systems in which settling chambers are eliminated are preferred. Enclosed stocking-type dust collectors that permit rapid effective fumigation are highly desirable from the standpoint of insect control. The system must be cleaned out regularly.

Elevator boots should be changed to the rounded-bottom type raised above the floor. This will eliminate most of the excess milling stock and prevent insects from crawling from one boot to another.

In modern concrete mills with concrete floors and walls, the problem of mill sanitation is not so difficult as in an old wooden mill. Every effort should be made to eliminate dead spaces in walls and floors where dust and flour can accumulate. Double, hollow walls and partitions should be eliminated. If floors are of wood, all cracks should be filled. Old wooden floors or badly worn concrete floors that are difficult to keep clean can be renovated by application of quick-setting plastic over the old surface.

Surplus flour-handling equipment, and all other unused machinery likely to harbor insects, should be disposed of.

Sanitation in the Mill

A good sanitation program should be followed in every mill. One man should be designated to see that the mill is kept clean and sanitary and to study ways and means of eliminating trouble spots. Daily inspections should be made, starting with the mill elevator and continuing through all floors of the mill and flour warehouse. Care should be taken to see that there are no leaks in grain or flour-handling machinery, or that leaky milling units are repaired; that the floors and hard-to-reach places are kept clean by the sweepers; that unused machinery, lumber, and other materials likely to collect dust are disposed of; that dead stock does not accumulate under milling units or other stationary objects, on beams, ledges, or other places; that insects are not breeding in elevator boots, conveyors, or other machinery where dead stock occurs; that dust-collecting machinery is functioning properly and is not choked. A more mechanized system of cleaning flour mills is highly desirable. A proper combination of vacuum, mechanical floor sweepers, and judiciously used compressed air jets must be used if sanitation in the milling industry is to become more effective and economical in comparison with other industries.

Prevention and Control

In spite of every precaution some insect infestation will show up in every mill. Conditions in the flour mill system are ideal for insect development, so that an active control program must be established and maintained in every mill to hold the insect population to negligible proportions at all times. The following program, if adhered to, can be depended upon to give satisfactory results.

A general fumigation with methyl bromide, hydrocyanic acid, or chloropicrin once a year during July or August, supplemented with the local fumigation of milling units every 2 weeks, and the biweekly removal of milling stock with a heavy-duty vacuum cleaner.

If it is impossible to adhere to this program during periods requiring continuous operation of the mill, considerable relief from infestation may be obtained by regular use of the heavy-duty vacuum cleaner in cleaning out dead stock in milling units during short periods of "down" time for necessary mill repairs. This operation will not require the amount of time needed for local fumigation. Certain heavily infested individual machines can be stopped long enough to vacuum-clean them.

Use of Sprays in the Mill

Insecticidal sprays are a very useful part of any mill sanitation program, but their use must be carefully controlled as it is mandatory that no insecticidal residues appear in the milled products. Synergized pyrethrum or allethrin are effective as contact sprays against mill insects and can be safely used inside and outside milling machinery. When stock is removed from milling units by vacuum cleaning, many millers follow up with pyrethrum spray. Many formulations are available commercially and they should be used as directed by the manufacturer. It is suggested that other insecticides used as residual sprays on walls and floors be limited to those approved for use on or around grain.

Keeping the Tail End of the Mill Free From Insects

The main bolters act as a natural barrier against insect infestation entering the tail end of the mill, as the sifter screens through which all flour must pass before it enters the flour-collecting conveyors are clothed with silk bolting cloth fine enough to remove all insect life. Occasionally, however, breaks in the silk bolting cloth allow insect infestation to pass into the flour-collecting conveyors.

Furthermore, whenever sifter sections are opened for inspection or repair, infested tail-overs may drop into the flour spouts and into the conveyors unless the sifter socks are first removed. When making these inspections and repairs, remove the lower sifter socks first, and place a close-fitting metal cap over the sock connection with the slide spout, until repairs have been completed and sifter sections have been thoroughly cleaned.

If infestations are allowed to build up without restraint in milling units in front of the main bolters, the danger of insects getting past the bolters by the avenues mentioned will be increased. When insects are abundant in any part of the mill they will migrate, and if flour conveyors are of wood or not entirely tight, insect infestation will result from the entry of these migrating insects or their progeny.

The introduction into mixing conveyors of clear, low-grade, and returned flours from rebolt reels is also an important source of infestation in the tail end of the mill. Such stock should be given a precautionary treatment before it is used for blending purposes.

Sweepings should be directed through a "shoe" or small sifter to remove foreign material and then treated by centrifugal force before being introduced into feed.

A centrifugal force machine (fig. 2), used alone or in conjunction with sifters, will provide added protection against infestation in finished flour. One of these machines can be installed directly in the top of packer bins, or outlet spouts from it can be directed to one or more bins as desired.

Handling Choke-up Stock

Clean choke-up stock fed into the head of the mill, usually into first, second, or third break, is picked up in sacks and may be stacked temporarily next to sweepings. This stock should be directed through a "shoe" or small size sifter and then treated with centrifugal force before being fed back into the mill.

Fumigation in the Flour Mill

At times all mills become so infested that simple sanitary measures are insufficient and more effective treatments, such as fumigation or heating, are necessary.

General Considerations

The fumigation of flour mills and warehouses is a specialized operation, the success of which is dependent on the care and skill with which it is accomplished. Owing to this fact and also because the fumigants used in the work are highly toxic to humans and dangerous to handle, it is usually best to have general mill fumigation done by professional fumigators. Reliable fumigating concerns are usually available in all parts of the country and on reasonably short notice, and render good service for a moderate price. Some of them specialize in mill fumigation and are particularly well equipped for it. For certain types of fumigation large concerns may wish to keep a corps of specially trained workers.

Success in the fumigation of any building depends on the proper preparation of the building itself, the choice of the fumigant, its proper application, and favorable weather conditions. Since insects are more susceptible to fumigants when temperatures are high and fumigants are correspondingly more active and efficient, better results will be obtained when the temperature is 75° F. or higher. If possible, conduct the fumigation when there is little or no wind, as a heavy wind will cause the fumigant to drift over to one side of the building, leaving an inadequate concentration at the other side.

It is desirable to obtain the maximum concentration of a fumigant in a building at the earliest possible moment. If the concentration builds up slowly, the natural leakage may be great enough to prevent an effective concentration from ever being attained.

Before starting to fumigate, notify the local police and fire departments as well as security organizations in writing. In most large cities a permit must be obtained. Search the entire mill to make certain that no visitors or workmen are still on the premises, lock all entrances, and put up warning signs. Adjoining buildings, if any, should be vacated.

After the fumigant has been introduced, post watchmen to prevent the entry of people who do not know the building is under fumigation.

At the end of the exposure period, ventilate the building thoroughly by opening doors, windows, and ventilators. This is usually accomplished by men wearing gas masks, although sometimes doors and windows can be opened from the outside. In all fumigation operations it is well to have men working in pairs so that in case of accident, one man may be able to help the other and perhaps even save his life. Watchmen must be particularly vigilant to prevent bystanders or workmen from entering until all danger from the fumigant has been removed.

Protection of Personnel

Every precaution should be taken to avoid exposure of the operators to heavy concentrations of fumigants. **If the operators must expose themselves to the vapors, or must enter a building being fumigated to open it up for ventilation or any other purpose, they must wear gas masks.**

Always have an adequate oxygen resuscitator available in case of emergency.

There are two general types of gas masks. One has a facepiece and a supply of oxygen or compressed air provided from a pressure cylinder carried on the operator's back (similar to those used in "skin-diving"), or from a remote source through a hose line. The other, which is most frequently used, has a facepiece and a canister. Gas-laden air is drawn through the canister and the gas removed by filtration. The facepiece of rubber or rubberized fabric can be adjusted to fit tightly across the forehead, along the cheeks, and under the chin, and is connected by a short, flexible, noncollapsible tube to a sheet-metal canister containing absorbent materials. A light harness or knapsack is provided to suspend the canister from the shoulders or to strap it to the chest. The facepiece is provided with shatterproof glass eyepieces and with a check valve through which exhaled air escapes. At the bottom of the canister is a check valve, which opens only to admit air.

Some canister types of masks have the facepiece reduced to a mouthpiece and a nose clamp. The wearer breathes through a rubber device inserted and held in the mouth. This type does not protect the eyes from irritating gases and is not recommended.

For each of the gases likely to be encountered in fumigation work, a special canister is available. Most canisters are charged with materials intended to absorb only a limited number of closely related gases, although the all-service canister is designed to afford protection from a combination of gases. A color code has been adopted by the Bureau of Mines whereby canisters designed for different gases are assigned a specific color, e. g., a white canister gives protection against low concentrations of acid gases such as hydrocyanic acid and sulfur dioxide; a black canister, against organic vapors such as carbon disulfide, carbon tetrachloride, chloropicrin, ethylene dichloride, and methyl bromide; a yellow canister, against a combination of acid gases and organic vapors; and a red canister against a combination of gases. A list of gas masks of different makes that have been approved by the U. S. Bureau of Mines is given in Bureau of Mines Information Circular 7636, and is available free from their Pittsburgh, Pa. (Zone 13) office.

Before using a canister-type gas mask in fumigation work, the operator should realize that it has certain limitations. (1) **A mask of the type described above cannot be safely used in an atmosphere seriously deficient in oxygen.** A gas mask ceases to be adequate if, in the presence of an excess of a simple asphyxiant gas, the oxygen content of the air falls below 14 percent, even though it removes any toxic gas present in the respired atmosphere. Not enough oxygen is available to support life. (2) **The ordinary gas mask does not afford protection against heavy concentrations of a fumigant such as might be encountered in a grain bin or atmospheric vault under fumigation.** Most canisters are designed to protect against concentrations of less than 2 percent of toxic gases in the air. In ordinary mill fumigations, concentrations heavier than this are not usually encountered. (3) **The life of the canister is limited; it can absorb just so much gas and then must be changed.** A good practice is to discard canisters after one-half hour of actual use in air containing a toxic gas. Each canister should be marked to indicate the total period it has been used.

Unless a gas mask fits tightly, is free from defects, and does not leak, it is useless. Before entering a gas-filled room, an operator should be sure that the mask is carefully fitted to the face and head, that it is securely fastened, and that there are no leaks. On first entering a gas-filled room while wearing a gas mask, he should make sure that there is no odor of the fumigant. If any odor is detected, he should leave the building immediately and determine the trouble.

It must also be realized that fumigants can be absorbed directly through the skin. Do not take for granted that the wearing of a gas mask will afford complete protection. Heavy gas concentrations are particularly dangerous, and care should be taken to avoid exposure to them, even though a mask be worn.

First Aid

In case of poisoning by toxic gases or asphyxiation due to lack of oxygen, a doctor should be summoned as quickly as possible. Forbes and Grove [6] suggest the following treatment:

1. **Remove the victim to fresh air as soon as possible.**
2. **If breathing has stopped, is weak and intermittent, or is present in only occasional gasps, give artificial respiration, preferably by the prone-pressure method, until normal breathing is restored or until it is definitely believed that the heart action has stopped.**
3. **Aid circulation by rubbing the limbs of the victim and keeping the body warm with blankets or hot-water bottles.**
4. **It cannot be emphasized too strongly that inhalation of pure oxygen or 5 to 7 percent of carbon dioxide and 95 to 93 percent of oxygen, beginning as soon as possible and continuing for 20 to 30 minutes in mild cases and as long as 1 to 2 hours, if necessary, will be helpful in gas poisoning or asphyxiation.**
5. **Keep the victim lying down so as to avoid a strain on the heart; later give him plenty of time to rest and recuperate.**

Preparing the Mill

Sealing

The effectiveness of a fumigation depends largely on the tightness of the building. Instead of each floor being fumigated separately, the entire mill should be considered as one unit, because inspection and observation after fumigation have shown that many insects can survive in the sacking or other material used to plug openings running from floor to floor. All windows should be tightly wedged or sealed, and any broken panes should be replaced. Loosely fitting window sashes should be sealed with paste and paper, or "puttied up" with flour and oil mixed to the consistency of putty. For stripping window frames that are only slightly loose, several types of material, such as masking tape, strips of newspaper smeared with grease or pasted with flour paste, or rolls of unsterilized adhesive tape, can be used. When it is impossible to tighten a window by the ordinary method of sealing or stripping, it is necessary to seal the entire aperture. For this purpose car-lining paper can be used.

Small doors leading to the exterior of the building can be tightened with any of the materials used for the windows. Large sliding metal or wooden doors that fit imperfectly can be calked up with the flour-and-oil mixture or with a paste composed of 4 parts of asbestos to 1 part of calcium chloride mixed with a little water. Either of these mixtures will form an effec-

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[6] Forbes, J. J., and Grove, G. W. Protection against mine gases. U. S. Bur. Mines Miner's Cir. 35, 52 pp., illus. 1954. (For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price 55 cents.)

tive seal yet can be easily removed after fumigation.

For sealing ventilators on the roof, use laminated paper, three thicknesses of heavy paper covered with sacking or canvas and well pasted and tied, or covers made of plastic film. Wherever possible, remove the mushroom-shaped cap of the ventilator and replace it with a metal cap, which fits the cyclone exhaust pipe snugly.

Cleaning Operations

Before Stopping the Mill

1. Shut off feed (wheat) at mixing bin.
2. Continue running all machinery until material is emptied from spouts, elevators, rolls, sifters, reels, purifiers, feed dusters, suction trunking, and dust collectors.
3. Remove elevator-boot slides and station men along the boots to keep stock pulled out where belt cups will not carry it up in its natural course.
4. Meanwhile, hammer elevator legs, machinery, frames, tubular dust collectors, and spouts with a rubber mallet or other device that will not bruise or injure the equipment.

After Stopping the Mill

1. Start the entire clean-up crew at the top of the mill and work downward.
2. Open all machines, conveyor boxes, and flour bins.
3. Clean out suction trunks, conveyors, and dust-collector systems.
4. Examine settling chambers of dust collectors and clean out all accumulations.
5. Open dust collector, back drafts, main trunks, and hand openings.
6. Loosen all sifter doors to permit entrance of gas during fumigation; remove sieves and stack same on the floor.
7. Clean out accumulations from bottom section of the bran duster.
8. Remove covers of all conveyors, making certain that all dead-end spaces are readily accessible.
9. Thoroughly clean all conveyors, including dead-end spaces.
10. Remove adjustable feed gage above grinding rolls and clean out accumulations above rolls and feeders.
11. Leave every machine open; also all hand openings to spouts, elevator legs, and similar places.
12. Give special attention to the cleaning out of dead spouts or conveyors, especially the corners.
13. Remove accumulations of stock from elevator boots.
14. Remove to the fumigation vault all infested materials accumulated in cleaning the mill.
15. Remove all bags or other materials used to plug spouts.
16. Seal roof ventilators or replace mushroom-shaped caps with a tight metal cap.

Fumigation With Hydrocyanic Acid

Hydrocyanic acid has been used extensively as a fumigant for flour mills for many years. It is particularly well adapted for this type of work because many mills are not built to hold a gaseous fumigant for any extended period and only a gas that acts quickly can be effective. Hydrocyanic acid gas kills with great rapidity; therefore, notwithstanding the fact that all the gas may be lost in a short time, a nearly perfect kill may have been obtained.

Several methods of fumigating with hydrocyanic acid have been developed, all of which have their application. Of the various methods of generating the gas, that of vaporizing liquid hydrocyanic acid is used most extensively.

Liquid hydrocyanic acid (96–98 percent HCN) is marketed in cylinders ranging in capacity from 30 to 75 pounds. There are several ways in which liquid hydrocyanic acid can be used, all of which are effective.

Open-Space Application

The method by which liquid hydrocyanic acid is most commonly used in the United States consists in forcing it into the open space of a flour mill through a system of metal piping equipped with spray nozzles. The cylinders containing the gas are attached to a manifold on the outside of the building and the fumigant is forced into the piping system by means of compressed air (fig. 4).

Piping the Mill

In mills fumigated by the liquid method a permanent system of piping is often installed. Either brass, copper, or certain plastic piping is recommended. Iron piping is less expensive, but because of its tendency to rust and cause clogging of the spray nozzles it is less desirable. A flexible copper tubing 3/8-inch in diameter costs about 13 cents a foot. Since it can be readily bent, elbow fittings are unnecessary, and compression couplings can be used, except at the main inlet, where the cylinders are connected.

In normal times most mills can be piped with copper tubing at a cost of 25 to 30 cents per 1,000 cubic feet of space, including cost of material and installation. Brass tubing costs several times as much as copper. Commercial fumigators are usually equipped with sufficient reinforced rubber hose so that they can introduce the liquid hydrocyanic acid through hose if a piping system has not been installed. The hose is laid on the floors of the mill and spray nozzles are connected in whenever desired. A line of hose is run from each floor to a point out-

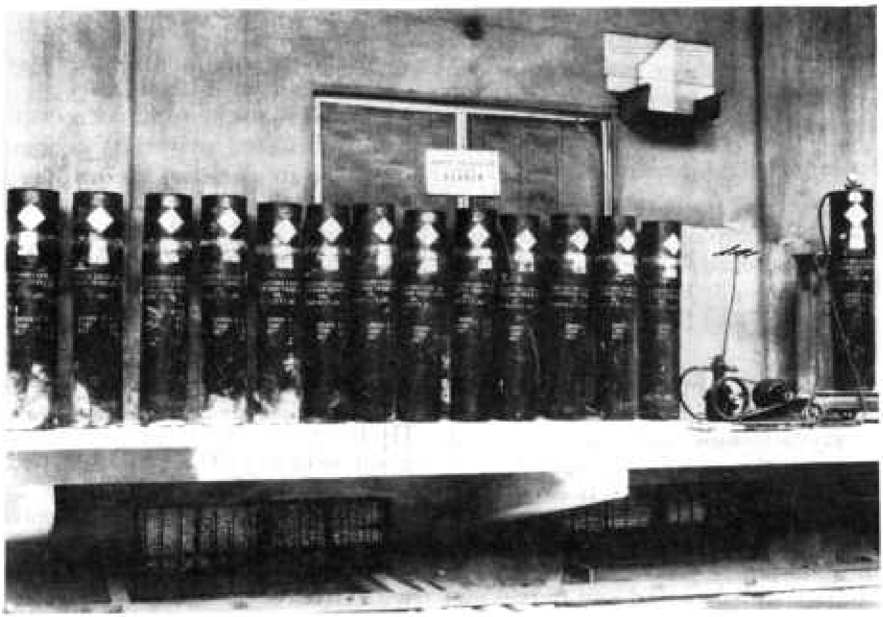


Figure 4.—Liquid hydrocyanic acid being pumped into a flour mill undergoing fumigation.

side the building where it can be connected to a cylinder of gas.

In large mills with several floors, where numerous branch lines are used, each floor should be provided with a separate riser. At least one spray nozzle should be provided for every 10,000 cubic feet of space, and it is generally advantageous to use more than this. The piping system should be so arranged that the pressure of the gas will be approximately the same at all nozzles, thus insuring an even distribution of the gas. Each riser is connected with a special inlet pipe leading through the outside wall of the building.

Piping plans are usually designed by an employee of the fumigating company after he has surveyed the building. Should blueprints of the mill or rough sketches and measurements be forwarded to one of these companies for making piping plans, be sure to show offsets and whole or part partitions. Note any other special condition, such as heavily infested machinery, rows of packing machines, or other places of heavy infestation, so that an extra spray nozzle may be added at this point if it is thought advisable. There should not be more than 10 spray nozzles to each riser. Where grain or flour bins are piped, a separate riser for these bins should be used.

Reinforced rubber hose is used to connect the cylinders to the piping system. This hose must be kept in good condition, since there is always some danger that the weakened hose may burst under pressure and shower the operator with the deadly fluid.

Before applying the material, take care that all connections outside the building are tight. Should a leak develop where the hose from the cylinder is attached to the piping, the connection can be tightened with reasonable safety if the operator wears a gas mask and is careful that the liquid does not spray his clothing. Operate the pipe wrench with the handle above the connection instead of below it, so the material will not run down the handle onto the arms and clothing. If in doubt whether the spray has reached the clothing, or if the liquid has run down the arms and possibly onto the shirt or coat, remove the clothing and wash the hands and arms *before removing the mask.*

Applying the Gas

Each cylinder of liquid hydrocyanic acid is supplied with an inlet and an outlet valve. The outlet valve is attached to a steel tube connected with the bottom of the cylinder. The inlet valve leads directly into the top of the cylinder, and through it air is pumped by means of a compressor, until a pressure of about 100 pounds is obtained. The outlet valve, which in the meantime has been connected with the inlet pipe to the building, is then opened and the liquid is forced into the building. The pressure must be maintained until all the liquid has been blown through the pipes into the building. The pipelines are then blown clear and the inlet pipes capped.

Removal of Spray Nozzles

After the fumigation and after the building has been well ventilated, the spray nozzles should be removed for storage and the pipes should be capped. **While removing spray nozzles the operator should take care to prevent any liquid, which sometimes remains in the pipe, from dropping onto the face or other parts of the body. He should never stand directly under the nozzle while removing it. Should any liquid hydrocyanic acid be lodged behind the nozzle, a decided cooling effect will be noticed while the nozzle is being unscrewed. It is**

best to use a gas mask in this work.

Special pressure nozzles which do not clog and need not be removed are now on the market.

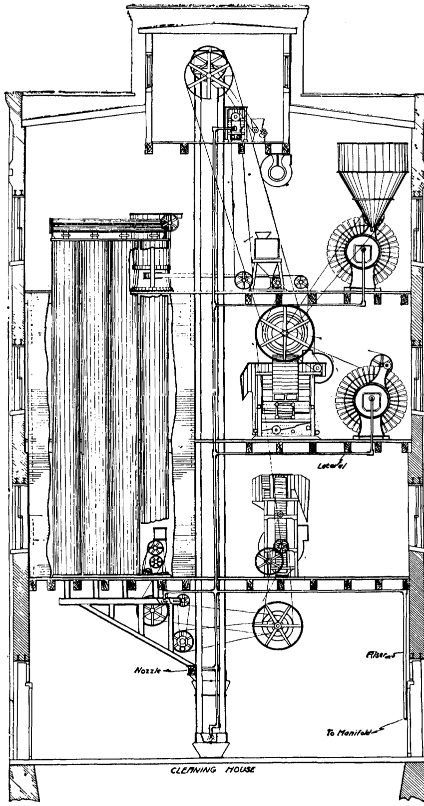
Dosage Rate

The dosage will depend on the construction of the mill and the degree of penetration desired. In general, 8 ounces of liquid hydrocyanic acid for each 1,000 cubic feet of space will give excellent results. Ordinarily the gas is evenly distributed on all floors, but a larger quantity should be used on floors that contain more machinery than others.

Experimental work has shown that if the mill is of modern concrete or brick construction much of the labor of preparing the mill for fumigation may be avoided by increasing the dosage to 16 ounces per 1,000 cubic feet of space. Aside from sealing up the building and opening up the machinery according to directions, no other preparations are necessary. The extra gas introduced will ensure the penetration of stock in the various milling units.

Machinery-Piping System

A refinement in the fumigation of flour mills with liquid hydrocyanic acid consists in applying the liquid fumigant directly into the milling units by means of a series of pipe lines (figs. 5 and 6). By using spray nozzles that open when a uniform pressure is obtained throughout the system, equal quantities of fumigant are supplied to each milling unit. The spray nozzles are so constructed that when the pressure is removed a flexible diaphragm recoils, the holes in the diaphragm through which the fumigant is discharged being closed by a central pin. This prevents foreign matter from plugging up the nozzles between fumigations.



AMS Neg. 4323-57(7)

Figure 5.—Method of piping machinery in a flour mill for fumigation with liquid hydrocyanic acid. Cleaning house.

As is the case with the open-space system, the gas is applied from outside the mill. A considerable saving in cost is effected by using this method, as a much smaller quantity of gas is required to produce a very high concentration in the milling units, where most of the insects in the modern mill are to be found. Furthermore, by this method it is unnecessary to dismantle and clean out the machinery. It is estimated that the saving in labor and shutdown time, together with the saving in fumigant required, will allow two fumigations for the same cost as one by the open-space method. It is considered that enough

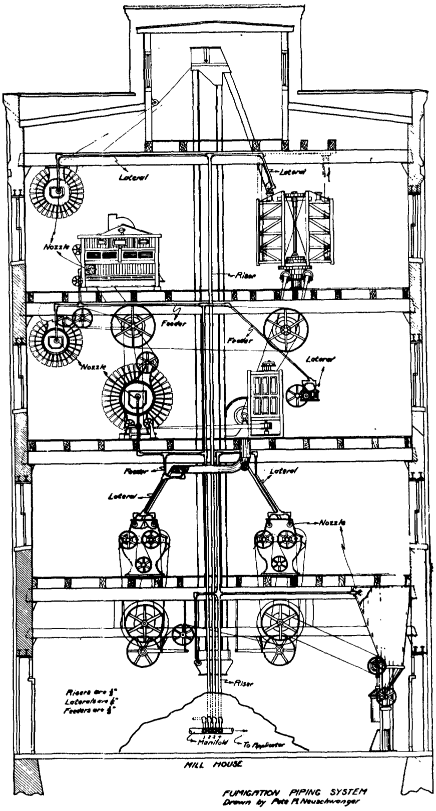


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Figure 6.—Method of piping machinery in a flour mill for fumigation with liquid hydrocyanic acid. Mill house.

gas will escape from the machinery to care for any insects that are in the open space of the mill. In old wooden mills the woodwork often harbors large numbers of insects, not all of which are reached by the gas when it is applied by the machinery-piping system. For this type of mill the open-space method of fumigation would probably be more satisfactory.

Additional Preparations

Before the mill is shut down the preparations noted previously should be followed; however, it is not necessary to open up the machinery. In addition:

1. Loosen sifter doors (except Wolf sifters) slightly to allow circulation of gas into all sifter sections.
2. Remove accumulations of milling stock behind feed gates or purifiers and either tie or block open the feed gates to allow passage of gas into slide spouts that carry stock into the purifiers. Seal purifier ventilator doors with kraft paper.
3. Adjust dividing gates, or tips, below the cant boards in reels and purifiers so that they are vertical or so that half will open one way and half the other way. This is essential in order that there may be equal distribution of gas into all the conveyors. Remove stock accumulations in reel and purifier-conveyor ends beyond reach of the flights, as well as any packed accumulations. Reel and purifier-conveyor housing covers should be kept closed.
4. Remove accumulations of stock above the roll feed gate, clean housings, block open the feeder gates, and close all housing doors.
5. Raise hand levers of Buckley grinders, thus compressing driving springs and separating grinding surfaces to permit passage of gas through the mechanism.
6. Splitter valves on slide spouts should be placed on center to eliminate possibility of dead-air spaces.
7. Before fumigation, apply air pressure to the piping system and examine each spray nozzle to see that it is working properly. Leaky connections should be tightened. The care expended in keeping the lines and nozzles clear of deposits will be a big factor in the success of fumigations by this method. Lines should be blown clear of the liquid fumigant after each fumigation.

Applying the Gas

When the liquid hydrocyanic acid is introduced into the various milling units the gas must be forced into the fumigation lines with sufficient pressure to ensure a uniform distribution. As the standard hydrocyanic acid cylinder has too small an aperture to allow this, it is necessary to employ a special applicator consisting of a small steel tank holding 35 pounds of the liquid and capable of withstanding a working pressure of 200 pounds. The gas-outlet valve on the top-central part of the cylinder is connected with a ½-inch copper tube extending to the bottom of the tank. This tube is larger than that used in the hydrocyanic acid cylinder and permits the gas to flow as rapidly as required. Gas-inlet valves (¼-inch brass) and a pressure gage are also located on the top-central part of the applicator. From the tank connection of the gage a bypass of ¼-inch copper tubing, supplied with a valve, is connected to the gas-outlet line between the gas-outlet valve and the manifold of the piping system. This bypass allows the pressure created by the transfer of the hydrocyanic acid from the shipping cylinder to the applicator to escape into the manifold, thus facilitating the filling of the applicator.

Dosage Rate

Liquid hydrocyanic acid is forced into the various lines at the rate of about 8 ounces for each spray nozzle. Some fumigators prefer to use a heavier dosage, but this is rarely necessary.

At the end of the fumigation the mill can be ventilated in the manner employed in other fumigations. Workmen wearing gas masks should open all doors and windows to allow air to circulate through the building. Roof vents should be opened as soon as possible to allow the gas to escape from the machinery.

To avoid accident from small quantities of fumigant left in the system, compressed air should be forced through all fumigation lines long enough to ensure a complete removal of hydrocyanic acid. This should be done during the ventilation process and before workmen are allowed to enter the building.

Fumigation With Methyl Bromide

For the fumigation of modern, tight, concrete, stone, or brick mills, methyl bromide has been found highly efficient. It is not recommended for use in mills of wood, or of frame and sheet-metal construction, owing to the difficulty of holding the vapors long enough to obtain a satisfactory kill. A special technique, ordinarily too costly to be employed, is required for making this type of building tight enough for methy bromide fumigation.

Methyl bromide is a colorless almost odorless liquid that boils at 40.1° F. At ordinary room temperature it is a gas, in which state it is more than 3 times heavier than air. It is obtainable commercially in liquid form in 1-pound cans or in cylinders containing 50 or 175 pounds net. The natural pressure of the gas is sufficient at room temperature so that both cans and cylinders are self-emptying when opened. The pressure in the cylinders, however, is increased slightly by the manufacturers to facilitate the rapid removal of the gas.

Methyl bromide is relatively inexpensive at the dosages required for fumigation, highly toxic to all stages of insects including their eggs, noninflammable at concentrations used in commercial practice, and can be used successfully at comparatively low temperatures.

It has remarkable powers of penetration and is undoubtedly the most efficient fumigant known for the treatment of warehouses filled with bagged commodities. **Lacking a distinctive odor, this gas is but faintly noticeable in small amounts, a feature that creates a hazard not present with some of the rapidly toxic gases that possess distinctive warning properties.**

Methyl bromide can be applied through a piping system in much the same manner as that described for liquid hydrocyanic acid or by releasing the gas directly into the open space from cylinders placed at strategic points in the mill. Each cylinder of methyl bromide is equipped with a siphon tube so that it can be emptied without inverting the cylinder.

If the gas is to be introduced into a mill through a piping system, the pressure in the cylinders should be increased with compressed air to 150 pounds. The cylinder or cylinders are then connected to the manifold of the piping system on the outside of the building. After the valve is opened, the pressure forces the fumigant from the cylinder into the fumigation lines at the rate of about 10 pounds per minute. In cool weather the pressure in the cylinder must sometimes be built up with compressed air a second time to speed up the emptying of the cylinder and the application of the gas. A 3-way connection between the cylinder, the manifold, and the air compressor will facilitate this operation. For large mills, where this method of applying the gas is best adapted, the 175-pound cylinders will be most convenient.

Small mills that do not have piping systems can be fumigated by distributing the requisite number of cylinders uniformly over the several floors and releasing the gas by opening the valves (fig. 7). The 50-

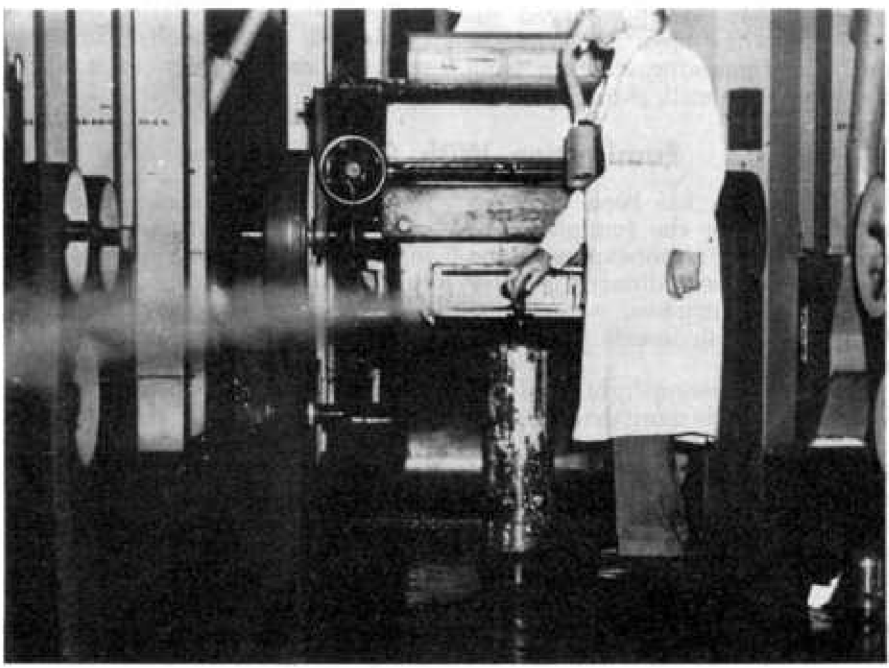

Figure 7.—Applying methyl bromide in a flour mill.

pound cylinders will be found most useful for the purpose and will enable the fumigator to distribute the gas uniformly over the building. One-pound cans can be used to supplement the dosage and are particulary useful for treating small rooms that are cut off from the regular mill space. Each floor of the mill should be provided with large portable fans, which should be operated for at least 1 hour after the gas is introduced, to ensure a proper distribution of the gas.

In applying the gas, the fumigator must be careful not to expose himself to the concentrated vapors, and for his protection he should be supplied with a gas mask equipped with a black canister designed to protect against organic vapors. If the gas is applied from the outside of the building it is not necessary to wear a gas mask unless the manifold or cylinder connections are leaky, although the mask should be kept handy for use in case of emergency. Where the cylinders are discharged directly into the open space of the mill, the fumigator, starting from the top of the mill, should proceed from floor to floor, opening the valves of the cylinders by hand and discharging any 1-pound cans required. **Two men wearing gas masks should work together and should release the gas as rapidly as possible so that they will not be exposed to a heavy concentration of the fumigant, which might be hazardous even though they are protected by masks.**

A dosage of 1 pound per 1,000 cubic feet of space is adequate for the fumigation of well-constructed mills.

An exposure period of from 16 to 24 hours should be allowed, after which the building may be opened up for aeration. The same precaution should be taken in ventilating the building as when hydrocyanic acid or other toxic gas has been used.

Workmen entering the building to open the windows and doors must wear gas masks equipped with black canisters. Under ordinary conditions, a mill that has been fumigated with methyl bromide will air out rapidly after it is opened up.

Fumigation With Chloropicrin

Chloropicrin has been used for many years for the fumigation of flour mills. It is nonexplosive and nonflammable as ordinarily used for fumigating purposes, and is extremely toxic to insects as well as man.

It is a colorless or slightly yellowish liquid a little more than one and a half times as heavy as water. It has a boiling point of 233.6° F. and on exposure to air evaporates slowly forming a mixture of gas and air that is slightly heavier than air at the same temperature and pressure. It is disagreeable to handle owing to the lachrymatory properties of its vapors; however, this can be considered as a safety factor since it is improbable that anyone would willingly enter an atmosphere containing an appreciable quantity of chloropicrin.

A full-face gas mask supplied with a canister designed to protect against organic vapors should be worn while applying the fumigant or in transferring it from cylinders to vessels used in dispensing it. Care should be taken not to spatter the liquid on the hands or feet or other areas of the body since blistering of the skin may result.

Chloropicrin is available in two forms, with or without a propellant. The propellant form is available in 50-pound containers of a 30–70 mixture of methyl chloride and chloropicrin.

When the valve is opened the methyl chloride propels the chloropicrin from the applicator in a fine mist that vaporizes rapidly. A plastic or copper tube extension can be fitted to the outlet valve so as to release the fumigant in the upper part of each floor of the mill. Place the container in the approximate center of the space to be fumigated, and adjust it so that there are no obstacles (particularly belting) within 12–15 feet of it in directions in which the fumigant will be discharged. Cap and plug the end of the extension tube leading from the cylinder and bore a hole in each side of the tube so that the fumigant will be discharged horizontally in two directions. In cold weather, store the containers in a warm room for at least 12 hours before they are used. This will increase the pressure in them sufficiently to insure a satisfactory discharge of the chloropicrin.

If condensation on the floor is expected, spread empty burlap sacks on the floor 10 feet on each side of the point of release.

The fumigators, wearing gas masks, should open the valves one full turn, and be careful to stand so that they will not be sprayed by the discharge. They should work rapidly and leave the mill as soon as possible.

In some cases a semi-permanent piping system is installed of 3/8-inch o. d. polyethylene tubing. Copper jets for discharging the gas are spaced 20 to 30 feet apart. One jet should be allowed for each 1,000 cubic feet of space, with not more than 3 jets to a line. The jets are rigid copper tubing 18 inches in length connected to the polyethylene tubing with a brass tee. The free end is pinched shut and is supplied with a 1/16-inch orifice drilled through both walls 1 inch above the pinched end.

Each floor of the mill or warehouse should be provided with one or more lines fastened to the ceiling and extending to the outside where they can be connected to a cylinder containing a mixture of chloropicrin and methyl chloride pressurized to 100 pounds. A dosage of from 1¼ to 1¾ pounds of the mixture should be used per 1,000 cubic feet of space depending upon the quantities of machinery in the mill.

If the chloropicrin is used without a propellant, it can be sprinkled on empty sacks spread on the floor or poured on a pile of empty sacks.

A minimum of 1 pound of chloropicrin should be used per 1,000 cubic feet of space. The required quantity of chloropicrin for each floor should be distributed in handy containers before the fumigation.

After an exposure of 24 hours, the mill should be thoroughly aerated before milling operations are resumed.

Local Fumigation

The treatment of an individual machine in a mill with a fumigant is referred to as a local fumigation. After a general fumigation to eliminate the insect population of a mill, it is only a matter of time before some of the milling units become reinfested from individual insects surviving the fumigation, or through one or more of the avenues by which insects enter the mill. The proper use of local fumigants will keep infestations at a point where they will not be a serious factor. This is particularly true in modern concrete mills where insects cannot find refuge in old woodwork. Some mills rely on periodic local fumigations instead of an occasional general fumigation, but insects that are established in the woodwork will not be affected by local fumigants and will continually reinfest the machinery. Local fumigations can be conducted on weekends or any night after the mill is shut down. For best results they should be given every 2 or 3 weeks. Chloropicrin and mixtures containing carbon tetrachloride, ethylene dichloride, ethylene dibromide, or methyl bromide are used extensively for this purpose.

Dosages of three commonly used formulations are given below as a general guide. For the many other formulations available, follow the directions on the manufacturer's label, but be sure to use a material approved for this use.

Milling Unit	Chloropicrin	Ethylene dichloride-carbon tetrachloride (3 : 1)	Ethylene dibromide 15 percent in a chlorinated solvent
	Fluid ounces	*Fluid ounces*	*Fluid ounces*
Elevator boots	8–10	12–16	12–16
Reels and purifiers	16	16–20	16–20
Sifters (each section)	2–3	12	12
Conveyors (per linear foot)	⅕	2	2
Rolls (each side)	1	8	8
Dusters	5–6	16	16
Bins (per 100 cu. ft.)	1	10	10

These dosages are general, and individual mills and individual machines may require more or less fumigant.

Prior to the application of local fumigants, the mill should be run until empty. However, the milling stock should not be removed until after the fumigation. All vents from milling machinery to the outside should be closed. Dead spouts and filled suction lines should be cleaned.

The fumigants are applied by workmen wearing full-face gas masks equipped with proper canisters. Starting from the top floor of the mill the liquid fumigants are poured, sprayed or dashed into the individual units. Care should be taken to keep liquids off polished metals such as rolls.

When chloropicrin is used, running the machinery for 2 or 3 minutes after application will aid in the distribution of the vapors.

Some manufacturers of local fumigants provide automatic applicators that will measure and inject the desired dose into each milling unit through a small hole made for this purpose.

The points of application will vary in each mill and will have to be determined by experience. In some mills application to the elevator system has been found sufficient. The fumigant is applied at three points—one in the head, and one in each leg on the back side. In most mills, sifters and some of the milling units will require individual doses. By checking results in each milling unit after a fumigation, one can soon discover which unit will require individual doses.

The fumigant should be applied to units on the lower floors first, the operators working up towards the top floor. This is the reverse of the usual method of applying local fumigants. Since it is a machinery fumigation the mill can be well ventilated during actual application of the fumigant. This mixture is also available in small cans containing just enough of the liquid to fumigate one unit. The contents of a can are poured through a funnel into the milling units through the same holes used in treating with the automatic applicator. This method can be used when an applicator is not available.

The mill should be thoroughly aerated after fumigation and before milling operations are resumed. Residual milling stock should be removed from fumigated units with a heavy-duty vacuum cleaner after fumigation so that dead insects will not add to the insect fragment count in the finished flour. This operation can be completed before the mill is restarted, or on the following weekend.

Heat and Cold for Treating Flour Mills

The effectiveness of heat in the control of insects infesting flour mills has been known for several decades. The cost of superheating mills compares favorably with that of fumigation; however, the length of exposure required and the deleterious effect of high temperature on some milling equipment has resulted in the abandonment of this method by all but a few mills. Where it is still employed, air drawn over the steam coils of unit heaters is blown through the mill. This method is superior to the old method which relied on radiation from steam pipes. To be successful, temperatures of from 120° to 130° F. must be maintained for from 10 to 12 hours.

The opening up of mills during a period of subzero weather to kill insects by freezing has been a practice used occasionally in the Northern States and in the Prairie Provinces of Canada. It is not widely practiced in the United States owing to the uncertainty of the weather. During the exposure period it is necessary to drain all water pipes to prevent damage from freezing.

Continuous-Process Heat Treatment of Milled Cereal Products

Milled cereal products too coarse to permit sieving to remove any insect life that might later start an infestation must be given some precautionary treatment to gain this end. Continuous-process sterilization by heat has been found most satisfactory and economical and is more commonly used than any other treatment.

Many concerns heat their product to temperatures of 160° F. or higher. The important point is to make certain that the product is uniformly heated. The maximum temperature that can be employed will depend on the product and use for which it is intended. Flours to be used for raised bread or pastry cannot be subjected to temperatures above 170° with safety. Cereal products, however, can stand much higher temperatures. Insects that might be found in milled cereal products can not survive exposure to a temperature of 140° for more than 5 minutes; hence, raising the temperature of the product to 140° or slightly higher and maintaining it at that level for about 10 minutes will produce satisfactory sterilization.

Figure 8 illustrates a procedure for heating and cooling a cereal product that, according to Chapman,[7] is highly satisfactory.

A number of machines on the market have been designed for heat-treating milled cereal products, the heat being derived from steam, hot air, or electricity. In many, pro-

[7] Chapman, R. N. Insects infesting stored food products. Minn. Agr. Expt. Sta. Bul. 198, 76 pp., illus. 1921.

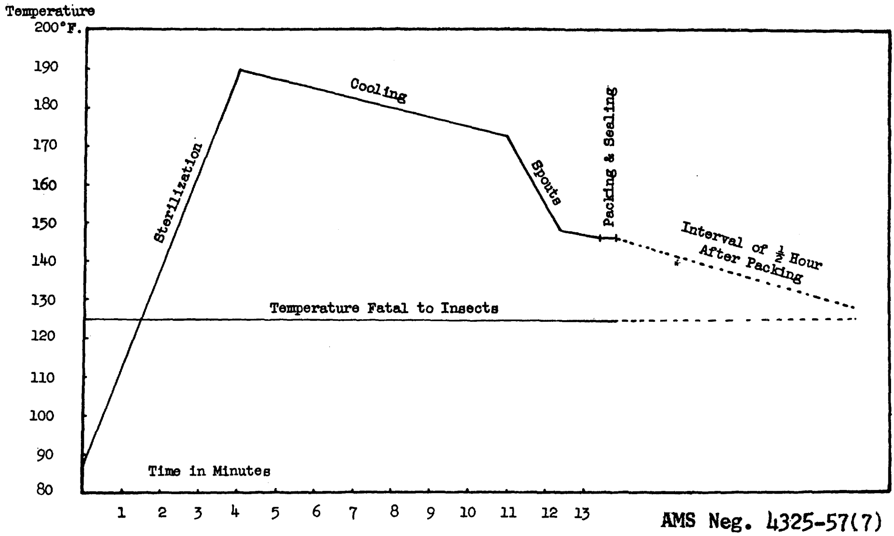

Figure 8.—A satisfactory temperature range for cereals during the process of heating and packing. (Chapman.)

vision is also made to prevent loss in moisture content of the product during the treatment. To be satisfactory for the purpose, a machine should heat the product uniformly.

Heat-sterilized cereal products should go directly from the sterilizer to the packer to prevent reinfestation before packing. A sterilizer of simple construction consists of a series of steam-jacketed metal cylinders or drums placed horizontally one above another and connected so that corn meal, farina, or any other milled cereal product introduced into one end of the top cylinder is conveyed to the other end of the cylinder by a screw conveyor, where it drops into the cylinder below. The cereal product is conveyed in a similar manner through the entire series of cylinders. In its passage through the various cylinders the product will be gradually and uniformly heated, until it emerges at the bottom at any desired temperature. With a series of three cylinders operating at a steam pressure of 100 pounds, the temperature of a cereal product can be raised to 160° F. in 5 to 6 minutes. The heated product should then be sifted through a 20-mesh screen to remove any material that may have been caked by the heat, and should be packed while still hot. Different combinations of heating cylinders and steam pressures can be used to suit individual situations.

Insect Contamination in Milled Cereal Products

Flour shipments used in blending operations, in mixes, or specialty products, or by bakers, should always be examined for both insect infestation and insect contamination. The presence of living infestation can be determined by sifting. At least 1 percent of the bags taken at random from each carload of flour should be sifted.

For the detection of insect fragments in milled cereals, which may be present but are not detectable by macroscopic examinations, procedures have been published by the Food and Drug Administration, The Association of Official Agricultural Chemists, and the American Association of Cereal Chemists. Recommendations relative to useful procedures for the examination of food products for extraneous materials that will also be found helpful to analysts are contained in the Report of the 1945–46 Committee of the New York Section of the American Association of Cereal Chemists. Essentially, the process consists of digesting the sample with pancreatin or hydrochloric acid, making gasoline or light mineral oil separations of the extraneous material, and identifying the separated material.

A method for detecting insect excreta in flour has also been published in "Methods of Analysis" of the Association of Official Agricultural Chemists (5th ed., p. 715).

Insect Control in the Warehouse

Sanitation and Warehouse Management

Under modern methods of flour manufacturing, freshly milled flour stocks can be considered free of insect infestation when they enter the warehouse. However, in flour warehouses every precaution should be taken to prevent the development of insect infestation in stocks awaiting shipment. Sources of infestation include the following: Infested accumulations of dust, feed, and flour in difficult-to-reach places, such as between double floors, walls, and partitions, and in unused machinery or bins; cross infestation from infested feeds, old stock, broken bags or returned goods; and invasion from nearby elevators.

Many warehouses are of modern construction and can easily be kept clean and sanitary. If necessary, warehouse construction should be improved, double hollow walls and partitions eliminated, and cracks in floors filled or the floor renovated by laying quick-setting plastic preparations over old ones. Food-handling equipment and all machinery or dunnage likely to harbor insects should be removed unless it is in constant use.

Flour should be stored in rooms separate from feeds. It should also be stacked on pallets of suitable size, in piles at least 12 inches from the walls and far enough apart to allow inspection and cleaning. Pallets should be inspected regularly for infestation, cleaned with compressed air, and the undersides sprayed with a residual spray. Information regarding sprays described for use in the mill will apply equally well for the warehouse.

Stocks of flour longest in storage should be moved first as the sales demand. Broken bags should be disposed of immediately. Floors should be regularly swept and all accumulations removed and burned or fumigated. Whenever a pile of flour is shipped, the floor beneath it should be thoroughly cleaned. The use of a heavy duty vacuum cleaner will be found invaluable. Mechanical sweepers with attached vacuum have been found to be efficient and economical.

Fumigation

The fumigation of flour and feed warehouses is frequently practiced in connection with mill fumigations. Observations indicate that in tight concrete or brick warehouses hydrocyanic acid, chloropicrin, methyl bromide, or mixtures of methyl bromide with ethylene dibromide can be used at the same dosage recommended for mill fumigation. Fumigation must be restricted to empty warehouses since no tolerances have been established for residues in manufactured foods resulting from fumigations.

Bulk Flour Storage

Where there is a bulk flour system care must be taken to prevent the buildup of insect infestation in the flour-handling equipment as well as in the bins. In addition to frequent cleaning of conveyors, elevators, and all other parts of the system, a centrifugal machine should be used to give the flour just ahead of the handling equipment a precautionary treatment.

Flour going from bulk storage to packers or to bulk cars or trucks should be rebolted and treated with a centrifugal machine as a precautionary treatment to remove insect life that might later start an infestation.

The type of storage bin is of considerable importance. Riveted metal bins are most desirable, concrete bins next best, and wooden bins least desirable. Metal bins, if welded, often crack at the joint due to stress and strain. Riveted seams should be calked with an inert plastic capable of retaining its resilience for several years.

Insect-Resistant Bags

Unless flour is properly packaged and protected from insect invasion in storage and transit, much of the effort expended in the manufacture of a clean product may be wasted.

Insects that attack flour are found wherever foodstuffs are stored or merchandised, and are frequently found infesting transportation facilities.

A mechanical barrier is the best protection against invasion by insects. Fabric bags afford little protection from insect attack since the insects can penetrate or lay their eggs through the mesh of the fabric or through needle holes along the seams or end closures. Paper bags have largely replaced fabric bags and offer considerable protection to flour from insect invasion if they are properly made and sealed. With the exception of the cadelle and the lesser grain borer, most flour-infesting insects cannot cut through the walls of substantial paper bags. They can and do, however, enter through needle holes where the bags are sewed unless the holes are protected in some way. All seams of paper bags should be cemented, and sewed tops should be protected with strips of gummed tape or other covering.

The use of an insect repellant impregnated in the outer wall of multiwalled paper bags offers excellent protection against insect invasion for many months. A combination of pyrethrins with a synergist, piperonyl butoxide, has been used successfully as a repellent, and bags so treated are now available commercially. They are somewhat more expensive than untreated bags.

For specialty flours or pre-mixes a tight-wrap carton offers the most satisfactory protection against insect infestation.

Infestation in Transit

Flour products leaving the mill or warehouse do not usually go directly to the consumer, but must be transported by truck or railway car to bakeries, other warehouses, or grocery stores for distribution. During this period of transit they are subject to invasion by insects.

Studies have shown that the railway cars used to transport flour have in many cases also been used to carry grain during the rush of the grain-harvesting season. The ordinary car is so constructed that waste grain, grain dust, or milled cereal products become lodged in cracks and crevices in the woodwork and behind linings. Consequently, insect infestations difficult to eradicate by ordinary clean-up methods become established in cars used to carry grain. As soon as fresh flour is placed in infested cars, the insects are attracted to it. They crawl over the bags, thrust eggs through the mesh of fabric bags, and enter them wherever they can.

The time of greatest danger from infestation in transit is during the summer after the cars have been used for carrying grain or feed. At this time, also, large numbers of insects of many kinds, including species that infest grain and flour, are in flight and enter the cars before or during loading operations. Lights used in loading cars may also attract many insects and, although they may not be important pests of stored flour, their presence is annoying and often causes cars to be rejected on arrival at destination.

One of the best ways to prevent the establishment of waste grain and milled products behind car linings is to install pads or blankets of fiber glass behind end and side linings. This material is resilient, and when compressed tightly behind wooden linings fills the void to the exclusion of any other material. Many railroads have equipped test cars with fiber-glass pads in the end linings and have demonstrated the value of this treatment.

It will probably be many years before more than a token number of such cars are available for flour shipments. Until that time the following procedures for treating railway boxcars to be used for flour shipments are recommended: Thoroughly sweep cars, and blow them out with a jet of compressed air. Spray with a residual-type spray at least 12 hours before papering and loading.

Sprays of DDT, TDE, methoxychlor, pyrethrum, or allethrin are safe to use. The first 3 chemicals should be used at a concentration of 2.5 percent in the form of emulsions or wettable powders, and the last two at a concentration of 0.5 percent as emulsions. They should all be applied at the rate of about 1 gallon per 1,000 square feet of surface area. A power sprayer is desirable for speed in application and to obtain good coverage. The absence of odor from the spray used is essential. In general, water emulsion sprays are less likely to leave odors than other forms.

Sprayed cars should be lined with a heavy kraft paper to a height above the load. This lining will protect the flour from spray deposits on the floor or walls of the car.

Bulk Transportation of Flour

Bulk transportation of flour offers fewer opportunities for insect contamination than previously used transport, provided the seller and buyer accept their fair share of responsibility for the inspection and care of equipment.

Bulk shipments of flour are presumably free from infestation if handled according to the recommendations given for bulk flour storage.

The sanitary condition of bulk flour cars, tote bins, and bulk flour containers is essential. The shipper must inspect all such equipment before loading. If inspection shows infestation or some residue of previous loadings, steps must be taken to put the car in acceptable condition for loading.

Upon receipt of the bulk commodity by the buyer and after unloading, the empty container must be inspected. The receiver of the commodity should assume the responsibility for complete unloading (leaving no residue) and the immediate closing, locking, and sealing of loading hatches and unloading ports.

Electromagnetic Energy

The use of radiant energy for the treatment of grain and cereal products has received considerable attention during the past few years. Radiant energy includes electrical energy of various wave lengths, such as radio, infrared, gamma rays, sound waves, and energy from electrons.

Many workers have demonstrated that insects can be killed with radiant energy; however, at present, the high cost of equipment, upkeep and operation, together with limitations in capacity, make it doubtful whether radiant energy can compete with other methods of insect control now in use. Continued research may result in the development of a practical method of using some form of radiant energy for treating grain and cereal products.