The scope of the work is constantly changing to meet the need for information on special types of storage, to evaluate the usefulness of new fumigants, sprays, drying, cleaning and grain-handling equipment, and storage structures, and to make adjustments for shortages of insecticides or structural material.

Insects are one of the most important hazards to the safe storage of grain—but the investigations have demonstrated time and again the basic truth that the factors favorable for preserving the keeping quality of grain are unfavorable for the development of insects.

The insects that attack stored grain are rather general feeders, but some of them definitely prefer certain grains. In the commercial corn area—Illinois, Iowa, Nebraska, Minnesota, and South Dakota—the six species most commonly found in stored shelled corn and constituting more than 98 percent of the insect population were the saw-toothed grain beetle, flat grain beetle, red flour beetle, foreign grain beetle, larger black flour beetle, and hairy fungus beetle. The first three comprised the greater portion of the insect population. In the South, where field infestation is common, the rice weevil is by far the most abundant species and constitutes the largest proportion of the insect population of stored corn.

In the Great Plains hard winter wheat region, seven species constitute more than 90 percent of the insect population of wheat in farm storage—the flat grain beetle, saw-toothed grain beetle, lesser grain borer, red flour beetle, long-headed flour beetle, cadelle, and rice weevil. Their abundance varies with climatic conditions. In the northern parts of the region, the harder species, the flat grain beetle and the saw-toothed grain beetle, predominate. In the southern part, the lesser grain borer and the rice weevil become increasingly abundant. Along the eastern seaboard the Angoumois grain moth is occasionally one of the common pests.
of stored wheat, although ordinarily the flat grain beetle and the rice weevil are the main species there. Found in greatest abundance in rough rice in storage are the Angoumois grain moth, rice weevil, flat grain beetle, lesser grain borer, and red flour beetle.

The moths that attack grain and seed are not among the most abundant species, but they occasionally appear in tremendous numbers wherever grain is stored. They confine their activities largely to the surface grain, where the caterpillars spin silken threads that mat the kernels together and form a silken web over the tops of bins. The Indian-meal moth, the chief offender, attacks all types of grain. It and the almond moth are also troublesome in seed stores and hybrid seed-corn establishments.

**Insects destroy** at least 5 percent of the world production of cereal grains. A survey in 1947 by the Food and Agriculture Organization of the United Nations indicated that in 29 countries the total loss of cereals was 25,750,000 tons, of which 50 percent could be attributed to insects.

Weevils, flour beetles, and many other bran beetles devour at least their own weight of food each week. Their larvae destroy many times their own weight of food during the 3 or 4 weeks they are developing. Loss of stored wheat in the Great Plains region may be as high as 10 percent in a season. Corn in storage in the deep South may be destroyed at the rate of 9 percent a month.

Insects may do other kinds of damage. Many species feed almost entirely on the germ of the grain, so that its viability is reduced and much larger amounts of infested than uninfested grain must be used for seed. They frequently cause grain to heat. A musty odor may result; deterioration and rotting of surface grain may be caused by the translocation of water vapor from the heated area to the cooler surface grain. A lowering of the grade may be caused by off-odors or insect damage. Finally, the milling quality of infested grain is reduced by the presence in the kernels of immature stages of weevils, which are hard to detect and cannot easily be removed during the milling process.

Many people still believe that insects are generated spontaneously in grain—probably because most of the insect pests of stored grain are so small that they remain unobserved until they have multiplied to such large numbers that the grain may suddenly seem alive with them.

The sources of insect infestations vary with crop and region.

In all grain crops in the South infestation begins in the field. The farther north the crop is grown, the less the degree of field infestation, until in the Great Plains and northward field infestation is almost negligible. Corn grown in the Corn Belt is comparatively free from field infestation except in the southern parts of Ohio, Indiana, Illinois, Missouri, and Kansas. Along the eastern seaboard, wheat may be infested to some extent in the field by the Angoumois grain moth, but in the main wheat-growing regions small grains are seldom infested in the field by this moth or by other stored-product pests. Leguminous seed—beans, peas, cowpeas, chickpeas, and others—are invariably infested with weevils in the field, so that the seed grower always must be prepared to prevent further damage in storage.

Besides field infestation, infestation in stored grain and seed originates in storage facilities or from nearby stores or accumulations of feed, grain, or other infested dry food products.

In the South, to minimize field infestation, early harvest is imperative. In the Gulf States, when harvest is delayed until October or November, 60 to 90 percent of the ears of corn in the field may be infested by the rice weevil and many ears almost completely destroyed. We know of no practical method of destroying insect infestation in grains and seeds in the field; hence harvest must be prompt so that control
measures can be applied in storage before serious damage occurs. Prompt harvesting of small grains is desirable wherever the Angoumois grain moth occurs. It helps to prevent infestation by the moth in the field and in the bin, because the soft-bodied moths cannot make their way far below the surface of binned grain to lay their eggs. The use of combine harvesters reduces damage to grain from the insect because the unthreshed grain does not stand in shocks or lie in the mow, where the moth can continue to breed in the entire mass.

The insect pests of stored grains and seed depend on their food supply for water. Seed or grain that is low in moisture is unfavorable for their development. The true grain weevils cannot breed in grain that has a moisture content below 9 percent, and their breeding is greatly restricted in grain unless the moisture content is above 11 percent. The bran beetles, of which the red flour beetle and the saw-toothed grain beetle are examples, do not breed in clean seed unless the moisture content is 11 percent or above or the temperature is above 80° F. If the seed contains floury dust or broken kernels, however, the beetles can breed in it regardless of the moisture in it. Moisture and temperature requirements of stored-grain insects are closely related. Up to certain levels their rate of development rises with the increase in temperature and the moisture content of the food.

Molding in bins causes considerable loss because the grain was not properly dry when stored or because water or snow leaked into the bin during the storage period. The percentage of loss is heaviest when temperatures are high.

Under storage conditions similar to those in Nebraska, wheat, oats, shelled corn, and like grains not intended for planting can be stored for a year with very little loss if the grain moisture content does not exceed 13 percent. Soybeans, which contain a high percentage of oil, are more difficult to store, and their moisture content should not exceed 11 percent for long-time storage. If the grain or seed is to be planted, the moisture content should be 1 or 2 percent less than we have indicated. The warmer the climate, the lower the moisture content at which it is safe to store grain or seeds.

Ear corn, since it is harvested in cool weather, can be stored safely in well-ventilated cribs in the Northern States with as much as 20 percent moisture and usually will dry to safe moisture levels by late spring.

The moisture-content requirements for long-time farm storage of grains and seeds are lower than those set by the United States official grain standards. The official standards are used primarily in marketing grain after it leaves the farm and enters commercial channels, where much of it is processed in a few weeks. Also, commercial handlers have better facilities than farmers for caring for grain. The bins in most large elevators have electric thermometers that enable the operator to read on a central instrument board the temperature of the grain at several places in each bin. The elevators have driers, conveyors, and elevator legs that make it easy to move the grain from one bin to another to break up hot spots or to mix damp grain from one bin with dry grain from another and thus reduce the average moisture content to a safe level for short-time storage.

Farmers hesitate to dry grain to safe moisture contents because in many markets they lose money if they have fewer pounds to sell even if part of that weight is water. Removing moisture from grain does not result in any loss of the dry matter, which is the valuable part. In fact, after a few months of storage, dry grain retains more of its original dry matter than moist, since the moister the grain the more dry matter is burned up by respiration of the kernel and by mold activity.

In Iowa 29 cribs were filled in November with corn having kernel moisture contents ranging from 15 to 26 percent. After 8 months of storage in
ventilated cribs, the average loss of dry matter from the kernels was almost 5 percent, the loss being greatest in the moistest corn. One crib was filled with car corn having 24.5 percent kernel moisture. When emptied in June, the corn had dried to 13.1 percent moisture—but besides the loss of water the kernels had lost 13 percent of the original dry matter.

Some elevator operators recognize the greater value of dry grain and pay a higher price for grain that is drier than the official grain standards require. More grain dealers might well follow that practice.

SAFE STORAGE is aided by freedom from cracked kernels and foreign material, which provide food for insects and fill up the spaces between kernels and interfere with the natural movement of air through the grain. In one test with shelled corn, in which air under pressure was used, 5 percent by weight of cracked corn, chaff, and other foreign material reduced air movement by 19 percent. Because the kernels continually give off heat and moisture by respiration, slowing down of air movement through the bulk of grain tends to develop hot spots and caked grain. Even the slow air movement in clean grain due to convection currents helps keep it in good condition.

Cleaning is best done when small grain, soybeans, or other seeds are combined or corn is shelled by properly adjusting the sieves and air blast of the machine. It can be done later with a fanning mill or by gravity flow over screens. A rod-bottomed section for an elevator spout to remove shelled corn and similar material when cribbing ear corn is illustrated in Farmers’ Bulletin 1976, Handling and Storing Soft Corn on the Farm.

To be satisfactory, a bin must hold the grain without loss of quantity; exclude rain, snow, and ground moisture; afford reasonable protection against thieves, rodents, birds, poultry, insects, and objectionable odors, such as might be caused by fertilizers, chemicals, dusts, gasoline, or kerosene; permit effective fumigation to control insects; and provide reasonable safety from fire and wind damage.

Many farm storages do not meet those requirements. A survey of 7,000 farms in Georgia, for example, disclosed that 74 percent of the storages visited could not be fumigated effectively, 96 percent were not rodentproof, and fewer than half gave good protection from the weather.

An examination by agricultural engineers of buildings used to store wheat and shelled-corn storages in six Midwestern States showed the importance of good foundations, floors, walls, roofs, well-constructed doors, and ventilator and roof-hatch openings in protecting grain. Even small leaks around a bolt without a lead washer in a metal roof may cause spoilage of 2 or 3 bushels of grain. Loose knots, split boards, or open joints in single-walled wood bins may allow leakage enough to spoil several bushels. Improperly flashed doors are other spots where leakage may occur. Floors that are too close to the ground may be flooded during heavy rains or by water backed up by snow and ice. Sometimes the top of the foundation is higher than the bin floor and catches water that finds its way into the grain. Concrete floors in damp locations should be raised well above the ground and protected by a vapor barrier (such as a layer of composition roofing under or on top of the concrete) to prevent rise of water vapor, which condenses in the grain and may cause serious spoilage.

SMALL GRAIN or shelled corn may be dried in batch or continuous driers before it is placed in the storage bin. Such driers consist of a ventilated container for the grain, a power-driven fan, a source of heat (usually an oil burner or a gas burner), and necessary handling devices and controls. Batch or continuous driers of a size to keep up with a small-grain combine or a corn
picker-sheller combination may cost $1,500 or more, depending on capacity, percentage of moisture to be removed, and the amount of construction done at home. They are rather expensive for the average farm, but they are good investments for farms that have large acreages of grains or seeds in areas where the grain cannot safely be left on the stalk until it is thoroughly dry. They could be used to advantage by groups of farmers.

The development of artificial drying methods and equipment suitable for farm use makes it possible to shell ear corn immediately after it is picked or to use the picker-sheller, a machine that leaves the cobs in the field. Corn can be shelled when the moisture content of the kernels is 25 percent or slightly more, although it must be dried immediately before placing in storage. Since shelled corn occupies only half as much space as ear corn, the cost of drying equipment may be offset by the saving in building cost. The method of field shelling, drying, and storage in bins instead of cribs may have special value in the South, where it is difficult to build cribs that can be ventilated well enough to dry the corn and then closed tightly enough for effective fumigation.

Drying grain in the bin is less efficient than drying with special driers, but the cost of equipment is usually lower. The ordinary method with small grains is to place a perforated or screened floor about a foot above the regular floor of the bin. Parallel rows of 8- by 8- by 16-inch concrete blocks may be laid on the floor, spaced 12 to 16 inches apart in each direction, and a 2- by 6-inch plank laid on top of each row of blocks. Special perforated and corrugated or ridged metal sheets are then laid over the 2 by 6's, thus making a continuous perforated floor. Air forced under the floor of the bin passes up through the grain. Hardware cloth supported on 2 by 4's, and covered with fly screen may be used instead of the perforated sheet metal.

The drying air may be heated or unheated. Drying with unheated air is slow, except when the atmospheric humidity is low and the temperature is above 60° F. For reasonably rapid drying, the air temperature should be above 80° and the relative humidity below 60 percent. In climates where atmospheric conditions at harvesttime are favorable, a heavy-duty electric fan or blower may give sufficient drying capacity, but under unfavorable conditions a unit that provides heated air is needed.

The best results are had when the thickness of grain on the perforated floor is not more than 2 or 3 feet. If air under sufficient pressure is available, drying can be done at depths of 6 or even 10 feet, depending on the moisture content of the grain and the resistance it offers to passage of air. For example, air passes through shelled corn and oats much more easily than through wheat. The wetter the grain the thinner the layers should be. From 5 to 10 cubic feet of air per minute per bushel of grain are needed when drying at temperatures between 60° and 130° F., which are about the limits for farm drying. Detailed information about equipment and methods for drying shelled corn and small grain in bins are described in Farmers' Bulletin 2009, Storage of Small Grains and Shelled Corn on the Farm.

Ear corn may be dried in almost any type of crib. One way to distribute the drying air is by using a large canvas on the side of the crib to form an air duct. Methods of drying corn are described in Farmers' Bulletin 2010, Storage of Ear Corn on the Farm, and Circular 839, Mechanical Drying of Corn on the Farm.

Ventilation is desirable to cool grain in large bins or flat storages in autumn and thus prevent "migration of moisture" from the warm interior to the cool top layers of grain. If the grain in large bins is not cooled rapidly, convection currents are set up by the temperature difference between the warm grain in the central part of the bin and the cool grain around the edges. The
upward air currents at the center of the grain mass carry moisture to the cool top layers of the grain, where it condenses and may cause molding. The condition is particularly bad when insect infestation is present on account of the warmth and vapor given off by their respiration. Winter cooling of the grain helps to destroy insects in it. The amount of air needed to cool grain is much less than to dry it, and comparatively small fans and air ducts are adequate.

To preserve grain from insect damage, one must think first of prevention of destructive outbreaks. Most of the insect pests of stored grain and seed have short generations, a high rate of reproduction, and long-lived individuals—characteristics that cause great fluctuations in numbers. Under favorable conditions, outbreaks are apt to occur suddenly.

The immediate causes of such outbreaks are the factors that affect the rate of egg laying, the rate of development, the death rate, or the longevity of the insects. The more important factors are moisture, temperature, food supply, and human activities. We cannot do much to alter the weather or change the existence of large supplies of food, but we can make grains less susceptible to insect attack by the use of efficient cleaning and drying equipment and by the application of fumigants and good storage management practices.

After prompt harvest, followed by drying when necessary, grain and seed should be stored in clean, insect-free, weather-proof storage on premises from which nearby sources of insect infestation have been eliminated. Steel bins that are easy to clean and can be made tight by calking are best for storage of small grains, shelled corn, or other seed. Wooden bins should be thoroughly cleaned and the walls and floors treated with a residual spray before they are refilled. This will kill most of the insects that emerge from burrows and cracks in the woodwork. Steel bins should be thoroughly cleaned. It is not necessary to spray the entire bin, but it is advisable to spray around the door frame where insects may be concealed. Wooden-crib elevator bins should also be sprayed.

For spraying bins use 2.5 percent of DDT, TDE, or methoxychlor by weight as emulsions or water suspensions, or 5 percent of piperonyl butoxide and 0.5 percent of pyrethrins by weight as an emulsion. The sprays should be applied at the rate of 2 gallons per 1,000 square feet of surface area. They may be applied safely and easily with an ordinary garden sprayer or a power sprayer.

Farm-stored small grains should be fumigated within 2 weeks after placing in the bin in the South and within 6 weeks in the central part of the United States. In the North, fumigation after storage may not be necessary but is good insurance against infestation. Fumigants and dosages recommended for small grains in farm storage are given in the chapter, "Fumigating Stored Foodstuffs," page 345.

In the Northern and Central States, one fumigation will probably be enough. Properly applied, the fumigant will destroy insect infestations present and will protect the grain from serious insect invasion until fall. Winter weather will then cool the grain to levels where insects are inactive.

Farm-stored grain should be inspected periodically to detect dangerous insect infestation. In Northern and Central States during the warmer months and in the South throughout the year, grain that has been in storage a month or more should be inspected every 2 to 4 weeks and refumigated if serious infestations are found.

The need for refumigation will depend on circumstances and the insect involved. In general, if living specimens of the rice weevil, granary weevil, or lesser grain borer are present, or if enough bran beetles are present to cause the grain to be graded weevily
(five beetles per quart), the situation calls for immediate application of remedial measures. Similarly, a surface infestation of moths, as indicated by the presence of webbing, is dangerous.

Rice is commonly infested in the field by the rice weevil and other insects. Hence it must be fumigated soon after it is put in storage. The fumigants and dosages recommended for small grains can be used. Rice is high in moisture content at harvest. It must therefore be dried after it is threshed if it is to be stored in bins on the farm.

Rice that is harvested with a binder is shocked and allowed to dry in the field until the grain moisture is approximately 14.5 percent. Then it is threshed from the shock and put in burlap bags for storage in warehouses. Rough rice in warehouse storage can be fumigated efficiently with hydrocyanic acid or methyl bromide at a dosage of 1.5 pounds per 1,000 cubic feet of space, provided the warehouses are made tight enough to hold the fumigant for 24 hours.

Soybeans stored in farm-type bins rarely become seriously infested with insects. Occasionally small infestations of bran beetles occur in high-moisture soybeans. If serious infestation should develop, the beans can be fumigated in the same way and with the same dosages recommended for small grains.

Field corn is usually stored on the ear for the first season because of its high moisture at harvest. With the exception of corn grown in the South and in the extreme southern part of the Corn Belt, field infestation is inconsequential and is killed out by winter temperatures that readily penetrate corn stored in slat cribs. During mild winters the Angoumois grain moth may survive in cribbed corn as far north as southern Indiana, Ohio, Illinois, Missouri, and Kansas, but in severe winters the moth will die.

Slatted crib bins afford no protection to corn from insects. In summer, therefore, a certain amount of infestation of ear corn is likely to develop. For corn that is fed or disposed of during the summer no treatment is required.

Corn that is to be stored for an additional year or longer should be shelled and put in bins as soon as the moisture in the kernels is down to a point as low as it is likely to go. In most seasons that is about the middle of May. Ear corn that is infested by the Angoumois grain moth will be seriously damaged unless it is shelled before the moths begin to emerge in the spring. As soon as the corn is shelled and binned it should be fumigated if infested. It should also be inspected every 2 to 4 weeks during warm weather, as recommended for small grains, and fumigated or refumigated if necessary.

In the area south of the Corn Belt, corn is more likely to become heavily infested in the field by the rice weevil and other insects. Where field infestation is light, ear corn should be fumigated as soon as possible after harvest. The cribs should be lined on the inside with roofing paper, fiber-reinforced paper, or other material to make them tight enough for fumigation, and also be provided with ventilators on the sides and gable ends that can be opened after the fumigation to facilitate drying.

In the South where field infestation is heavy, corn should be harvested as early as possible after maturity and promptly dried, shelled, cleaned, stored in tight bins, and treated with fumigants. Thereafter it can be handled as recommended for shelled corn in other regions.

In the warehouse storage of bagged grain or seed, the warehouse has to be of modern construction, easily cleaned, and tight enough for fumigation. Much can be done to improve the condition of old, poorly constructed warehouses. Every effort should be made to eliminate dead spaces in walls and floors where accumulations of grain and seed offer food and housing for insects.

Double, hollow walls and partitions should be eliminated. If floors are of wood, see that all cracks are filled or
kept clean of dust or accumulations of grain. Mop boards should be removed and openings where floor and walls meet should be filled with an elastic cement, such as a good calking material or a good grade of roofing cement. All cracks around posts and in walls should be similarly filled and the walls painted.

Old wooden floors and badly worn concrete floors are difficult to keep clean. They can be renovated by laying quick-setting plastic preparations over the old ones. Light and ventilation should be adequate. Most insect pests of stored grain seek dark corners in which to hide.

Strict sanitation in the warehouse is imperative. Bagged grain and seed should be stacked on racks or lift platforms, if possible in piles at least 12 inches from the walls of the warehouse and far enough apart to allow inspection and cleaning. Floors and walls should be sprayed periodically with a residual spray as a preventive measure—a help in preventing trouble from migrating insects. If the warehouse is filled or partly filled with bagged grain, the stacks of grain must be covered during spraying operations to prevent contamination.

**Fumigation of Grains and Seed on the Farm**

The farm where infestations often originate is important, but it is no less important to fumigate them in the elevator or warehouse. Much of the grain and seed produced goes directly to such storage without temporary storage on the farm. In the rush of the harvest season it is difficult to be sure that some old stocks of infested grain are not mixed in with uninfested grain as it is put into elevator storage. Furthermore, many country elevators that handle grain between the farm and the terminal elevators have wooden crib bins that are a continuous source of infestation. It is just as important to clean up the premises of country elevators and spray empty wooden bins with residual sprays as it is on the farm. The same sprays and dosages recommended for farm bins should be used.

At times when most bins are empty the entire elevator can be fumigated. A close and continuous check should be kept on all grain stored in elevators, and it should be fumigated at the first sign of trouble. As a precautionary measure it is desirable to fumigate all new stocks of grain received from farm storage.

Many fumigants and fumigant mixtures that are difficult and dangerous to use in farm storage are suitable for elevators, and different methods are available for applying them. Automatic applicators controlled by the flow of the grain now eliminate the possibility of inaccurate dosages and relieve the operator of the discomfort and danger of applying liquid fumigants by hand. Mixtures of carbon tetrachloride with carbon disulfide, ethylene dichloride, propylene dichloride, trichloroethylene, chloropicrin, ethylene dibromide, various combinations of those chemicals, and calcium cyanide are being used successfully.

The case with which grains are handled in elevators makes it simple to use cleaning or drying machinery to turn it during periods of cold weather, and thereby improve its condition or cool it to temperatures where it will be safe from insect attack.

Fumigation of seed may be done in bins, vaults, and warehouses, or under tarpaulins. Hydrocyanic acid can be used at the rate of 1 pound to 1,000 cubic feet of space. No damage to germination need be feared under normal conditions. For treating binned seed a 3 to 1 mixture of ethylene dichloride and carbon tetrachloride is recommended at a dosage of 5 gallons per 1,000 bushels of seed. The mixture does not appear to injure germination of bulk seed regardless of the seed moisture, the dosage, or the exposure period.

The vapor from naphthalene and paradichlorobenzene crystals is toxic to insects, and they have been used extensively for the protection of seed. The recommended dosages vary greatly. A popular dosage is about 1 ounce.
of the crystals per bushel, although much heavier dosages are sometimes recommended. The maximum weights of naphthalene and of paradichlorobenzene needed to saturate the atmosphere at 77° F. are 0.04 and 0.5 pound respectively for 1,000 cubic feet of space. Thus the small dosage recommended is more than sufficient to provide a saturated atmosphere.

Little injury to germination of seed corn need be feared from naphthalene vapors if the moisture content of the corn is below 12 percent. Paradichlorobenzene vapors cause serious injury to germination even in very dry seed, however. Seed treated with either chemical is rendered unfit for animal feeds, since an obnoxious odor and taste are imparted to the flesh of animals and poultry fed treated grain and to the eggs laid by poultry so fed.

**Hybrid Seed Corn** or other seeds must be fumigated carefully in order not to injure the viability. If seed moisture is more than 12 percent, or if the dosage or the exposure period is excessive, many fumigants will cause such injury. Exposure periods should not exceed 24 hours. If bulk seed is treated, provision must be made to aerate it after 24 hours unless the fumigant is known to be harmless under all conditions. Most bulk seed absorbs and retains fumigants for long periods; therefore, unless it is aerated, the exposure period is automatically extended and serious germ damage will result.

The entire warehouse can be fumigated satisfactorily if it can be made gas-tight. If it is not full enough to make it worth while, individual stacks can be fumigated under gas-tight tar- Paulins. For grains other than seed, methyl bromide is the best fumigant to use; if the temperature is 70° F. or above, a good kill can be obtained with a dosage of 1 to 1.5 pounds per 1,000 cubic feet of space. At temperatures below 70° the dosage can be increased at the rate of one-half pound per 1,000 cubic feet of space for every 5° drop.

To fumigate corn or milled rice in warehouses, hydrocyanic acid can also be used at a dosage of 1.5 pounds of liquid hydrocyanic acid per 1,000 cubic feet. That dosage is also safe to use for the fumigation of seed of all kinds.

**Mixing seed** with dust is simple and economical. It gives long-time protection against insects and does not affect the viability of the seed.

Many dusts have been used. Some are active insect poisons. Others apparently affect the insects physically rather than chemically. In the following discussion, we designate the poisonous dusts as chemically active; those that appear to have only a physical effect on the insects we refer to as chemically inert.

Chemically inert dusts are thought to be effective by causing breaks in the waterproof fatty covering of insects so that the dusted insect dies as a result of the evaporation of excessive amounts of body moisture. Because of their mode of action, the effectiveness of inert dusts declines as the moisture content of the seed increases over 12 percent.

Inert dusts that have been used successfully for treating seed include finely divided silica gel, rock phosphates, precipitated chalk, magnesium oxide, and aluminum oxide. Dusts with a particle size of 1 micron or less can be used at the rate of 1 part per 1,000 parts by weight or approximately 1 ounce per bushel.

Pyrethrin powder has often been recommended for mixing with seed. Finely ground dusts impregnated with pyrethrins and piperonyl butoxide also have been advocated for this purpose; they show promise as preventives of insect infestation.

Poisonous dusts are effective regardless of the moisture content of the seed. Because surplus seed stocks often are fed to animals, however, the dusts have not been popular. Outstanding among them are lindane and DDT. Lindane is effective at a dosage of 1 part per mil-
lion and DDT at the rate of 15 parts per million. Both are best used in combination with a carrier such as pyrophyllite or similar chemically inert dust. The carrier increases the volume and therefore insures thorough distribution over the seed. A dust containing 3 percent of DDT is effective when mixed with seed at the rate of one-half ounce per bushel. No damage to seed viability has been observed as a result of treatment with either compound at recommended dosages.

The practice of treating many types of seed with disinfectant dusts to protect it from fungus diseases is being amplified by the incorporation of small percentages of DDT to insure protection from insects.

Dusts may be applied by any method that will insure a uniform coverage. To treat bulk seed, a seed-treating machine is satisfactory. Operators applying the dusts should be equipped with adequate respirators. Because of the poison hazard involved, seed that has been treated with DDT, lindane, or a fungicide should not be used as food for man or livestock.

Grain is transported to mills and terminal elevators chiefly by railways. Boxcars used for the purpose are so constructed that grain and grain dust invariably accumulate in cracks in the floor, at the junction of the walls with the floor, between the ends and the wooden-end linings, and sometimes between the side walls and the inner grain linings of the cars. Such accumulations of grain and dust become infested, and the infestations are difficult to remove or destroy by ordinary methods. Consequently they are dangerous sources of infestation to other, later shipments of grain or milled cereal products. Obviously it would be desirable to prevent the contamination of the cars by shipping only insect-free grain or other products. While much is being done to reduce infestation in grains and grain products, it is doubtful whether we shall ever reach the stage where total elimination of insect infestation in these products will be possible.

Changes in the construction of boxcars would help reduce the opportunities for insect colonies to become established in them. The removal of the bottom board on the inner grain linings on the sides of the cars facilitates cleaning and prevents the accumulation of grain and waste material between the linings and the side walls. The placing of layers of resilient insulating material between the end linings and the corrugated ends of the cars would help eliminate space in which grain and dust could accumulate. Fibrous glass shows promise of being useful for this purpose. The impregnation of such insulating materials with DDT would probably add to their efficiency in preventing the establishment of insect infestations.

As remedial measures where infestations do occur, cars should be thoroughly cleaned out with compressed air after each use. The application of a residual spray (with a knapsack sprayer, a power sprayer, or an aerosol-type generator) also is helpful. Residues from it do not appear to be a hazard to shipments of grain or milled cereals. In most cases, cars are lined with paper before loading with milled cereals.

Grain and grain products are so attractive to insects that they have to be packaged in containers that afford them the greatest protection from infestation during later storage.

Most insects that infest cereal products have comparatively weak mouth parts and cannot cut through substantial wrappers. Many can thrust their ovipositors through the meshes of fabric bags and lay their eggs directly in the cereal products within the bags. The immature stages of many insects also can crawl through the meshes and through needle holes along the seams and at the top or bottom where the bags are sewn. The more closely woven fabrics offer the greatest resistance to penetration. Bags made of paper, paper laminated to cloth or back-filled fabrics, and cartons of fiberboard offer
more resistance to insect penetration than ordinary cotton or jute bags. Unless such containers are adequately sealed, however, small flat beetles, such as the saw-toothed grain beetle and the larvae of other beetles and moths, may easily penetrate through minute openings where the seals are imperfect. Most commercial methods of sealing bags and cartons are inadequate. If bags are closed by sewing, the sewed ends must be protected by the use of a gummed strip that will cover all needle holes. For fiberboard cartons the application of a wet-wrap cover offers the best protection. Experimental work with insect repellents for incorporation in the adhesives used to seal fiberboard cartons and paper bags may help solve the problem.

Impregnation of fabric and paper bags with pyrethrins or pyrethrins and synergists has been found to afford considerable protection against penetration by insects. In fabric bags this protection is more efficient when the weave is close enough to offer some mechanical resistance against penetration. More powerful insecticides such as DDT, benzene hexachloride, and chlordane also are effective in resisting penetration when used to impregnate bags, but (because of the danger of contaminating the food) are not practical for use in insect-proofing bags intended for packaging food. Insect-repellent chemicals may offer the best means of providing an insect-proof container. Packages impregnated with them are particularly useful in resisting the invasion of certain insects that have wood-boring habits.

The cadelle, probably the most troublesome of the boring insects, feeds on a wide variety of stored commodities and is widely distributed. It is primarily a pest of grain and flour and is commonly found in railway boxcars, ships, warehouses, farm granaries, and other places in which foodstuffs are stored or transported. The larva bores into woodwork to form a sheltered place in which to hibernate or to transform to the pupal or adult form. It has jaws powerful enough to cut through many types of packages. It will cut through a multiwall paper bag or metal-foil-wrapped carton overnight.

Termites also burrow through cartons and other packages that are stored in warm, damp locations, or in warehouses with wooden floors that are infested. The larvae of many insects, when fully grown, have the urge to migrate in search of pupation quarters.

The steady rise of population in this country and the increasing demand placed on us to share our food supply with people of other nations makes it imperative that we conserve as much as possible of our harvested crops.

More pest-free storage, on and off the farm, is needed for handling crops at harvest time and to carry over reserves from year to year.

We cannot in the foreseeable future expect research concerned with the control of insects in stored grain to be completed, but on the other hand, we are more than holding our own against these pests. As we learn more and more about sprays, fumigants, control of grain moisture, and the habits and weaknesses of the insects themselves we are better able to meet their threats.

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