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Controlling

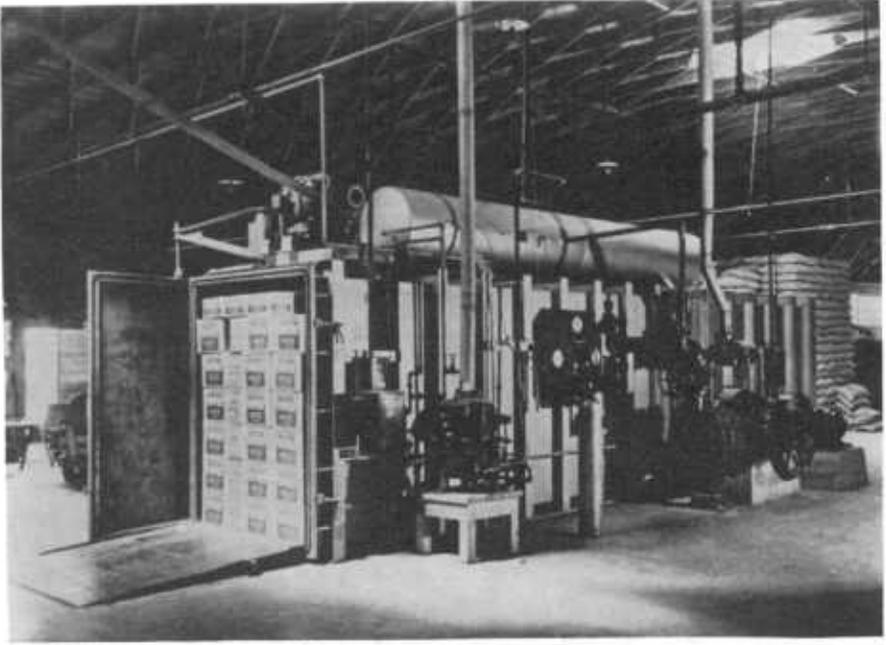
INSECT PESTS of STORED RICE

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BN-4153

Restangular vacuum vault loaded with rice ready for fumigation.

Climatic conditions prevailing in the Gulf States and in California where rice is grown favor the rapid increase of insect pests in the rice after it is placed in storage. Strict sanitation on the farm, in elevators, warehouses, and mills, and the storage of rough and milled rice in structures that are tight enough for fumigation can do much to prevent serious losses from insect attack.

The bulletin discusses the use of methyl bromide, hydrocyanic acid, ethylene oxide, and other fumigants found effective in treating stored rice. New and more efficient methods of fumigating rice are described.

This handbook replaces Farmers' Bulletin No. 1906, Insect Pests of Stored Rice and Their Control.

Washington, D. C.

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CONTROLLING INSECT PESTS OF STORED RICE

Prepared by Stored-Product Insects Section, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service, U. S. Department of Agriculture

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Rice is produced commercially on a large scale in the United States principally in Louisiana, Texas, Arkansas, Mississippi, and California. The average production of rough rice for the 10 years 1942 to 1951 in these states was 35,120,000 hundred-pound bags. In 1955 it was 53,420,000 bags.

Annual losses caused by insects that attack rice in storage are estimated to be about 1 percent of the total value of the crop. This does not take into consideration the cost of prevention and control of insect infestations or any injury which the reputation of a milling company may suffer if its well-established

brands of products are found to be contaminated by the presence of insects.

Rice is for the most part harvested with the combine. In the Gulf States, it is harvested when the moisture content is about 22 percent, so that artificial drying is necessary before it can be stored safely.

Rough rice is stored in sacks in warehouses or in bulk in farm bins, elevators, or in flat storages. Warehouses used for storing sacked rough rice are often simple, loose construction, many of them of the frame and sheet-metal type shown in figures 1 and 2.



BN-4165

Figure 1.—Warehouse used for storing rough rice. This building is 300 feet long and 180 feet wide and has a storage capacity of 20 million pounds of rice.

They vary in storage capacity from a few thousand to more than a million bags in the blimp hangar shown in figure 3.

Warehouses used for storing rough rice are now being built with well-fitted, sheet-metal walls and may be of the quonset type or the conventional warehouse construction. Many of them are equipped for aerating the rice (fig. 4).

Elevators used for storing bulk rice are sometimes of the crib type (fig. 5), although modern concrete elevators are available for storage in many areas.

The rough rice is sold to the miller, who may transfer it to the mill immediately, or leave it in the producer's warehouse or elevator until he is ready to move it. The rice is milled as rapidly as practicable,



BN-4162

Figure 2.—Interior view of warehouse shown in figure 1, showing method of stacking rough rice. The concrete floor simplifies cleaning operations.



BN-4168

Figure 3.—Blimp base at Hitchcock, Tex., being used to store 1,200,000 cwt. of rice. The building is 1,000 feet long, 300 feet wide, and 190 feet high. (Courtesy H. T. McGill.)

and the milled rice stored in bulk in bins, or in burlap sacks, commonly called pockets, each weighing 100 pounds. Much of the milled rice is stored in the mills and may be re-conditioned before it is shipped.

Large stocks of rice acquired by the Government in payment of loans are stored in warehouses as both milled and rough rice.

Milled rice is wholesaled in 100-pound burlap or cotton sacks, and sometimes in paper bags, which are enclosed in cotton bags. For retail sale it may be packaged in small cardboard cartons with or without cellophane windows, in heavy paper bags, or in cellophane bags.

Most of the packaged rice is packed shortly before it is shipped,

and is shipped in corrugated-paper shipping cases.

The climate in much of the area in which the rice is produced and stored is highly favorable for the multiplication of insect pests of stored rice. The warm season is long, the winters are mild, and conditions seldom become too dry in the gulf region to interfere with insect activity. Many of the warehouses and mills used are not tight enough for successful mass fumigation with gas, nor are they equipped to store the infested and uninfested rice separately. Some rice mills carry rough and milled rice in the same building, providing opportunity for the insects to migrate



BN-4150

Figure 4.—Quonset type warehouse equipped with floor ducts and fan for aerating rice.

from one lot to the other. A few mills are equipped with atmospheric or vacuum vaults in which milled

rice is fumigated just prior to being shipped.

Some 30 species of insects have been found infesting stored rice and rice products, but only a few of these are a serious menace to rice in good condition. Only the more important insects are considered in this bulletin. For brief accounts of the life histories and habits of the insects that infest rice and other stored grains, together with illustrations of the more destructive forms, the reader is referred to Farmers' Bulletin No. 1260, *Stored-Grain Pests*, issued by the United States Department of Agriculture.

INSECTS INFESTING ROUGH RICE

The lesser grain borer (*Rhizopertha dominica* (F.)), the rice weevil (*Sitophilus oryza* (L.)), and the Angoumois grain moth (*Sitotroga cerealella* (Oliv.)) are the most destructive insect pests of rough rice. These insects bore into the kernels, at times almost completely destroying them. Illustrations of their abundance and the damage they cause are shown in figures 6 and 7. The Angoumois grain moth and the lesser grain borer are capable of entering the grain through the hull, but the rice weevil attacks only grains with broken hulls or with hulls that have failed to close properly after blooming. In addition to these pests there are several species that feed on the surface of the kernels, on broken grains, and on grains damaged by the boring insects. The commonest of these are the cadelle (*Tenebroides mauritanicus* (L.)),

the saw-toothed grain beetle (*Oryzaephilus surinamensis* (L.)), the flat grain beetle (*Laemophloeus*



BN-4152

Figure 5.—Crib-type elevator sometimes used for storing rough rice.

pusillus (Schönh.), psocids, the Indian-meal moth (*Plodia interpunctella* (Hbn.)), the almond moth (*Ephesia cautella* (Wlkr.)), and the rice moth (*Corcyra cephalonica* (Staint.)).

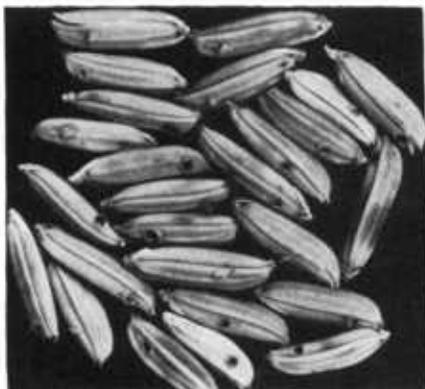
Rough rice stored in bulk sometimes suffers considerable damage from heating that may be partly attributed to the activities of insects. Active insects generate body heat and give off moisture, both of which are absorbed by the surrounding grain, thus producing hot spots. The grain returned to normal temperature after being fumigated unless other factors were involved in the heating. Conditions other than insect infestation may, of course, cause grain to heat.

Damage to rough rice in storage from insect attack is difficult to esti-



BN-4154

Figure 6.—Windrows of dead lesser grain borers on bags and floor in rough rice warehouse after treatment with pyrethrum aerosol.



BN-4157

Figure 7.—Rough rice showing exit holes of the Angoumois grain moth.

mate; however, a few actual records will serve to indicate the magnitude of the losses that occasionally occur. In one case there was a loss in weight of 3.23 percent during July and August from the attack of the Angoumois grain moth. In another instance rough rice placed in storage in the fall suffered a weight loss from miscellaneous insect pests of 2.2 percent at the end of 6 months, 4 percent after 9 months, and 10.7 percent at the end of 1 year.

During the 1954-55 storage season in southern Texas observations were made on the damage caused by the lesser grain borer to 1 lot of 106,000 barrels of rough rice that was in storage for 14 months. During this period there was a weight loss of 2.3 percent, of which 0.6 percent, based on previous observations, was due to normal shrinkage. Cleaning loss at the mill was 3.1 percent greater than the average loss expected for rice in storage for 1 season. The total loss resulting from lesser grain borer damage to the 106,000 barrels of rough rice

was 4.8 percent. With an average value of \$8 a barrel the loss totaled \$40,704. This loss does not include

the loss in milling yield, or the cost of fumigating the rice before shipment to the mill.

INSECTS INFESTING MILLED RICE

After the hulls have been removed from the rice the situation is somewhat different, and some insects of minor consideration in rough rice become important. The main offenders in brown and milled rice, in screenings, and in brewers' rice are the saw-toothed grain beetle, the flour beetles (*Tribolium castaneum* (Hbst.) and *T. confusum* Duv.), the cadelle, the flat grain beetle, the Indian-meal moth, the almond moth, the rice moth, the corn sap beetle (*Carpophilus dimidiatus* (F.)), psocids, the lesser grain borer, and the rice weevil. Of these, only the rice weevil and the lesser grain borer bore into the kernels (figs. 8 and 9). The others feed externally, only damaging the surface of the kernel, but their presence and the fact that they injure the surface of the kernels make

them not only very objectionable but costly to the industry. In brown rice the rice weevil is the major pest and frequently does much damage. Occasionally the lesser grain borer infests brown rice, especially when it is packaged in paper bags or cardboard cartons. Practically all rice pests prefer brown to milled rice.

The larvae of the almond moth, the Indian-meal moth, and the rice moth are particularly troublesome on account of their habit of spinning silken threads. The moth larvae spin a web as they develop and leave behind them a silken thread wherever they crawl, and when they pupate they attach to the sack a silken cocoon, which is rather difficult to remove. The rice moth larvae spin dense tubes, webbing the kernels into the walls of



BN-4158

Figure 8.—Kernels of milled rice damaged by the rice weevil.



BN-4159

Figure 9.—Characteristic damage to milled rice from the attack of the lesser grain borer.

the tube. These webs are difficult to remove from the rice, and some rice is lost in the cleaning process.

The practice is to fumigate the rice and remove the dead insects just prior to shipping. Both these

processes require costly equipment and careful manipulation. Badly infested milled rice must sometimes be run through a system of brushes and aspirators to be restored to a satisfactory condition.

SOURCES OF INFESTATION

Harvesting of rice by combine has eliminated most of the field infestation that formerly occurred when rice was harvested with binders and left to dry in the field.

Insect infestation may originate while rice is stored on the farm, in warehouses, in elevators, and to some extent during transit in railway cars or ships.

Warehouses, elevators, and storehouses on the farm usually harbor insects from year to year in feed, old rice, sweepings, and grain that has lodged in or dropped through cracks and crevices in the floor and walls. When insects are present they almost immediately migrate to the new rice to start their destructive work, the resulting rate of infestation and damage depending on the insect population present in the storehouse when the new rice is moved in, the condition of the rice, and the prevailing temperatures.

Railway boxcars used to transport rice are likely to carry large numbers of grain insects concealed in cracks and crevices and breeding in accumulations of waste grain and milled products that have become lodged behind the car linings,

particularly at the ends of the cars. Infestation of rice shipments is certain to take place in such cars. Infested rice arriving at a warehouse, elevator, or mill affords an opportunity for insects to spread to insect-free rice already in storage.

Stored-grain insects can and do enter warehouses and mills by flight. In one experiment, nine species of stored-grain insects, including the worst enemies of milled and rough rice, were collected in insect flight traps at two rice mills.

Insects live and breed in the rice materials lodged in the milling machinery and infest the rice as it flows by and through the points of infestation. These grain deposits are important sources of infestation in milled rice. In one study an average of 425 insects was found per 1-pint samples of material collected in elevator boots, conveyors, spouts, and milling units, in a survey of 4 rice mills along the gulf coast that had been closed down at the end of the milling season. In these collections 23 species of stored-grain insects were identified, including all the important pests of stored rice.

GOOD HOUSEKEEPING

Sanitation on the farm, in elevators, warehouses, and in mills will do much to prevent insect infesta-

tion and reduce the losses from this cause.

Sanitation on the Farm

It is essential that clean, insect-free and weatherproof storage be provided and that nearby sources of insect infestation be eliminated. If possible, metal bins that are easy to clean should be used. When wooden bins are employed they should be thoroughly cleaned, and as long as possible before they are refilled they should be sprayed with a 2.5 percent concentration of methoxychlor or other materials

approved for this purpose (see statement on p. 30). A dosage of 2 gallons per 1,000 square feet of surface area should be applied. If there are spaces under the floors of the bins, they should be cleaned out and sprayed. Waste grain or animal feeds likely to harbor insects should be removed from nearby buildings and fumigated so that they will not serve as sources of infestations to the rough rice.

Sanitation in the Elevator

In addition to cleaning, elevator bins should be sprayed at intervals when they are empty, with a residual spray as recommended for wooden farm bins. In the elevator proper, remove all junk and unused machinery, sacking, tools, and parts, or store them where dust or waste grain cannot accumulate. Arrange fire barrels or other equipment so that they will not interfere with cleaning operations.

Remove waste grain and chaff from the parts, tunnels, or lower portions of the elevator. Clean elevator boots, legs and heads, horizontal screw conveyers, and spouting.

Remove promptly and dispose of all waste grain and dust gathered during cleaning operations. Inspect cleaning machinery and dispose of tailovers promptly.

Elevator legs and screw con-

vveyers should be fumigated as often as necessary to prevent infestation. A 3-to-1 mixture of ethylene dichloride and carbon tetrachloride or a 3-to-17 mixture of ethylene dibromide and carbon tetrachloride can be used at a dosage rate of from 1½ pints in the small elevator boots of country elevators to one-half gallon in the boots of the large terminal elevators. Screw conveyers will require about 4 ounces per foot. Other fumigants are commercially available that are suitable for this purpose. They should be used according to the directions of the manufacturer.

In warm weather the walls of the tunnels, gallery floor, and head house should be thoroughly sprayed with any of the residual sprays approved for this purpose. Sprays should be applied 3 or 4 times during the spring, summer, and fall.

Sanitation in the Warehouse

Before the warehouse is filled it should be thoroughly cleaned and freed of all dust, waste grain, or

other debris likely to harbor insects. Floors should be repaired and all accumulations of waste

grain under the floor or between partitions should be removed and disposed of.

Compressed air can be used to dislodge dust and waste grain from beams, ledges, and other places in the superstructure of the building.

After the building has been

thoroughly cleaned and made weathertight, it should be sprayed with a residual spray approved for this purpose.

The use of pallets on the floor is desirable for sanitary reasons and to facilitate fumigation of stocks of rice.

Use of Aerosols and Space Sprays

In rough rice warehouses, aerosols or space sprays applied periodically are useful in preventing the buildup of moth infestations. They are not effective against deep-seated infestations of such insects as the lesser grain borer, the rice weevil, or bran beetles, but kill many of these insects in flight or crawling on the outside of the bags of rice (fig. 6).

Aerosol formula:

12.5 percent pyrethrins—piperonyl butoxide (1-to-10 concentrate)

37.5 percent deodorized kerosene

50.0 percent approved solvent

Apply with an aerosol generator at the rate of 1½ gallons per 50,000

cubic feet of warehouse space over the load every 2 weeks during warm weather.

In order to avoid the buildup of residues of pyrethrum and piperonyl butoxide in excess of the established tolerance, it is suggested that periodical aerosol applications be limited to 20 for any 1 lot of rice, when the space above the load is approximately equal to the space occupied by the load; or be limited to 10 applications if the load equals only one-fourth of the warehouse capacity; and correspondingly fewer applications for smaller loads.

Several types of pyrethrum space sprays are commercially available. They should be used as recommended by the manufacturer.

TREATMENT OF ROUGH RICE

The proper care of rough rice while it is in storage waiting to be milled will do much to maintain its high quality and prevent loss in weight or loss in yield of head rice.

Prompt and timely fumigation and treatment with aerosols, sprays,

or grain protectives offer the solution of many of the insect problems of the warehouseman. The following pages contain a discussion of the methods in use for conserving rough rice in storage.

Fumigating Rough Rice in Bins

Insects in rough rice stored in covered wooden cribbed bins can be satisfactorily fumigated with

granular calcium cyanide. On exposure to air, the calcium cyanide reacts with the atmospheric mois-

ture to form hydrocyanic acid. This treatment does not affect the germination or milling qualities of the rice, and after the rice is milled, no undesirable residue is left. Milled rice should not be fumigated with this chemical, however, as it is likely to produce a spotted product.

The fumigant is applied by feeding it into the center of the stream of rice in the spout, as the bin is being filled. Specially designed gravity feed devices that fit into the calcium cyanide containers are obtainable for this purpose. The devices are equipped with graduated dosage plugs so that the fumigant can be run into the rice streams at any desired rate. A dosage of 8 pounds of the calcium cyanide per 100 barrels, approximately 24 pounds per 1,000 bushels, or 16 pounds per 1,000 cubic feet of space, gave a satisfactory kill in covered wooden cribbed bins. For concrete or metal elevator bins a dosage of 15 pounds per 1,000 bushels is satisfactory.

The first 30 and last 30 barrels of rice run into the bin should be treated with a double dosage to compensate for any gas that may escape.

Rough rice stored in concrete elevators may also be successfully fumigated with heavier-than-air fumigant mixtures at the following

dosages per 1,000 bushels: Carbon disulfide-carbon tetrachloride, 1-to-4 mixture, 2 gallons; the ethylene dichloride-carbon tetrachloride, 3-to-1 mixture, 3 gallons, or the carbon tetrachloride-ethylene dichloride-ethylene dibromide 60-to-35-to-5 mixture, 2 gallons. Other heavier-than-air mixtures are available which would be suitable for this purpose. These should be used as directed by the manufacturer but only if approved for this use (see statement on p. 30). In wooden cribbed bins and farm bins the dosage should be doubled. These fumigants can best be applied in proportionate doses to every 1,000 or 1,500-bushel draft of rice as the bin is filled. When it is inexpedient to turn the rice, these fumigants can be applied by spraying the entire dosage uniformly over the top layer providing grain temperatures are 75° F. or above. Milled rice in bin storage can safely be fumigated with heavier-than-air fumigants. Surface application of dosages recommended for use in concrete elevators are suggested. **For protection against the vapors of these fumigants during application the operator should wear a gas mask equipped with a canister adapted to provide protection against the fumigant being used.**

Control of Surface Infestation of Moths

Surface infestations of rough rice in elevator bins by the Indian-meal moth, almond moth, or other species are occasionally troublesome. In closed top bins they can be com-

bated by applying fumigants in vapor or atomized form to the over-space. A dosage of 1 pound of methyl bromide, or commercial mixtures of methyl bromide with

ethylene dibromide, per 1,000 cubic feet of overhead space will be found adequate. These fumigants can be applied whenever flying moths are seen in the tops of elevator bins or there is evidence of surface webbing of the grain.

A synergized pyrethrum spray is also useful for this purpose. Commercial formulations are available which should be applied as a

mist in the overspace of elevator bins, at a rate recommended by the manufacturer.

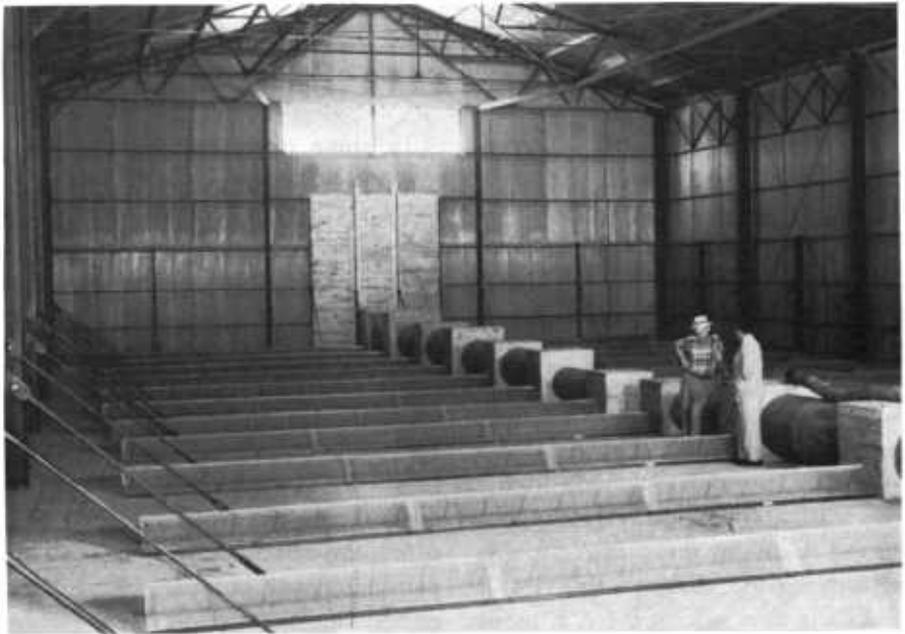
As a preventive treatment, a synergized pyrethrum spray can be applied to the surface of the grain as a coarse spray after a bin is fumigated. Any commercial formulation approved for this use can be used, at the rate recommended by the manufacturers.

Forced Circulation Method of Rough Rice Fumigations

In recent years the method of circulating fumigants through large masses of grain has been used successfully for the treatment of bulk rough rice in flat storage. The method has the advantage of greater effectiveness with decreased dosages owing to the better distri-

bution of the toxic vapors. Furthermore the toxic vapors can readily be removed from the rice after fumigation.

The installation of aerating systems in rough rice warehouses (fig. 10) has encouraged the use of the forced circulation system of rice



BN-4148

Figure 10.—System for aerating rough rice in warehouse. Central floor duct consists of concrete tile connected by square wooden boxes from which perforated floor ducts extend laterally to the walls of the building. The central duct is connected to a fan capable of moving air through the grain at the desired rate of air flow.



BN-4146

Figure 11.—Closed circulation system within warehouses. Ducts or tunnels from the wooden boxes of the central floor duct shown in figure 10 extend up through the rough rice. Fans installed on the tops of these ducts replace the fan used for aerating the rice and the ends of the central duct are closed.

fumigation since it is a simple matter to adapt such systems for circulation. All that is necessary is to provide a return duct system so that air or fumigant pulled down through the rice or forced upward through the rice, is returned to the fan. Essentially the aeration system consists of a central floor duct from which perforated lateral ducts extend at regular intervals to the side walls. The central duct is connected to one or more fans capable of moving air through the rice.

An air flow rate of 0.1 c. f. m. or less per bushel of rice has proved to be sufficient to distribute fumigant gases uniformly throughout the bulk rice

In some cases the recirculation system is constructed within the building by providing ducts or tunnels from the main floor duct extending vertically up through the rice (fig. 11), with the fan or fans installed at the top of the ducts above the top surface. In others (fig. 4), the lateral floor ducts are connected to a manifold on the outside of the building and return ducts from the fan extend to the overspace above the rice. The fumigant can be introduced into either the exhaust or intake side of the fan.

A dosage of $1\frac{1}{2}$ to 2 pounds of methyl bromide per 1,000 cubic feet of space has been found to be

satisfactory depending on the tightness of the storage structure. Although other fumigants than methyl bromide can be used in this method, no dosage rates have been established for them as yet.

The fumigant should be circulated for 10 to 30 minutes after all the gas has been introduced or until

it is equally distributed. In practice the circulation system is started when the gas is first released.

After an exposure period of 24 hours the rice can be aerated and the fumigant removed.

Steel storage bins and elevator bins can also be readily adapted to this type of fumigation.

Heating and Drying Rice

The exposure of the rice to high temperatures kills the insects. Temperatures normally used in the commercial drying of rough rice are not high enough to kill insects. An exposure of 10 minutes to a temperature of 140° F. is necessary to kill insects infesting stored rice. Several problems are involved, however, in subjecting rice to heat. The rice heats so slowly that the insects are protected by the rice itself. In experimenting with a commercial drier using hot-air blasts, it was found impossible to obtain a satisfactory kill of insects in rough rice with air blasts at 140° for 30 minutes. This treatment raised the temperature of the rice to only 122°, which was not high enough to kill the insects. Furthermore, heating for insect control

is not favored by the rice industry owing to the danger of causing the rice to check and because of the removal of too much moisture.

The drying of moist rice and rice byproducts reduces their susceptibility to insect damage. Insects infesting stored grain are largely dependent on the moisture in the grain for their life processes. Some species are able to subsist on drier grain than others. Most of the insects infesting stored rice prefer grain having a relatively high moisture content; for example, wheat grown in the Pacific Northwest is usually harvested with a moisture content of 8 or 9 percent and is singularly free from insect damage. Rice stored in the Southern States, however, is seldom, if ever, too dry to sustain insect life.

Synergized Pyrethrum Protective Dusts and Sprays

Pyrethrum powder has often been recommended for mixing with grain to protect it from insect attack.

Pyrethrins synergized with piperonyl butoxide are now available commercially in both dust and spray formulations for treating newly harvested grain or grain

known to be relatively free from insect infestation.

These formulations afford excellent protection to other small grains during storage for one season, particularly in the Great Plains region.

For use in protecting rough rice in storage, in the Gulf States heav-



BN-4145

Figure 12.—Bags of screenings, sweepings, etc. left in the mill harbor many insects.

ier dosages of these dust and spray formulations are needed for rice than for wheat in the Midwest.

Experimental work is now underway to determine satisfactory dosages.

INSECT CONTROL IN THE RICE MILL

Strict sanitation in the mill is as essential as it is in the warehouse. Grain, feed, and deposits of floury material harboring insects should not be allowed to accumulate on the floor, under or near the building, or in the machinery (fig. 12). As far as possible machinery should be arranged so that it can be readily cleaned. The building should be constructed so as to avoid the possibility of damp, dark places. Floors, walls, and ceilings should be smooth, to eliminate hiding places and facilitate cleaning. Double floors, walls, or partitions should be avoided. Insects removed in the process of cleaning or

milling the rice should be destroyed by burning or by treating the accumulations in which they occur with fumigants.

Insecticidal sprays are quite useful in any mill sanitation program. Residual sprays can be applied to the walls of a mill but should not be applied to the interior or exterior of milling machinery.

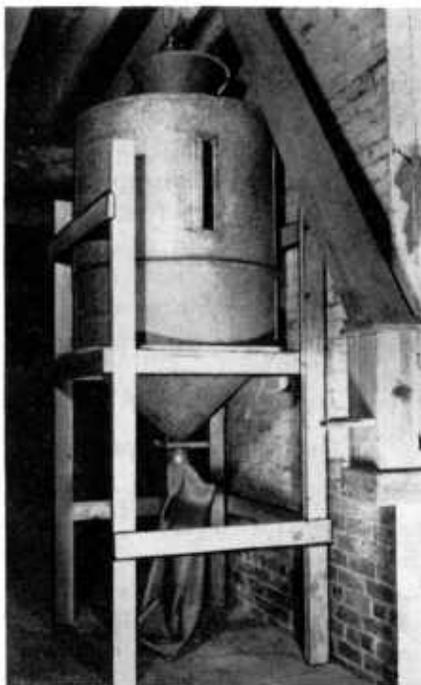
Synergized pyrethrum sprays are effective as contact sprays against mill insects and can be used safely inside and outside machinery without danger of hazardous residues.

When milling machinery is cleaned out, an oil or water emul-

sion pyrethrum spray can be applied inside the machinery. Many formulations are available commercially. They should be used as directed by the manufacturer.

A general fumigation of the mill proper once a year with HCN or methyl bromide is desirable. This may be done in conjunction with the warehouse fumigation described in succeeding pages and at similar dosages.

As a supplementary measure the local fumigation of elevator boots and other milling equipment containing milling stock that may harbor insect infestations, at monthly intervals during the milling season, will serve to hold the insect population of the mill to a low level. Fumigants in common use for this purpose are the 3-to-1 mixture of ethylene dichloride and carbon tetrachloride, the 3-to-17 mixture of ethylene dibromide and carbon tetrachloride, and a mixture of 70 percent ethylene dibromide, 29.5 percent methyl bromide, and 0.5 percent inert ingredients. The amount of material required for each milling unit depends upon its size. The recommendations of the manufacturers should be followed. **Millers applying their own fumi-**



BN-4155

Figure 13.—Metal containers used for collecting tailings from rice-cleaning machinery. The tailings fall into the container through a funnel which is heated by an infrared-ray lamp to prevent the escape of insects. After the container is filled, it is fumigated to kill the insects in the tailings, or the tailings may be removed and fumigated. A glass window has been inserted in the container to show when it is full.

gants should wear suitable gas masks and take precautions described in the section on fumigants.

Treatment of Tailings From Cleaning Machinery

Tailings from rice-cleaning machinery usually contain many insects that, unless properly disposed of, are likely to spread to stocks of uninfested rice in the mill. In many cases the tailings are caught in burlap sacks that, when filled, are set aside for an indefinite period

without treatment. To avoid infestation from this source, a satisfactory method has been devised for collecting the tailings in a tight metal container (fig. 13) which should be large enough to hold a day's run of tailings. To prevent the escape of insects from such a

container while it is being filled, arrangement can be made for the tailings to fall into the container through a metal funnel heated by means of an infrared lamp. The insects will not climb up over the heated sides of the funnel; hence they are unable to escape. The tailings can be treated overnight in the container with a mixture composed of 75 percent ethylene di-

chloride and 25 percent carbon tetrachloride at the rate of about 1½ ounces of the mixture per 100 pounds of tailings, or the tailings may be removed from the container and fumigated immediately. If the tailings are treated in the container in which they are collected, mills operating on a 24-hour basis should have two of these containers, to be treated alternately.

TREATMENT OF MILLED RICE

Warehouse Fumigation

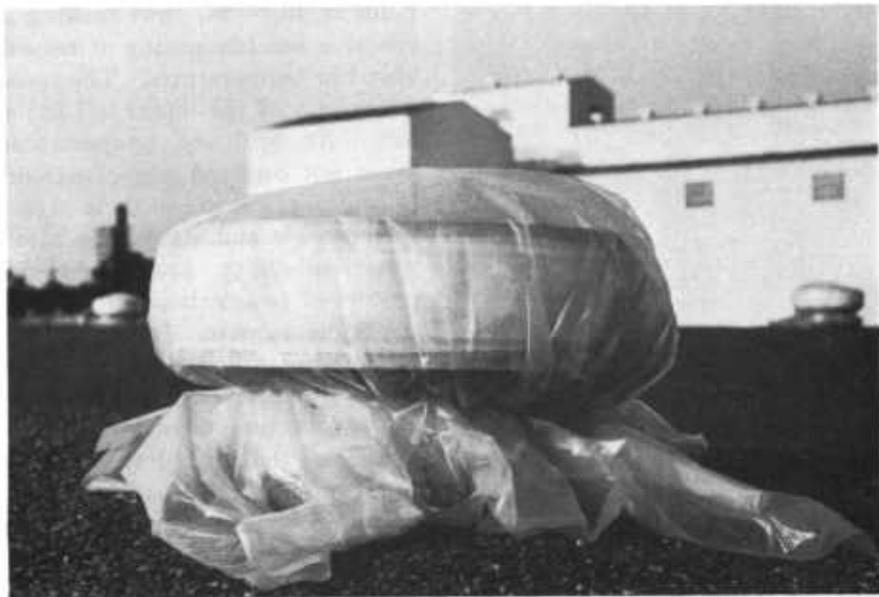
The fumigation of entire warehouses filled with pockets of milled rice is being practiced successfully in buildings that are or can be made gastight. Efficient fumigation arrests the insect infestation and damage until the plant becomes reinfested from outside sources. Usually only one or two treatments a year are necessary to keep the contents of a tight warehouse reasonably free from insect damage. The number of fumigations required depends on the quantity and condition of the rice carried over from one season to the next, entry of insects from outside sources, and the effectiveness of the first treatment. Ordinarily if new-crop rice is stored in a clean warehouse, one fumigation about midsummer is sufficient, provided there is no reinfestation from outside sources. If rice is carried over from one season to the next, however, or if insects from outside sources fly into or otherwise enter the warehouse, an early summer and a fall fumigation are sometimes necessary. A second fumigation also becomes necessary when the first proves un-

successful. For warehouse fumigation both hydrocyanic acid and methyl bromide are effective.

All polish, bran, sweepings, and other materials that harbor insect pests and are difficult to penetrate with the fumigant used should be treated separately in an atmospheric vault or vacuum chamber when preparation is being made for mass fumigation of milled rice in pockets. Where this is not feasible, the dosage of fumigant should be increased to take care of the situation. All windows, doors, eaves, and other openings in the building should be closed and carefully sealed with laminated paper and paste, or with putty. Ventilators can be sealed on the outside by covering with a plastic sheet (fig. 14). This is essential; otherwise the gas will escape, thereby preventing the building-up of a concentration fatal to insect life.

Liquid Hydrocyanic Acid for Warehouse Fumigation

Hydrocyanic acid is a satisfactory fumigant for milled rice stored in pockets in a reasonably tight



BN-4159

Figure 14.—Roof ventilator sealed on outside by covering with plastic sheeting.

building or for rough rice in bags. Although this gas can be produced in several ways, only the liquid method will be discussed, as this has been used almost exclusively for the fumigation of rice warehouses. Liquid hydrocyanic acid (96 to 98 percent HCN) is a volatile, colorless liquid boiling at 79.7° F. It evaporates to form a gas, the specific gravity of which is 0.93 as compared with air. It is marketed in cylinders containing 30, 75, and 166 pounds of liquid. **Hydrocyanic acid is extremely poisonous to human beings**, although it can be used safely if properly handled. This fumigant does not injure the quality or color of the rice.

Liquid hydrocyanic acid is usually applied through a piping system of $\frac{3}{8}$ -inch soft, seamless copper tubing installed throughout the building. Disk-type spray nozzles,

so spaced as to insure uniform distribution of the gas, should be provided, one for each 10,000 to 15,000 cubic feet of space. Special pressure-type nozzles now on the market are fitted with a device to prevent clogging and need not be removed for cleaning. The inlets to the piping system, one for each floor, are at convenient points outside the building, usually on the loading platform (fig. 15). The cylinders of hydrocyanic acid are connected to the piping inlets by means of short lengths of special rubber hose, or, if desired, a manifold arrangement may be used. The liquid is forced into the warehouse by means of air pressure applied to the cylinders. When an air compressor is not readily available, a cylinder of compressed nitrogen makes a good substitute (fig. 16). One cylinder of nitrogen supplies enough pres-



BN-4149

Figure 15.—Cylinder of liquid hydrocyanic acid and air compressor placed in readiness to fumigate a rice warehouse.

sure to empty approximately ten 75-pound cylinders of HCN.

A dosage of 16 to 24 ounces of liquid hydrocyanic acid per 1,000 cubic feet of space is recommended. The exact dosage required will depend upon the temperature of and the quantity of rice in the building—the lower the temperature and the larger the quantity of rice, the higher the dosage should be. Both rice bran and polish require a considerably higher dosage than the rice itself.

An exposure of 72 hours should be allowed, after which the building may be opened for aeration. **A gas mask should be worn by the operator while he is opening the building.**

Methyl Bromide for Warehouse Fumigation

Methyl bromide is another fumigant found to be well adapted for treating rough or milled rice stored in bags in tight warehouses. This fumigant is a colorless liquid which

boils at 40.1° F., thus making it effective for fumigating at reasonably low temperatures. The specific gravity of the liquid is 1.732 at 32°. At ordinary temperatures, when not confined under pressure in containers, it is a gas. It is non-inflammable and stable, has a low water solubility, has remarkable powers of penetration, and is relatively inexpensive. In low concentrations methyl bromide does not have a distinctive odor, but in high concentrations a sweetish odor approaching that of chloroform may be perceived.

Methyl bromide is obtainable in liquid form under low pressure in cylinders containing 10 to 200 pounds net, or in 1-pound cans. The pressure within the cylinders, due to the vapor pressure of the



BN-4151

Figure 16.—Cylinder of nitrogen attached to HCN cylinder. One cylinder of nitrogen supplies enough pressure to empty ten 75-pound cylinders of HCN.

methyl bromide, will vary with the temperature. At high temperatures it is sufficient to eject the liquid forcibly from the cylinder when the valve is opened, whereas at 40° F. the pressure gage reads 0. To facilitate its use at all temperatures, therefore, the pressure normally occurring within the cylinder is increased by charging it with sufficient air at the time of shipment to eject all the liquid forcibly, even at temperatures below 40°.

The cylinders are equipped with siphon tubes extending to the bottom so that the pressure will cause the liquid to issue from the exit port at the top when the valve is opened, without the necessity of inverting the cylinder.

Methyl bromide may be applied in several ways for the fumigation of rice in warehouses. It is usually released from a number of locations in the warehouse so as to insure a uniform distribution of the gas. The fumigant is released above the rice near the ceiling through a length of 1/4-inch copper or plastic tubing connected to the exit port of each cylinder, the open end of the tube being plugged or pinched shut and two 1/8-inch holes bored through the tube near the closed end so that the liquid is ejected horizontally in opposite directions above the rice (fig. 17). In some cases the plastic tubing is dispensed with and a special fitting is attached to the exit port of each cylinder which directs the fumigant upwards instead of horizontally (fig. 18). The pressure in the cylinder is sufficient to force the fumigant into the overspace above the rice and



BN-4161

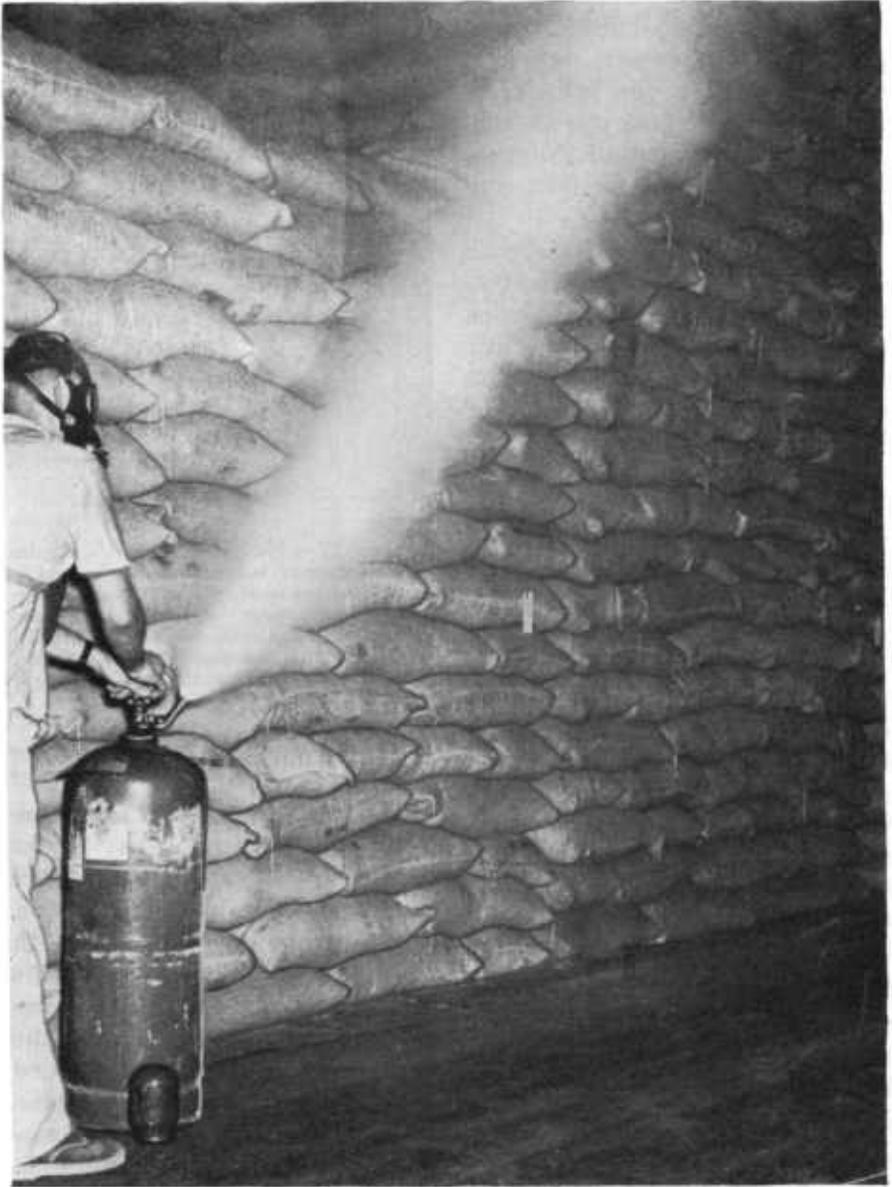
Figure 17.—Methyl bromide cylinder with copper tubing attached so as to release gas near ceiling of warehouse. In many cases plastic tubing connected to the cylinder is led up to the ceiling and fastened so that the free end will discharge the gas above the stacks of rice.

give a good distribution of the vapors.

The men who release the fumigant must wear gas masks equipped with canisters that give protection from methyl bromide, and they should begin first with the cylinders farthest from the exit, opening each valve completely and working toward the door. The door left unfastened for exit should be sealed immediately after the persons releasing the gas have left the building. The liquid evaporates as soon as it is released. Circulating fans should be operated inside the ware-

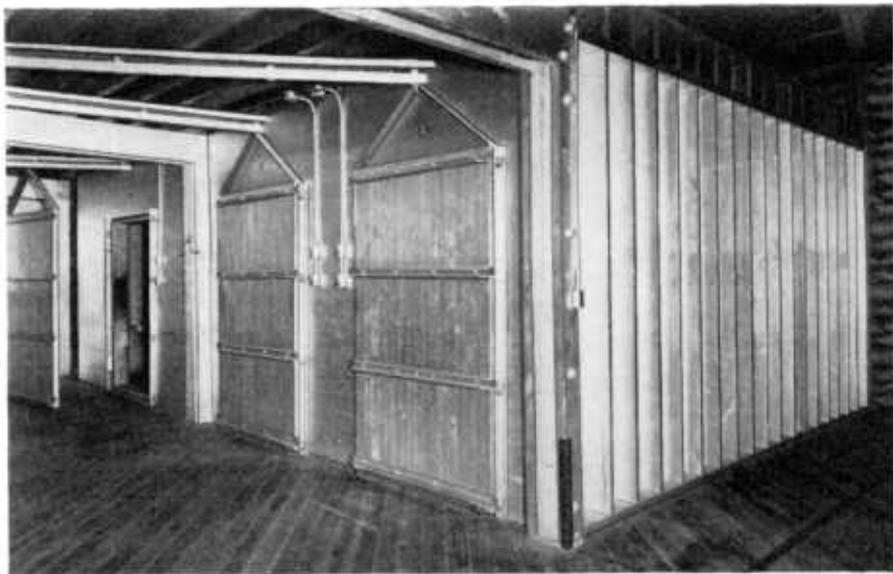
house during the period of fumigation to facilitate the distribution of the gas. If desirable, the methyl bromide can be applied from the outside through a piping system

similar to that described for the use of liquid hydrocyanic acid. When this latter method of fumigation is used, the pressure in the cylinder should be increased to 150 pounds



BN-4160

Figure 18.—Methyl bromide being released during the fumigation of a rice warehouse. The special fitting attached to the exit port of the cylinder directs the fumigant upwards.



BN-4164

Figure 19.—A battery of three atmospheric vaults of frame construction lined with 24-gage galvanized sheet metal. These vaults have a combined capacity of 2,000 pockets of milled rice. One discharge fan is used to ventilate all three vaults. Note the convenient arrangement by which the doors are swung out of the way during the loading and unloading of the vaults.

by charging it with compressed air to insure the complete ejection of the methyl bromide. In cool weather the pressure in the cylinder may have to be renewed in order to empty it quickly.

A dosage of 1 pound for milled rice and $1\frac{1}{4}$ pounds for rough rice per thousand cubic feet of space is recommended for a satisfactory insect kill. An exposure of 16 to 24 hours should be allowed, and after

this the building can be opened for aeration. The workmen opening the building should wear gas masks. Ordinarily it requires from 4 to 8 hours to aerate a building fumigated with methyl bromide so that it may be entered safely without a gas mask. The speed of ventilation will, of course, depend upon the number of windows and doors opened and the draft of air through the building.

Atmospheric-Vault Fumigation of Milled Rice

Small lots of rice or rice products are economically treated in a gas-tight room of suitable size, commonly known as an atmospheric fumigation vault or chamber, because the treatment is made at atmospheric pressures. Such a fumigation chamber may be con-

structed of any material that can be made gastight (fig. 19). Sheet metal, plywood, masonite, or even concrete linings are satisfactory. The latter three types need to be coated with a gas impervious paint.

Suitable doors, complete with frame and rubber gasket, may be

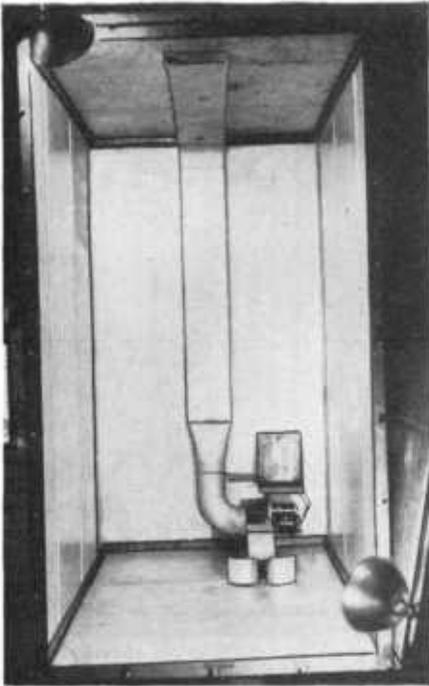


Figure 20.—View of interior of small vault, showing fan used to circulate the fumigant or to eject it from the vault.

purchased already assembled, or a tight door can be constructed on the lid principle, the flat surface of the door being turned toward the door frame of the chamber. A rubber gasket attached to the door frame on the chamber makes a tight seal. The door should be fastened in place by means of bolts extending through it from the casing on all four sides. Hinged doors are hard to fasten tightly unless the hinges have loose joints which allow the door to be drawn up against the casing by means of bolts.

A fan can be used satisfactorily for circulating the gas within the vault during the treatment and also to eject the gas afterward (fig. 20).

The size of the fan to be used depends on the size of the chamber. It should be large enough to change the gas in the chamber twice per minute. If the fan is mounted on the inside of the chamber, an explosion-proof motor should be used.

The rice is usually cleaned and resacked after fumigation in order to remove dead insects.

In handling the fumigated rice a ventilating hood equipped with a suction fan should be placed over the hopper, as shown near the top of figure 21, to carry off any fumes released from the rice and to insure the comfort and safety of the workmen.

Fumigants used have had tolerances for residues established under Public Law 518, since milled rice, as well as rough rice, is a raw agricultural product. Two fumigants approved for this use are discussed in the following pages. If other fumigants are to be used, consult the label or the container to be sure they have been approved for this use, and that tolerances have been established for their residues on rice.

Methyl Bromide for Atmospheric-Vault Fumigation

Methyl bromide has been found to be a highly effective and comparatively inexpensive fumigant for the treatment of milled rice and rice products. In atmospheric-chamber fumigation, methyl bromide is introduced from the outside through the wall by means of a $\frac{1}{4}$ -inch plastic or copper tube. The



BN-4163

Figure 21.—Mixing-hopper room in rice mill showing, near top of picture, the ventilating hood over the hopper into which the fumigated grain is being dumped.

dosage and exposure time will depend on the type of container in which the rice is to be packaged, the time available for fumigation, the temperature, and the quantity of rice contained in the vault. The dosages shown in table 1 have given satisfactory results for the fumigation of milled and brewers' rice at 70° F. and over, in a gastight chamber equipped with a circulating system (see statement p. 30). The dosage and the exposure period must be increased when rice is being fumigated at lower temperatures.

After fumigation the treated rice, still in the chamber, should be aerated. This requires approximately 1 hour, depending on the size of the exhaust fan. The gas having been

expelled in this way, the workmen may safely handle the rice without wearing gas masks.

TABLE 1.—*Dosages of methyl bromide giving satisfactory results in the atmospheric-vault fumigation of milled rice at 70° F. and over*

| Type of package | Exposure period | Dosage per 1,000 pounds of rice | Minimum dosage per 1,000 cubic feet of space ¹ |
|-----------------------|-----------------|---------------------------------|---|
| Burlap or cotton bag— | Hours | Ounces | Pounds |
| Do----- | 4 | 1½ | 1¾ |
| Do----- | 6 | 1 | 1½ |
| Do----- | 12 | ½ | ¾ |
| Carton----- | 15 | 1¼ | 1¾ |

¹ Do not use less regardless of size of load.

Liquid Hydrocyanic Acid for Atmospheric-Vault Fumigation

Excellent results in the fumigation of bagged milled rice in atmospheric vaults can also be obtained with liquid hydrocyanic acid gas. Dosages of $1\frac{1}{2}$ ounces per thousand pounds of rice, or $2\frac{1}{2}$ pounds per thousand cubic feet of space, for a 4-hour exposure, and 1 ounce per thousand pounds of rice or $1\frac{1}{2}$

pounds per thousand cubic feet of space for a 15-hour exposure, were found satisfactory when the temperature of the rice was 80° F. or above.

The fumigant is introduced into the vault through a short piping system. In all cases the fumigant should be circulated in the vault during the exposure by means of a fan.

Vacuum Fumigation

In vacuum fumigation the rice is placed in a steel chamber from which a large proportion of the air is subsequently evacuated by a pump and then is replaced with a fumigant (see inside front cover). By this method the gas penetrates the rice with much greater rapidity than in atmospheric fumigation. This permits shorter exposures than at atmospheric pressure, especially when tightly packed materials are being treated.

Vacuum fumigation chambers are made in many sizes, the larger ones being capable of holding one or more carloads. Both cylindrical and rectangular chambers are available.

At the end of the period of exposure the chamber is aerated by pumping the fumigant out of the tank and breaking the vacuum with air. Usually the fumigated products are "air-washed" several times by alternately drawing and breaking a vacuum of about 28 inches. Another very satisfactory method of ventilating the vacuum chamber is by the use of an exhaust fan. In this method the vacuum is broken at the end of the exposure; and, as

normal atmospheric pressure is approached, the discharge fan is started, and the chamber door from which the unloading is to begin is opened. This method is more rapid than that of breaking and pumping several vacuums and makes it unnecessary to operate the exhaust pump. The discharge fan should be operated while the workmen unload the fumigated products. As in the case of atmospheric vaults, the exhaust pipe should carry the gas to a safe point outside the building.

Liquid Hydrocyanic Acid for Vacuum Fumigation

Liquid hydrocyanic acid is highly satisfactory for the vacuum fumigation of milled rice and rice products. For maximum efficiency the hydrocyanic acid should be let into the vacuum chamber in the gaseous form. This is accomplished by drawing the liquid from the cylinder through a volatilizer.

Rice readily absorbs hydrocyanic acid and very slowly liberates it on exposure to the air—a feature that is of considerable advantage, since the insecticidal effect persists for

some time after the rice has been removed from the vault. Unless fumigated rice is stored in a tightly closed room the slowly liberated gas is not likely to accumulate in quantities dangerous to any person. Treated rice can be run through an aspirator immediately after the fumigation and still retain enough gas after it is resacked to be lethal to insects—an effect known as post-fumigation.

The dose for vacuum treatment of rice with hydrocyanic acid depends on the type of chamber, the length of exposure, and the temperature of the rice. For treating rice at 60° F. or above, a dosage of 1¼ ounces per thousand pounds of rice, and never less than a minimum of 1¾ pounds per thousand cubic feet of space, has been found satisfactory at a 3-hour exposure for rice in burlap and cotton pockets, and cartons of all types.

After the fumigation the chamber should be air-washed twice before the workmen are allowed to enter to handle the treated products. When a strong discharge blower is used, it may be safe to enter the vault after 5 minutes of aeration. The fan should be operated during the entire time the rice is being unloaded, except when

plenty of time has been allowed for aeration.

Methyl Bromide for Vacuum Fumigation

The dosage required depends on the temperature, the length of the exposure period, and the type of container in which the rice is packaged. For treating rice at 65° F. or above, the dosages shown in table 2 have been found to give satisfactory results.

TABLE 2.—*Dosages of methyl bromide required under various conditions for fumigating milled rice in a vacuum chamber*

| Type of package | Exposure period | Dosage per 1,000 pounds of rice | Minimum dosage per 1,000 cubic feet of space ¹ |
|-----------------|-----------------|---------------------------------|---|
| | <i>Hours</i> | <i>Ounces</i> | <i>Pounds</i> |
| Pocket----- | 2 | 1½ | 3 |
| Do----- | 3 | ¾ | 2 |
| Do----- | 12 | ½ | 1 |
| Carton----- | 2 | 2 | 4¼ |
| Do----- | 3 | 1½ | 3 |
| Do----- | 12 | ¾ | 2½ |

¹ Use no less regardless of size of load.

After the fumigation, the rice is aerated by the same methods as described for vacuum fumigation with hydrocyanic acid.

Fumigation of Rice in Railway Boxcars

Milled rice in pockets and rough rice in bags or in bulk can be successfully fumigated in all-steel grain boxcars that are tight and that have been properly sealed. If possible the cars should be prepared for fumigation before they are loaded, one door and all cracks be-

ing sealed from the inside with masking tape or putty, and oil (fig. 22). Car floors can be made more gastight by covering them with a layer of laminated paper that will not "bleed" due to the pressure of the load.

Wooden cars are not as satisfac-



BN-4147

Figure 22.—Sealing railway boxcar for fumigation. (Courtesy of H. T. McGill.)

tory as steel cars since it is difficult to make them tight enough to hold a high concentration of fumigant. When it is necessary to use them the dosage must be increased to offset the greater leakage.

For the fumigation of bagged rice, either milled or rough, methyl bromide or hydrocyanic acid can be used. Of the two fumigants, methyl bromide is most commonly used, owing to the ease of application and aeration.

If methyl bromide is used a dosage of from 10 to 12 pounds per car for steel cars and 12 to 15 for wood cars is recommended, based on the quantity of rice in the car and the temperature of the rice. The methyl bromide is applied by means of one or two $\frac{1}{4}$ -inch plastic tubes inserted through a crack in the doorway and

extended to a point above the rice. The upper ends of the tubes should be plugged, and $\frac{1}{8}$ -inch holes drilled in each side to allow the fumigant to be ejected horizontally in opposite directions above the rice. Liquid methyl bromide can dissolve the asphaltic compounds used on freight car ceilings, therefore the discharge from the tube should be directed so that no liquid strikes the ceiling. The tubes should be fastened near the ceiling with string or soft wire and tacks, but lightly enough so that they can easily be pulled loose and withdrawn after the gas is applied.

The same precautions should be taken in the application of methyl bromide and in the aeration of the car after fumigation as is required for its use in atmospheric vaults.

Hydrocyanic acid can be used at a dosage of 1½ ounces of liquid hydrocyanic acid per thousand pounds of rice with a minimum dosage of 1¾ pounds per thousand cubic feet of space for a 72-hour exposure.

For the fumigation of rough rice in bulk in railway boxcars any of the heavier-than-air fumigants recommended for the fumigation of rough rice in farm bins can be used by applying uniformly over the surface of the grain, at the same dosages.

Where complete and quick kills are essential, bulk rice in boxcars, both milled and rough, may be fumigated with methyl bromide by the recirculation method. By this method 10 steel probes 6 feet in length with perforated tips are inserted in the grain equidistant in a line down the center of the car (fig. 23). The probes are connected by a duct system to a blower inserted in the middle of the system. When in operation, air is withdrawn from the floor level and discharged into the headspace, thus setting up recirculation. To simplify things the duct system can be constructed with a length of metal spouting to serve as a manifold. The blower should have a capacity of not less than 625 c. f. m. against 5-inch static pressure. The entire system should be set up inside the car.

The fumigant can be introduced through a ¼-inch plastic tube into



BN-4144

Figure 23.—Interior of railway boxcar filled with rice, showing metal probes, duct system, and blower for circulating methyl bromide through rice.

the air space above the grain and the blower allowed to run for 30 minutes after the gas is applied. A dosage of from 12 to 15 pounds per car of methyl bromide will be found satisfactory.

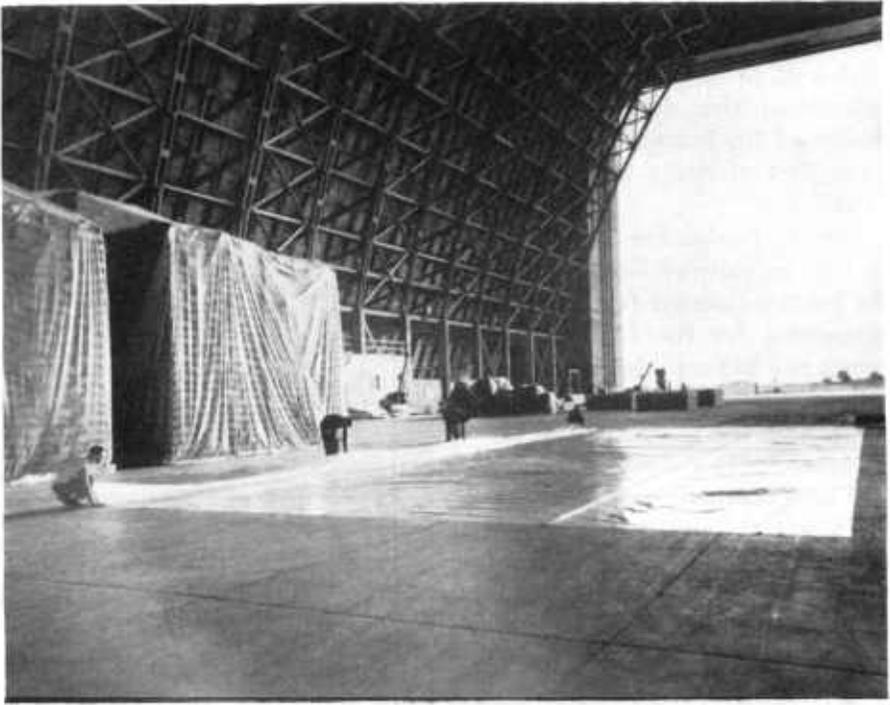
All fumigated cars should be placarded on both side doors with a red card showing that the car has been fumigated, giving the date, naming the fumigant used, and warning against entry before aeration.

In the case of cars fumigated with liquid HCN or methyl bromide it will be necessary to aerate them before they are shipped.

Fumigation of Rice Under Gastight Sheets

In warehouses that are too loosely constructed for successful fumigation, or in large storages where it

would be impractical to fumigate the entire space, it is advantageous to fumigate individual stacks of



BN-4166

Figure 24.—Tarpaulin covered stack of rice, also sheet of polyethylene plastic material laid out ready to cover another stack.

bagged rice under a gastight tarpaulin (figs. 3 and 24). In some cases the plastic covers may be left in place over the stacks as long as they remain in the warehouse. These covers then serve to protect the stack from reinfestation by flying insects and are always ready for an additional fumigation as required. Polyethylene sheeting makes an inexpensive covering for this purpose. A 3-mil gauge sheet is heavy enough where it is to be left in place; however, if it is to be moved from one stack to another, 4-mil or 6-mil gauge sheeting should be used. Other materials that can be used are plastic-coated nylon, plastic-coated canvas, balloon cloth, or rubberized fabrics.

A plastic tube connected to a cylinder of fumigant can be used to introduce the gas at the top of the stack in one or more places depending upon the size of the stack. In very large stacks it is desirable to connect the cylinder to two or more nozzles installed in wells made by stacking the top layer of bags in an appropriate pattern. In most cases, however, it is only necessary to use a single open-ended plastic tube to introduce the gas. An air dome at the top of the stack should always be provided so that the gas can be introduced without wetting the plastic sheet.

The plastic tube from the cylinder can be run up from the base of the stack or introduced through a

hole in the tarpaulin. After the gas is introduced the tube can be withdrawn and a patch pasted over the entry point.

The base of the stack should be made airtight by the use of "sand snakes."

Dosages of 1½ pounds of methyl bromide or 1½ to 2½ pounds liquid HCN per 1,000 cubic feet are recom-

mended for the fumigation of bagged, milled, or rough rice at temperatures of 70° F. or above.

At lower temperatures it is necessary to increase these dosages in order to obtain complete kills. To facilitate penetration of the gas it is recommended that all rice be stacked on pallets.

Precautions in the Use of Fumigants

Fumigants toxic to insects are also toxic to human beings and animals. In handling them, the operator should take all necessary precautions and follow all directions given on manufactured products. Care should be taken not to breathe the vapors or spill the liquid fumigants on the skin or clothing. Unless the operator is acquainted with the fumigant and methods of using it, it is preferable before undertaking fumigation work to have a professional or experienced fumigator instruct the workmen who are responsible for its use, or, in large operations, to have it done by professional fumigators.

Gas masks equipped with canisters of the proper type for protec-

tion against the particular fumigant being used can be relied upon for complete protection only against low concentrations encountered around the equipment being used and the outside of bins. They are not to be used in the bins or in other high concentrations of the gas. Even where used in light concentrations, a canister should not be used for more than the period recommended by the manufacturer and after that time it should be replaced by a fresh, unused canister. The only complete protection from high concentrations is to use an air-line mask supplied with air from a safe source and have the entire skin area protected.

CAUTION

A Federal law (518, 83d Congress) known as the Miller amendment to the Food, Drug, and Cosmetic Act, provides for establishment of safe tolerances for residues of useful insecticides on raw agricultural products. Both rough and milled rice are classed as raw agricultural products. Insecticides which leave no residue may, of course, be used on or around rice without regard to any tolerance. But most insecticides do leave a residue, and should be used on or around rice only if they are insecticides for the residues of which, on rice, tolerances or exemptions from the requirement for a tolerance have been established; and should be used only in such a way that their residues will not exceed their respective tolerances.

Directions for use of a pesticide, appearing on its label, are subject to clearance under another Federal law, the Insecticide, Fungicide, and Rodenticide Act. Such clearance is withheld if it appears likely, on the basis of experimental evidence, that the usage proposed would contribute residue in excess of the applicable tolerance; or, in event no applicable tolerance or exemption exists, if the proposed usage would be likely to contribute any residue.

For these reasons, it is the joint opinion of the Food and Drug Administration of the Department of Health, Education, and Welfare and of the Pesticide Regulation Section of the Department of Agriculture, that labels of pesticides in commercial channels should generally furnish a reliable guide to their usage in such way as to avoid incurrence of excessive residues.

Some pesticides contribute residue that is cumulative with repeated treatment. When, for example, rice is fumigated with methyl bromide, a certain amount of fixed bromide residue accrues from each fumigation; if repetition of fumigation were unlimited, a residue in excess of the tolerance would eventually accrue. Users of methyl bromide are cautioned not to fumigate rice more than three times at recommended dosage. If the fumigation history of a particular lot is unknown, or if it is known that it has already been fumigated three times with methyl bromide, it should not be refumigated with methyl bromide, or other bromine-bearing fumigant, unless chemical analysis for already-incurred bromide residue is first made, and such analysis establishes that there remains adequate tolerance allowance for the additional residue to accrue from the contemplated fumigation.

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