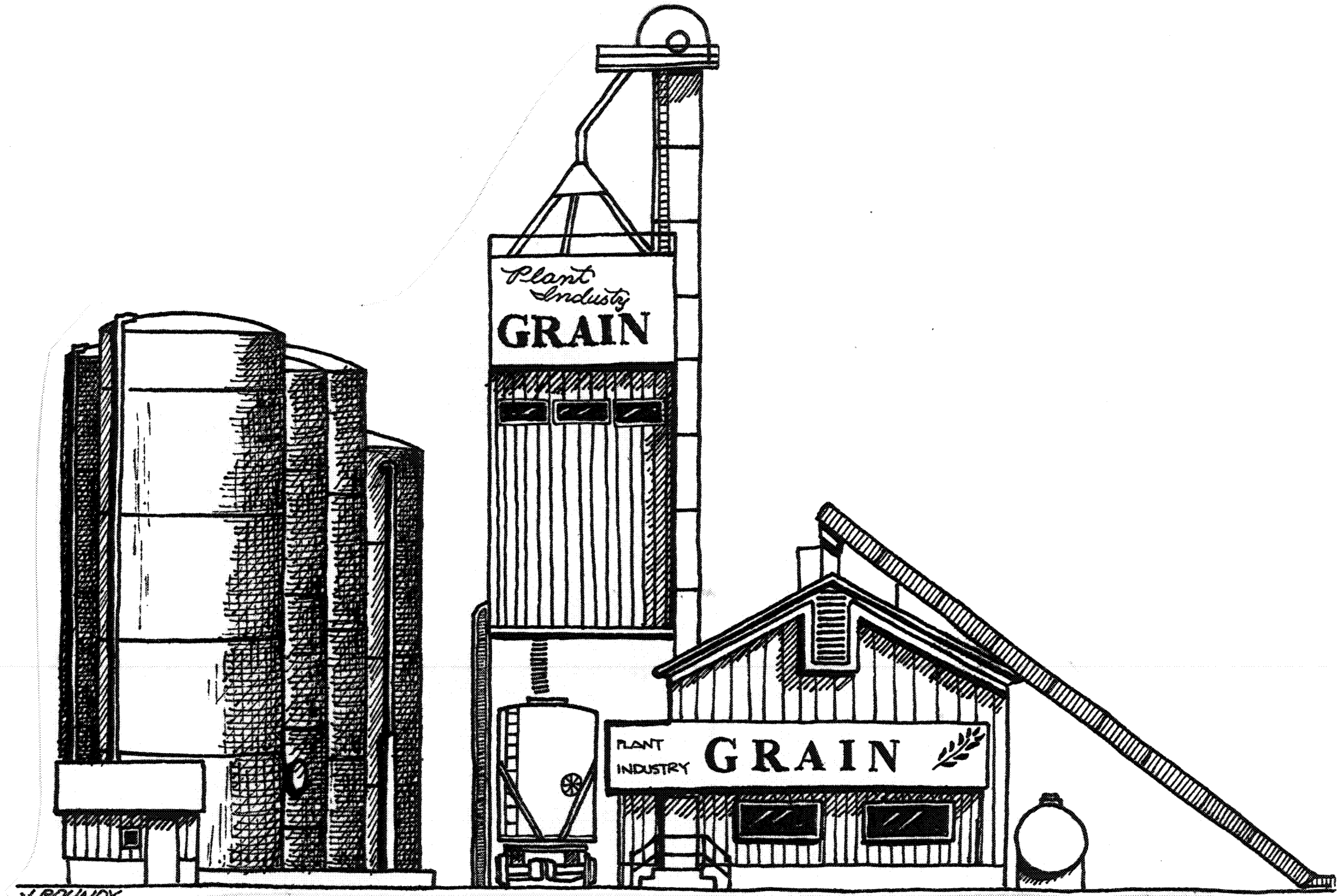
FUMIGATION / STORED COMMODITIES PEST CONTROL

PESTICIDE APPLICATION AND SAFETY TRAINING STUDY GUIDE



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STUDY GUIDE FOR FUMIGATION/ STORED COMMODITIES PEST CONTROL

The educational material in this study guide is practical information to prepare you to meet the written test requirements. It doesn't include all the things you need to know about this pest-control subject or your pest-control profession. It will, however, help you prepare for your test.

Contributors include the Utah Department of Agriculture and Utah State University Extension Service. This study guide is based on a similar one published by the Colorado Department of Agriculture. Materials were prepared by Colorado State University Extension Service. Other contributors include: University Extension Service personnel of California, Kansas, New York, Oregon, Pacific Northwest, Illinois, Georgia, Pennsylvania, and Wyoming. The U.S. Department of Agriculture -- Forest Service, the U.S. Environmental Protection Agency (Region VIII), and the Department of Interior -- Bureau of Reclamation, and Metro Pest Management. Other materials were prepared in a previous draft by Metro-Pest Management Consultants, Inc.

Other topics that may be covered in your examinations include First Aid, Personal Protective Equipment (PPE), Protecting the Environment, Pesticide Movement, Groundwater, Endangered Species, Application Methods and Equipment, Equipment Calibration, Insecticide Use, Application, Area Measurements, and Weights and Measures. Information on these topics can be found in the following books:

1. **National Pesticide Applicator Certification Core Manual,** Published by the National Association of State Departments of Agriculture Research Foundation.

2. **The Workers Protection Standard for Agricultural Pesticides – How to Comply: What Employers Need to Know.** U.S. EPA, Revised September 2005, Publication EPA/735-B-05-002.

These books can be obtained from the Utah Department of Agriculture or Utah State University Extension Service. Please contact your local Utah Department of Agriculture Compliance Specialists or Utah State University extension agent.

TABLE OF CONTENTS

BASIC PRINCIPLES OF GRAIN STORAGE

Grains can be stored several years, under proper conditions, with little or no detectable loss of quality. Under improper conditions, however, grains can begin to spoil within a few hours. Under the proper environmental conditions, certain micro-organisms can produce toxins or other products which can cause serious illness and even death when eaten by livestock or humans. Researchers have identified several of these toxins and the micro-organisms which produce them. Some of the conditions necessary for growth and the production of toxins also are known, but much work remains to be done in this important area of research.

To store grain successfully, grain and the atmosphere in which it's stored must be maintained under conditions that discourage or prevent the growth of micro-organisms that cause spoilage. The major influences on the growth and reproduction of micro-organisms in grain are:

1. Moisture
2. Temperature
3. Oxygen supply
4. pH
5. Condition or soundness of the grain.

MOISTURE

Moisture content is the most important factor affecting the growth of micro-organisms in stored grain. If moisture can be maintained at a low enough level, the other factors which influence storage won't greatly affect spoilage of the grain. Both the moisture content of the grain sample and the relative humidity of the surrounding air affect microbial growth and grain spoilage.

If a sample of grain is placed in a closed jar, water will move both from the grain into the air in the jar and from the air into the grain. If the grain and air are maintained at a constant temperature, a condition will be established at which the rate of water movement from the grain will exactly equal the rate of water movement into the grain. The net amount of moisture in the grain and in the air will be constant, establishing an equilibrium condition. The moisture content of the grain in this condition is known as the equilibrium moisture content, and the relative humidity in this condition is known as the equilibrium relative humidity. The equilibrium moisture content increases with an increase in equilibrium relative humidity. At a given moisture content, a higher temperature will result in a higher equilibrium relative humidity while a lower temperature will result in a lower equilibrium relative humidity.

For example, if a relatively wet sample of shelled corn with a moisture content of 25 percent is placed in an environment being maintained at 65 percent relative humidity, it will dry to the moisture equilibrium corresponding to this relative humidity, about 13-percent moisture content. Likewise, if a dry sample is placed in this environment, it will absorb moisture until it reaches the equilibrium moisture content. Grain is dried by forcing air with low relative humidities through the grain. The grain dries as it attempts to come into equilibrium with the air, which is at low relative humidity.

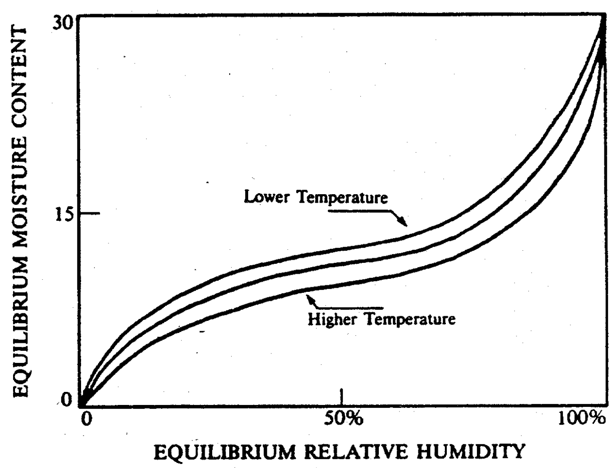


Figure 1.1 - Basic relationship between equilibrium moisture content and equilibrium humidity.

Conversely, if a large quantity of grain is placed in a tight storage structure, the air between the particles in the grain mass will come into moisture equilibrium with the grain. For example, if shelled corn at a moisture content of 13 percent is placed in a bin where the air has a relative humidity of 40 percent, the grain will lose moisture and the relative humidity of the air will increase to about 65 percent. The moisture content of the grain decreases slightly during this equalization period.

However, in view of the normally large amount of grain and small amount of closed air, this loss of moisture is insignificant and will affect the grain's moisture content only slightly.

Micro-organisms respond to their environment in somewhat the same way as grains. They absorb water in which the nutrients required for their growth and reproduction are dissolved. Nutrients can enter the micro-organism cell only if they are dissolved. When the relative humidity is high enough, micro-organisms can absorb moisture. If the relative humidity drops below a critical level, however, they can’t absorb water, which halts their growth and reproduction. Fungi have been recognized as a major cause of spoilage in grains. If the grain's moisture content is maintained at such a level that the equilibrium relative humidity of the surrounding air is at or below 62 percent, microbial growth will be minimal or arrested, and spoilage won’t occur. For shelled corn, this moisture content is about 13 percent at normal summer temperatures. This is why it’s generally recommended that shelled corn be dried to 13 percent moisture content for storage if the corn is to be stored through summer.

As stated earlier, temperature affects the equilibrium relative humidity of grains. At higher temperatures, the equilibrium relative humidity increases for a given grain moisture content. Grain that has a moisture content safe for storage at 75 degrees F. (for shelled corn, a moisture content of 13 percent and equilibrium relative humidity of approximately 65 percent) may not be safe for storage at 95 degrees F. since the equilibrium-relative humidity would increase. This is the reason (along with some other factors to be discussed in the effects of temperature on storage) that in the warmer climates, the recommended long-term safe storage moisture content for shelled corn is lower than 13 percent, and in colder climates it’s higher.

Average Moisture Contents

It isn’t sufficient to have a "safe" average moisture content if that moisture content is determined by averaging a very wet lot of grain with a very dry lot. If the wet lot is placed in the bin in one location (not mixed with the dry grain), microbial growth can take place in the wet lot and cause problems in the entire bin. Also, if moisture migrates to a certain area within the storage bin, which area may become wet enough to support microbial growth, which will result in spoilage. When thoroughly mixed, wet and dry grain will equilibrate to a moisture content at some point between the original moisture contents.

Moisture Migration

Moisture often accumulates in the top layers of stored grain, even though the grain is stored at a safe moisture content in weather-tight bins. The accumulation is a result of moisture migration, which is caused by temperature differences in the grain mass. Grain harvested and placed in storage during the warm months of late summer or early fall loses its heat slowly as the weather gets colder. Grain near the surface and next to the walls cools first, while that in the center of the bin remains warm. This temperature difference creates slowly moving air currents. Cool air near the walls moves downward, forcing warm air upward. When the warm air reaches the cold grain near the top surface, condensation may occur in the same way moisture condenses on the exterior of a glass of ice water. Although the moisture migrates slowly, it continues as long as temperature differences exist in the grain. If allowed to continue for months or even a few weeks, especially in large bins, the accumulated moisture may promote insect activity, microbial growth, and spoilage in the upper layers of the stored grain.

Moisture migration can be controlled by equalizing the temperature throughout the grain. An effective method of doing this is to move small quantities (one-tenth cfm per bushel) of air through the grain more or less continuously, or to move larger quantities (three to four cfm per bushel) of air through the grain periodically. Ventilating grain to control moisture migration is referred to as "grain aeration" or sometimes as "grain cooling." Proper operation of aeration equipment can keep dry-stored grain close to the average air temperature throughout the fall and winter. Aeration is a practical way to help maintain stored grain quality by providing better storage conditions.

TEMPERATURE

The effect of temperature on growth for two general groups of micro-organisms -- the thermophiles, whose growth is optimum at higher temperatures, and the mesophiles, whose growth is optimum at normal atmospheric temperatures. The growth curve for a third group, the psychrophiles, whose growth is optimum at low temperatures, isn't shown. Psychrophiles are not a major factor in grain spoilage.

Common storage fungi grow most rapidly at temperatures of 85 to 90 degrees F. Below these temperatures, growth rates decrease and reach a minimum at 35 to 40 degrees F. This is the reason that stored grains should be cooled to about 40 degrees F. by aeration when possible. Cooling below 40 degrees F. isn't recommended because storage fungi activity is already at a near minimum. Cooling the grain to below 32 degrees F. may result in freezing the grain to the extent that its removal from the bin may present a problem. Likewise, additional fan operation will be required to warm the grain mass as summer approaches.

GRAIN CONDITION

Grain condition refers to its quality. An increase in the amount of cracked, damaged kernels in stored grains can increase spoilage, thereby reducing its quality. This is one of the reasons it's impossible to establish an absolute maximum safe storage moisture for grains. Although the reason why cracked or damaged kernels affect spoilage are still a matter of speculation, it certainly involves the ability of micro-organisms to invade the grain kernel. Grain which is in poor condition must be dried to a lower moisture content than grain in good condition if it's to be stored over long periods.

GRAIN-STORAGE PROBLEMS

MOISTURE AND AIR MOVEMENT

To minimize the risk of post-harvest losses, grain must be placed in storage at the proper moisture content and temperature. It must be aerated and a regular and accurate method of inspection and sampling followed to maintain the stored-grain quality. Potential problems exist when:

1. Damaged and/or high-moisture grain is stored.
2. The aeration system is inadequate or improperly used.
3. The grain bin is incorrectly filled or unloaded.

Grain is a good insulator; heat loss from grain is relatively slow in comparison to other materials. For this reason, when grain is placed in a bin in the fall, the grain near the center tends to maintain the temperature at which it came from the dryer or field. The grain near the bin wall tends to cool to about the average outside temperature. As the outside temperature decreases, the difference in temperature between the grain at the center of the bin and that near the bin wall produces air currents inside the grain mass. The cool air near the bin wall falls, since it's more dense, forcing the warmer air up through the center of the grain mass. As the moist air passes through the center of the grain mass, it warms and picks up more moisture. As this air nears the top center surface of grain, it cools to a point where it can no longer hold the moisture it has picked up. This moisture condenses on the surface of the grain, increasing the grain's moisture content and creating an environment that enhances mold or insect growth. This can also cause bridging, when the grain level is lower -- a hazard to anyone entering the bin. This surface moisture change can occur even though the average grain moisture content is at or below recommended levels. The reverse situation occurs during the summer months. In this case, the moisture condenses near the bottom center of the grain mass.

Generally, the problem of natural air currents developing within a bin may be minimized by covering fan outlets when not in use and by keeping the grain temperature in the center of the bin within 10 degrees F. of the average grain temperature near the bin wall Temperatures can be maintained in most farm structures by using aeration fans that pull air down through the grain at airflow rates of at least 0.1 cfm (cubic feet per minute) for each bushel of grain in the bin until the temperature of the grain mass is within 10 degrees F. of the average monthly temperature. A slightly lower airflow rate may be used in very large farm or commercial structures. However, it isn't necessary to lower the temperature of the grain mass below 40 degrees F. because fungi that attack stored grain can't develop below this temperature. The grain shouldn't be frozen, because it will take longer to warm it back up and may present unloading problems. Also, the aeration system shouldn't be used to raise the temperature above 60 degrees F., because mold and insect growth occur at a much faster rate above this temperature. It takes about 120 hours (five days) for the entire grain mass to cool or warm when air is supplied at the rate of 0.1 cfm per bushel. This time is reduced to 12 hours when the airflow rate is increased to one cfm per bushel, which would be typical of the performance of a drying fan used for aeration.

Aeration Systems

The best method for distributing air evenly through the grain mass is to use a perforated floor.

Filling and Unloading Grain Bins

Storage problems may result from factors other than inadequate aeration. For example, when grain bins are filled, the foreign and light material such as trash, weed seed, and broken parts of kernels tend to accumulate in the center of the bin and may form a "core" of material from the top to bottom. This core may be so tightly packed that aeration or drying air will go around it through the surrounding loose, clean grain. Consequently, this zone may not dry properly, and in the case of in-bin drying systems, it provides an excellent environment for mold and insect problems. This potential problem may be reduced by using a grain-spreader that evenly distributes the fines. It’s also possible to remove the center material by unloading the bin with a center-draw unloading auger, and then uniformly spreading this material over the top surface of the grain after leveling. Other options would include feeding or selling the core material.

When probing a bin, investigate points where the probe has relative difficulty in penetrating. Generally, wet grain or trash offers more resistance to probe penetration than does dry grain. These areas that have higher moisture and an abundance of fine material may be where “hot spots” might occur. These hot spots may be found in any part of the grain mass.

INSECTS AND RELATED ARTHROPODS

Harborage Sites

Good sanitation is the foundation upon which a sound stored-grain insect-management program must be built. In many cases, severe insect infestation in grain bins develops from low-level populations of pests that are able to exist in grain-handling equipment or in and around the storage facilities. A thorough preharvest sanitation program can reduce these sources of insect infestations. The consequences of not cleaning up these infestations may not be seen until later in the storage cycle, after the insect population increases. The economic effects of poor prebinning sanitation may include kernel destruction, commodity contamination, moisture and temperature problems resulting from the insect's metabolic processes, or structural damage to the bin due to the heat and moisture buildup.

Insect harborage sites may be classified as internal and external, with reference to the bin facilities. Internal harborage sites include grain residues on the bin floor, accumulations of grain clinging to bin walls, and the fines and kernels which build up beneath the bin floor and in the duct-work of the drying system. The obvious, visible accumulations in the bin should be cleaned thoroughly when the bin is emptied. Accumulations beneath perforated floors mustn’t be overlooked. Often, floor construction makes thorough cleaning hard, and the use of vacuum hoses is helpful. Treatment of the floor-void area with a fumigant may have to substitute for cleaning, in some situations. Use of long-handled brooms and shovels may be sufficient to clean out the bin area itself. Very thorough cleaning is necessary to reduce the likelihood of infestation. Properly dispose of grain and debris collected in the cleaning process.

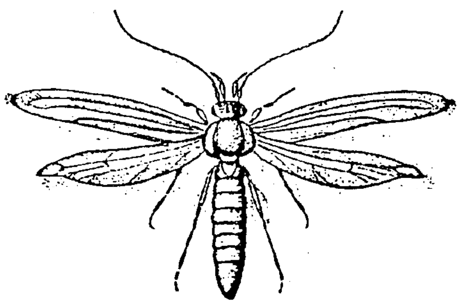
"External harborage sites" is a catchall category that includes a number of sites around the bin that can contain small numbers of stored-grain insect pests. Spillage near the auger, grain residues in harvesting equipment, and structures used to store animal feed are potential sources of stored-grain pests. Auger pits are especially important sources of infestation. These areas must be watched carefully and kept clean. A comparatively small amount of spilled grain can provide enough insects to produce a serious infestation in stored grain.

IDENTIFICATION, BIOLOGY AND BEHAVIOR

ANGOUMOIS GRAIN MOTH

Damage -- Angoumois grain-moth larvae attack and feed within whole kernels of a variety of grains, and this damage may result in weight losses per kernel of as much as 50 percent for wheat and 24 percent for corn. Badly infested grain has an unpleasant smell and is unpalatable.

Angoumois grain moths are primarily pests of crib-stored corn. Its importance as a grain pest has been downgraded in recent years because of the increased use of the picker-sheller. Infestations in bins are confined to the surface layer of grain. The presence of small holes in kernels and adult moths are the most likely evidence of infestation.



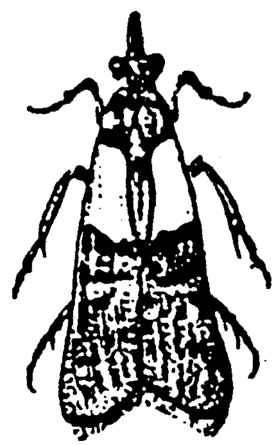
Angoumois grain moth (Sitotroga cerealella)

Description -- Angoumois grain moths are delicate, 0.3- inch-long insects with a wingspan of about 0.5 inch. The front wings are clay-yellow; the hind wings are gray and end in a thumb-like projection. The long fringe on the rear margin of both front and hind wings and the distinctive shape of the rear wings are the best identifying characters for this insect Full-grown larvae are 0.2 inch long, white caterpillars with yellow heads. This stage occurs within the kernel and normally isn't seen.

Biology -- The female oviposits in damp grain in preference to old, dry grain; maturing grains can be attacked in the field as well as in storage. They lay from 40 to 300 eggs (averaging 100) singly or in small clusters on or near grain kernels. The tiny, newly-hatched larva crawls to a kernel and spins a small cocoon to help it as it bores a hole, no larger than a pin prick, into the hard kernel covering. There are three larval instars. The larva feeds on the endosperm and germ, finishing development in two to three weeks. It chews a tunnel to the surface and eats a small exit hole, leaving a flap (small window) over the opening. The mature larva remains in the kernel and spins a silken cocoon in which it transforms to a reddish- brown pupa. The emerging moth pushes its way through the flap to leave the kernel.

Development from egg to adult may be complete in four weeks. One larva develops within a wheat kernel, while two to three larvae may develop within a single corn kernel.

INDIAN MEAL MOTH
Piodia interpunctella



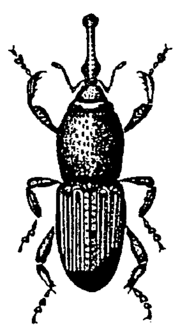
Damage -- The Indian meal moth larvae prefer to feed on fines or broken or damaged kernels. Infestations are most common in the upper four to six inches of grain in a bin. The larvae produce silken threads which result in "caking" or "crusting" of the surface grain. Their frass (products of their activity), cast exoskeletons (exterior skin-like covering) and silk contaminate the grain.

Description -- Indian meal moths at rest with wings folded over their backs are about 0.4 inch long. The wingspan is about 0.6 inch. The outer portion of the front pair of wings is bronzed to purple; however, this color is lost as the moth ages. The inner half of the wings near the body is light gray. The hind wings are gray and without distinctive markings. The larvae are the feeding stage and are caterpillars that may range from yellow-white to pink to light green with a light brown head. Full-grown larvae are about 0.7 inches long.

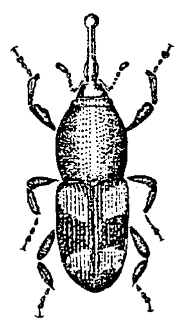
Biology -- Female moths deposit from 60 to 300 eggs, singly or in groups on or within the upper surface of the grain mass. The female lays her eggs over a three-week period. The larvae move about in the upper grain mass, feeding on fines and cracked kernels and producing a silken webbing as they feed. Full-grown caterpillars may leave their food source and climb up walls to pupate. The life cycle from egg to adult takes about six to eight weeks during warm weather. There are usually four to six generations per year, depending on food supply and temperature conditions.

GRANARY WEEVIL, RICE AND MAIZE WEEVILS

Sitophilus granarius; *Sitophilus oryzae*; *Sitophilus zeamais*



Granary weevil



Rice weevil

Damage -- These weevils are very destructive grain pests. The larvae attack in grain-kernels and develop within them. They can completely destroy grain in elevators or bins where conditions are favorable and the grain is left undisturbed.

Infested grain will usually heat at the surface and may be so damp that sprouting occurs. Eaten-out kernels containing small, white, legless grubs and small yellow-brown to black snout beetles are signs of infestation. Damaged kernels may be attacked by other storage insect pests.

Description -- The adults of all three species are about 0.2 inches long. The head is prolonged into a distinct snout; a pair of elbowed antennae may be seen coming off the snout near the head. The granary weevil is polished red-brown to black, has no wings under its hardened elytra (outer wing covers), and has a thorax well-marked with oval pits. The rice and maize weevils are dull red-brown, have wings and round pits on the thorax, and usually have light red to yellow spots on the hind-wing covers.

The larvae are soft, white, legless grubs that develop within the grain kernel. The hump-backed grubs have small, dark heads.

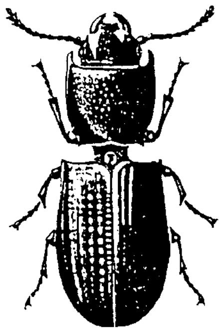
Biology -- The life cycles of these weevils are very similar. The female uses the strong mandibles on the end of her snout to chew a small hole into the grain kernel. She deposits a single egg in the hole and seals it with a gelatinous material. Females of both species can lay 50 to 200 eggs during their lifetime. The period of egg-laying depends on temperature and is usually very sporadic during the winter months. Rice-weevil eggs will hatch in about three days at temperatures in the 60- to 65-degree F. range. The weevil grubs feed entirely within the kernel. Rice and maize weevils may complete their development from egg to adult in about four weeks. Granary weevils generally require five to ten days more. The rice weevil has three larval instars. It requires warmer temperatures than the granary weevil. Development occurs only at temperatures above 55 degrees F. The life cycle may be completed in as few as 32 days in the warmest portions of the year.

The rice and maize weevils can fly, and infestations may develop in the field prior to harvest. Granary weevils can't fly and so are most likely to be found where grain is stored and to be moved about in infested grain. They have a tendency to wander and may be seen far from the source of infestation.

CADELLE BEETLE

Damage -- Cadelles produce irregular borings in kernels. They prefer the seed germ but will eat endosperm as well, and they can feed on a variety of grains, flour and meal. This beetle is commonly found in wooden bins. Both larvae and adults will bore into wood surfaces during their development cycle.

Description -- Cadelles, the largest of the major stored- grain beetles, are shiny dark to red-brown and about .06 inch long. Their ventral surface, antennae and legs are red-brown. A distinct narrowing of the body between the prothorax and elytra (wing covers) gives the appearance of a distinct "waist." The outer corners of the prothorax project forward toward the head.



Cadelle beetle

Cadelle larvae are the wormlike, immature stage. They have creamy white, elongate bodies with distinct black heads. There are two dark plates on the pronotum (upper part of the segment just behind the head). A distinct plate bearing two curved hooks is present on the rear of the larvae. Full-grown larvae are about 0.6 inch to one inch long.

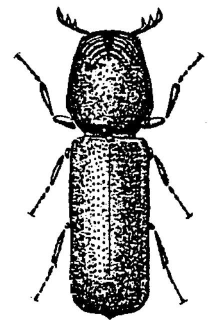
Biology -- Females may live more than a year and lay an average of 1,000 eggs each. The eggs are laid in batches of ten to 60 in the grain of food materials. Both larvae and adults attack grain and typically go from kernel to kernel, feeding on the germ. There are usually four larval instars and one or two generations of the insect per year in temperate regions. Larval development may be as short as eight weeks under optimum conditions. The larvae often migrate from the source of the infestation to pupate in a hole within wood or other materials. Eggs and pupae are easily killed at 0 degrees F.; however, larvae and adults can survive at 15 to 20 degrees F. for several weeks.

LESSER GRAIN BORER

Rhyzopertha dominica

Damage -- Lesser grain borers mainly attack wheat, corn, rice and millet. Both the larvae and adults are primary pests, which mean they bore irregularly shaped holes into kernels, and the larvae may develop inside the grain. Grain kernels may be reduced to thin brown shells as a result of larval and adult feeding. A sweet, musty odor is often associated with infestations of this insect.

Description -- The adults are brown-to-black beetles 0.1 inch long. They have cylindrical bodies with numerous small pits on the wing covers. The head is directed downward and covered by the prothorax so that it isn’t visible when the insect is viewed from above. The creamy white larvae are grubs. The small, dark head is partially retracted into the widened thorax. The thorax has three pairs of small legs. The abdomen is more slender than the thorax and may be curved to give the grub a C-shaped appearance.



Lesser grain borer (Rhyzopertha dominica)

Biology -- The female deposits her eggs in clusters of two to about 30 outside the kernels. Most of the newly-hatched larvae chew their way into kernels and complete their entire development there. However, the larvae are capable of feeding on fines and can develop as free-living insects in the grain. The larvae molt two to four times and can develop from egg to adult in about 60 days. Both the larvae and adults produce a large amount of frass. Larval fecal pellets are pushed out of the kernel, and large amounts of fecal pellets may accumulate in the grain. The adults are winged and may fly to spread infestations.

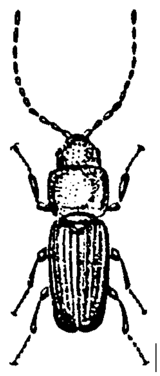
FLAT GRAIN BEETLE

Damage -- These insects are usually associated with high-moisture and/or heating grain. Flat grain beetles can’t feed on whole, undamaged kernels; however, even the smallest damage will allow invasions. Both the adult and larval stages feed on grain. Additional heat and moisture, as well as their waste products, may cause the most problems.

Description -- Two other species of *Cryptolestes*, the rusty grain beetle, *C. ferrugineus* and the flour-mill beetles, *C. turcicus*, are usually present with the flat grain beetle. Often all three species are referred to as flat grain beetles, and their appearance and biology are so similar that most people can't tell them apart.

Flat grain beetles are small, less than 0.1 inch in length, and red-brown. Antennae are long, often nearly the length of the entire body. Each wing cover has five ridges running its length. Adults are very active and can both jump and fly.

Immatures are elongate, slender, pale-colored and worm-like. The head is black, and the tip of the abdomen supports a pair of slender, black, spinelike processes.

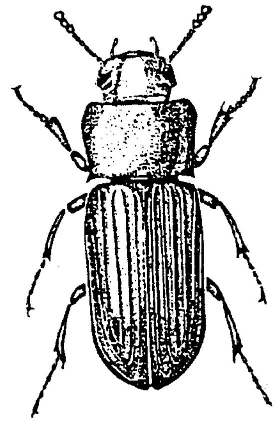


Flat grain beetle (Cryptolestes pusillus)

Biology -- Flat grain beetles are among the first insects to attack newly binned grain. They prefer high-moisture grain. Females may lay up to 200 eggs, which they place in cracks in kernels or drop loosely in the grain. Egg-to-adult development time is about five to nine weeks.

FLOUR BEETLES

Confused flour beetle -- *Tribolium confusum*
Red flour beetle -- *Tribolium castaneum*



Red flour beetle

Damage -- Flour beetles can't feed on whole, undamaged grain; they are, however, often found among dust, fines and dockage. Both species cause damage by feeding but probably cause more problems because of contamination. Large numbers of dead bodies, cast skins, and fecal pellets, as well as liquids (quinones), can produce extremely pungent odors in the grain.

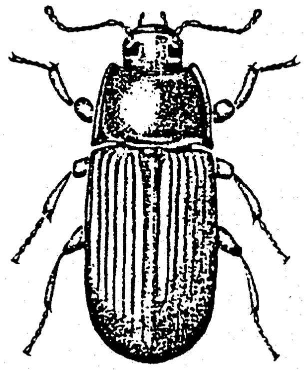
Description -- Both beetles are slender, red-brown, and about 0.1 inch long. They are very similar in appearance but can be distinguished by the shape of their antennae. Confused flour beetles' antennae gradually enlarge toward the tip, producing a four-segment club. The red flour beetle's antennae become clubbed abruptly, forming a three-segment club. In addition, the pronotum of the confused flour beetle has straight sides, while this segment on the red flour beetle has curved sides.

Full-grown larvae are yellow-white worms less than 0.1 inch long,. The head and the pair of projections on the tip of the abdomen are dark.

Biology -- Under favorable conditions, a female may lay 400 or more eggs at a rate of six to 12 eggs per day. Eggs are covered with a sticky fluid that allows particles of debris to adhere to them, resulting in almost perfect camouflage. Larvae undergo from five to twelve molts; the egg-to-adult-life cycle takes about 30 days.

MEALWORMS

Yellow mealworm -- *Tenebrio molitor*
Dark mealworm -- *Tenebrio obscurus*



Mealworm

Damage -- Damage by mealworms is largely limited to contamination by the worms and their waste products.

Description -- Mealworms are beetles very similar in size, shape and color, and both species are about 0.5 inch long. However, the dark mealworm adult is a dull pitch- black while the yellow mealworm adult is a shiny "polished" dark brown or black. Both species have well-developed wings and are attracted to light.

Larvae are 1.25 inch long when fully developed. They are cylindrical, hard bodied, and very similar in appearance to wireworms. The yellow mealworm is bright yellow, while the dark mealworm is dark brown.

Biology -- Adults emerge in spring and early summer. Females lay eggs for 22 to 137 days. On the average, a dark-mealworm female will lay 463 eggs, while a yellow mealworm female will lay about 276 eggs. The eggs are white, bean-shaped, and covered with a sticky secretion. This secretion allows particles of debris to adhere to the eggs. The larval period for both insects can last more than 600 days. Pupation occurs near the surface of the grain. The complete life cycle of both mealworms is ten months to two years.

FOREIGN GRAIN BEETLE

Stegobium paniceum

Damage -- Foreign grain beetles don't feed on the kernels or damaged grain; rather, they feed and develop on molds and fungi. Therefore, the presence of foreign grain beetles indicates grain that is too wet for prolonged storage.

Description -- The foreign grain beetle is a small camel-brown beetle about 0.1 inch long. It belongs to the same family as the saw-toothed grain beetle and is similar in size but can be distinguished from that insect by the lack of "saw-toothed" projections on the pronotum. The foreign grain beetle has a conspicuous rounded lobe on each front corner of the pronotum. A microscope or good-quality hand lens is necessary to see this characteristic.

Biology -- Foreign grain beetles are often found in stored grain. These beetles are one of a group of beetles called fungivores that feed on the molds and fungi that grow on high-moisture grain. If they are found on stored grain, the grain is invariably moldy. Eggs are laid in the moldy material, and the larvae feed on the molds and fungi.

CIGARETTE BEETLES

Lasioderma serricorne

Damage -- Cigarette beetle adults and larvae are omnivorous pests of stored products. They may be found in stored grain, where they may be feeding on debris or dead insects as well as damaged grain.

Description -- Adult cigarette beetles are light brown and about 0.1 inch long. They have a humpbacked appearance because their head and prothorax are bent downward. These insects have distinct saw-like antennae and smooth wing covers.

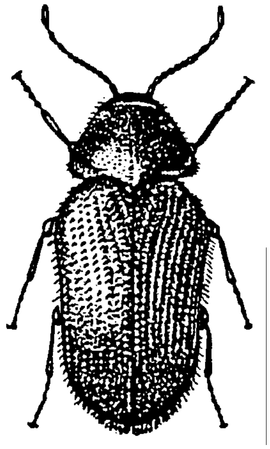
The C-shaped larvae are 0.2 inch long when fully developed. They are creamy-white and are covered with long hairs.

Biology -- The adult females lay eggs singly on food materials. The eggs hatch in six to ten days, and the larvae develop over the next five to ten weeks. There are four to six larval instars, after which they pupate in silken cocoons disguised by food debris. The entire life cycle takes from 40 to 50 days, and there may be from three to six generations per year.

DRUGSTORE BEETLES

Stegobium paniceum

Damage -- Drugstore beetles infest a very wide variety of stored products, including some plant materials that are poisonous. They are often found in stored grain, usually in association with other insect infestations such as Indian meal moths.



Drugstore beetles (Stegobium paniceum)

Description -- Adult drugstore beetles look almost identical to cigarette beetles. They are about 0.1 inch long, light brown to red-brown, cylindrical humpback-appearing beetles. Drugstore beetles have distinct grooves in their wing covers whereas cigarette beetles have smooth wing covers. Drugstore beetles have antennae that end in three enlarged segments, while those on cigarette beetles are saw-like.

Drugstore beetle larvae are C-shaped grubs that are relatively hairless, without the fuzzy appearance of cigarette beetle larvae.

Biology -- Female drugstore beetles lay their oval white eggs on food materials, where they hatch in six to ten days. The larvae have six to nine instars and are about 0.2 inch long when fully developed. The larvae form a small cell out of silk and food material in which they pupate. The entire life cycle takes from 40 to 50 days. There may be from one to four generations per year.

Adult drugstore beetles are very active and are often found in samples of infested grain. They can be identified by their rapid skittering movement in a grain-sample pan.

MERCHANT GRAIN BEETLE

Oryzaephilus mercator

Damage -- Merchant grain beetles are generally pests of processed foods such as cereals, flour, macaroni and nuts. They are commonly found associated with oil seeds. Their infestations are usually found associated with grains damaged mechanically during harvest or by other insects.

Description -- Adult merchant grain beetles look very similar to saw-toothed grain beetles but can be separated from saw-toothed grain beetles by inspecting the "temple" region between the eye and the pronotum. The length of this area on the merchant grain beetle is less than one-half the vertical diameter of the eye. These insects have fully developed wings and, unlike the saw-toothed grain beetle, have been observed to fly.

Merchant grain beetle larvae are about 0.1 inch long when fully grown. They are yellow-white with dark brown heads, three pairs of legs, and a pair of abdominal prolegs.

Biology -- Merchant grain beetles are not as cold-hardy as saw-toothed grain beetles and therefore don’t constitute as much of a problem in the northern U.S. and Canada.

Female merchant grain beetles lay about 200 eggs during their lifetime at a rate of three eggs per day. Eggs are laid in crevices of food material. The optimum temperature for egg-hatch and larval development is 87 to 90 degrees F. These insects develop more readily on oil seeds than they do on cereal grains.

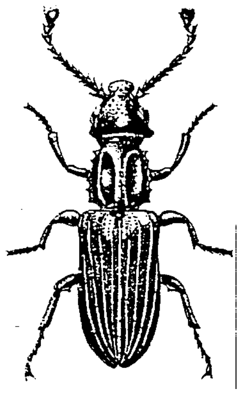
Merchant grain-beetle larvae have two to four molts, but the average is three. Larvae subjected to lower temperatures often need four molts to finish development. Larval development lasts an average of ten days at 86 degrees F. The pupal stage lasts an average of five days. The total life cycle from egg to egg takes about 30 days.

SAW-TOOTHED GRAIN BEETLE

Oryzaephilus surinamensis

Damage -- Saw-toothed grain beetles prefer to feed on damaged kernels but will sometimes penetrate and feed on and/or develop in the endosperm of sound kernels.

Description -- Adult saw-toothed grain beetles are small, slender, dark brown, flat insects about 0.1 inch long. Their most distinguishing characteristic is the six saw-like teeth found on either edge of their pronotum. Saw-toothed grain beetles look very much like merchant grain beetles except that the "temple" region between the eye and the pronotum is longer than one-half the vertical diameter of the eye. The flattened body is well-adapted for crawling into cracks and crevices. The adults have well-developed wings but have never been observed to fly.



Saw-toothed grain beetle
(Oryzaephilus surinamensis)

Biology -- Female saw-toothed grain beetles may lay from 50 to 300 eggs in their six- to ten-month lifetimes. Eggs are laid singly or in small batches in cracks or crevices in the food material. Eggs may also be laid directly into finely ground materials such as flour or grain dust.

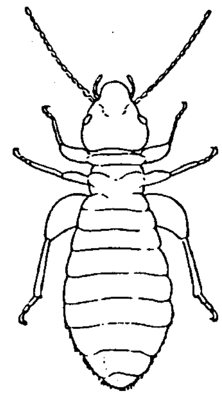
At temperatures of 80 to 85 degrees F., saw-toothed grain beetle eggs hatch in four to five days, whereas at 68 to 73 degrees F., it takes eight to 17 days. Larvae molt two to four times, depending on temperatures. The larval stage lasts about 40 days.

When mature, the larvae construct crude pupal cells using bits of food material held together with oral secretions. When pupating, the larva attaches its anal end to a solid object. The pupal stage lasts about seven days.

The entire life cycle from egg to egg takes from 27 to 375 days. The adult life span can last up to three years. Saw-toothed grain beetles feed on a wide variety of stored products, including flour, bread, breakfast cereals, macaroni, dried fruits, nuts, dried meats and sugar. Since these beetles are very flat, they easily hide in cracks and crevices and often penetrate improperly sealed packaged foods. They are also found in grain bins or grain-handling facilities. They are usually associated with grain dust, fines and kernels that have been damaged during harvest or by other types of grain-feeding insects.

PSOCIDS *(Liposcelis spp.)*

Damage -- These insects may be very abundant in or around high-moisture stored grain. Their nuisance value generally far outweighs the actual damage they cause.



Psocids (Liposcelis)

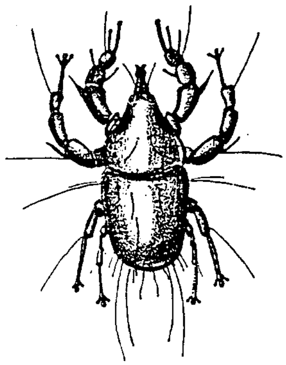
Description -- Psocids are pale gray to yellow insects about 0.04 inch long. These soft-bodied, louse-like insects have relatively large heads, poorly developed eyes and long, slender antennae. The hind legs are long and well-developed. The immature stage (nymphs) resemble the adults in general appearance.

Biology -- Females lay as many as 100 eggs, and development from egg to adult requires about three to four weeks. Psocids feed on a great variety of organic matter of both plant and animal origin. Warm, moist, dark, undisturbed places provide favorable conditions for psocid development, along with microscopic molds on which they feed. Adults may live about a year.

GRAIN MITE (*Acarus siro)*

Damage -- Grain mites primarily attack the germ. However, they will feed on other parts of the kernel, as well as on mold growing on the grain. These mites are responsible for the spread of various fungal spores throughout a grain mass and into adjoining bins.

Description -- Grain mites are very small (almost microscopic), gray-white and smooth. Adults have eight legs. The legs may be darker than the body, and each leg has one claw at the end. Juvenile mites have a very similar appearance to the adults. The first or larval stage has only six legs. However, when they molt into the nymphal stage, they will have eight legs.



Grain mite (Acarus siro)

Biology -- Female grain mites may lay up to 800 eggs. These eggs are deposited singly on the surface of food material. The entire life cycle takes only nine to 11 days to complete. These mites proliferate under high-moisture conditions and are often found in conjunction with fungal growth. At some time during the juvenile period, grain mites can go into a stage known as the hypopus. During this unique stage, the body wall hardens, and suckers appear on the underside. These suckers allow the mite to attach to insects and other animals, thus allowing them to disperse.

The eggs and especially the hypopuses appear to be more tolerant of insecticides than the other juveniles or adults, and they may be the primary stages responsible for resurgences in mite populations after chemical control appeared to have been successful.

PATHOGENS

Storage rots or moldy grain may develop in grain-storage bins if the moisture content of the kernels is excessive and the air temperature is high enough to permit fungus growth. More than 150 different species of fungi have been reported on cereal grains. The major storage fungi are species of the common molds, *Aspergillus* and *Penicillium*. Some species of fungi such as *Alternaria sp.* and *Fusarium sp.* can cause infection in the field and can cause advanced decay in high-moisture grains. Some of the fungi that grow in grains and other seeds before harvest or in storage produce toxins. One of the common storage fungi, *Aspergillus flavus*, produces several toxins, called aflatoxin, that cause problems when fed to animals and can cause cancer in humans.

Storage fungi cause loss of germination, dark germs (in wheat, designated germ damage or sick wheat), bin burning, mustiness and heating. These are the final results of invasion of grain by storage fungi. Storage fungi are the cause, not the result, of spoilage.

Depending on the commodity, toxin contamination is either a field problem, a storage problem, or a combination of the two. Since toxins are produced by fungi, they should be viewed as a potential danger anywhere fungi grow on materials which are used as food or feed. Fungal contamination is necessary for production of toxins, but toxicity is certainly not the inevitable result of all fungal invasions. Fungi are almost universally present on and in cereal grains, nuts, and nearly all other plant materials, but toxicity seems to be the exception rather than the rule.

CHEMICAL CONTROLS

PROTECTANTS

TREATMENT BEFORE STORAGE

Just because grain is eventually harvested and stored doesn't mean it’s safe from insects. Any grain that is to be stored for more than six months can be seriously infested. The key to good storage is anticipating and preventing potential problems through good bin management.

Before treating with protectants, make sure the storage structure itself is free of insect-infested grain. Leftover grain should be removed from the bins, and the walls should be swept and vacuumed.

All grain-handling equipment, including augers, combines, trucks and wagons, should also be cleaned and grain residues removed before harvest. Places where livestock feed or where pet foods or seeds are stored can be serious sources of infestations. Grain and feed accumulations that
are often overlooked include empty feed sacks, dusts created by the feed grinders, seed litter from the hay-mowers, feed left in animal self-feeders, and grain-based rodenticides. New grain should never be

placed on old grain unless the old grain is completely free from insect infestation.

BIN WALL, CEILINGS, AND FLOOR TREATMENTS -- As soon as the bin is cleaned, it can be treated with protective insecticides. However, it's better to treat during the warmer months when insects are active. If treatments were applied more than three months earlier, an additional treatment should be applied two to three weeks before new grain is placed in the bin. The treatment will kill insects emerging from their hiding places (cracks, crevices, under floors, and in aeration systems). Also, insects crawling or flying in from the outside will be killed.

Apply the spray to as many surfaces as possible, especially joints, seams, cracks, ledges and corners. Spray the ceilings, walls and floors to the point of runoff. Use a coarse spray and aim for the cracks and crevices.

Spray beneath the bin, its supports and a six-foot border around the outside foundation. Treat the outside surface, especially cracks and ledges near the door and fans. In addition, treat pertinent areas in your cleaned harvesting equipment, elevators, augers, trucks or wagons.

EMPTY METAL GRAIN BINS-- The increased use of metal bins with perforated floors for grain drying and aeration has helped produce a serious insect problem in farm-stored grain. Grain dockage (broken kernels, grain dust and chaff) sifts through the floor perforations and collects in the sub-floor plenum, creating a favorable environment for insect development. Unfortunately, the floors are usually hard to remove, making inspection, cleaning, and insecticide spraying in the plenum hard if not impractical. The infested plenum may be disinfested using approved fumigants.

BULK-TREATMENT EFFECTIVENESS

The effectiveness of treating bulk grain depends on many factors including the following:

Proper Mixing -- Thorough and complete application of grain protectants so that the protectant is applied to most of the kernels isn't important. This was apparent when the "drip-on application" procedure for liquid protectants was found adequate by both insect-kill and residue analysis. One disadvantage of the emulsifiable formulations is that most of them must be agitated to avoid settling. Gravity flow or "drip-on" applicators or pressure-type sprayers must be shaken periodically to ensure that the formulation is mixed evenly. Power sprayers don't have this problem because the formulation is agitated continuously.

A Fresh Spray Mixture -- Mix only enough insecticide for one day's use. Don't use excess insecticide mixture for the next day's treatment. The concentrated insecticide, mixed spray, or insecticide dust should be kept cool and not stored in direct sunlight. Use fresh dust formulations and avoid carry-over from one year to the next.

Point of Application -- Protectants should be applied to the grain just before it reaches final storage. Protectants can be applied into an auger or into the grain stream as it falls into the hopper of the elevating equipment. However, grain which is treated and then transferred long distances through numerous grain-handling systems (such as pneumatic systems, belt augers, conveyors, spouts and legs, etc.) before storage will have less insecticide residue when the grain is finally dropped into the bin. However, insecticide left in the handling system will help reduce insects in these areas.

Application Pressure -- If you use other than a gravity-flow system, the spray pressure should be as low as possible; 10 to 20 p.s.i. (pounds per square inch) is preferred. With low spray pressures, larger spray droplets are produced. The larger droplets fall onto the grain and are less likely to drift off into the air.

Moisture and Temperature of the Grain -- Most failures occur because of excessive grain moisture and/or temperatures. If warm grain is treated, it should be cooled with an aeration system as soon as it's practical. The operation of an aeration system won't remove the protectant from the grain.

Application -- Grain protectants can be applied as liquids or as dusts. When liquid formulations are employed, the uniform addition of the water-chemical mixture won't significantly increase the moisture content of the grain.

The chemical, regardless of formulation, may be applied by several methods. The chemical can be applied just prior to placement of the grain in a storage bin. If a dust is applied, it may be mixed with the grain as it's leaving the grain truck, or the dust can be applied through the auger with an automatic duster. If a liquid application is used, it may be applied with a gravity "drip-on" system or with a pressurized sprayer.

SURFACE TREATMENT

Immediately after the bin is filled and the grain leveled, a surface treatment may be applied. A surface treatment may also be applied when the grain is going to be stored through a warm season or after a general fumigation to help prevent insect reinfestation. The surface treatment will help control insects that enter the grain through roof openings and will kill insects found in the surface areas.

Surface treatments alone generally won't keep the grain completely insect-free, but they will help keep insect populations lower during the storage period. Surface treatments are effective if the following limitations are understood:

1. Surface treatments won't control insects already in the storage bin; thus, the grain must not be infested prior to surface treatment.
2. The storage structure must be insect-tight below the treated two inches of grain.
3. The surface treatment shouldn't be disturbed, since it provides the protective barrier against insect infestations.

Bacillus thuringiensis (Bt), a bacterium that controls moth larvae, has been approved for use in stored grains and soybeans. This material (see commercial label for dilution and application rate) is mixed with the surface four inches of grain either by adding it to the last grain as it's augered into the bin or by applying it to the grain surface after the grain has been binned. This treatment won't control weevils or other beetles that infest grain. The *B. thuringiensis* formulation is exempt from tolerance restrictions.

FUMIGATION

Effective fumigation is possible when good storage practices are followed. For example, condensation and eventually caking and spoilage will occur if people fail to level grain peaks as outside temperatures drop during the fall and winter months. This same peaking will prevent even distribution of fumigants, allowing insects to survive in the areas that receive an insufficient amount of fumigant.

A fumigant is a tool that may be needed to help preserve the grain quality. Fumigants should only be used when needed, since they are the most hazardous type of pesticide treatment that can be used in grain treatment. In addition, fumigation is expensive and provides no long-term residual protection.

Fumigation is needed when no other pesticide or control method can reach the insect infestation. If the insects are already inside the grain mass, no spray or dust can reach them.

In some parts of the country, field infestations can be heavy, with considerable internal feeding by the time the grain is harvested and brought in for storage. In these cases, especially if the infesting insects develop within kernels, the grain should be fumigated at the time of storage. Later, if the infestation is discovered throughout the grain mass, control could be difficult. Only a properly applied fumigant will circulate to all the pests.

Insect infestations can also occur in pockets deep within the grain mass. Special fumigation techniques are available to provide control in this situation, whereas insecticide sprays wouldn't be effective.

Fumigation isn't always practical. If grain is stored in the open, it would have to be covered with special gas-retaining tarps. This would also be true of most open-slat cribs or even wooden buildings. This procedure is very expensive and time-consuming. While it's possible to find dosage recommendations for wooden buildings, the increased amount of fumigant required and the poor control often achieved make this practice cost-prohibitive. Poor control often results in reinfestation just as large and damaging soon thereafter. Fumigants act on all insect life stages. They control pests by diffusing through the space between grain kernels as well as through the kernel itself. Thus, fumigants are able to penetrate into places that are inaccessible to insecticide sprays or dusts.

Fumigants exert their effect on grain pests only during the time in which the gas is present in the insects' environment. After the fumigant diffuses out of the grain, no residual protection is left behind, and the grain is again susceptible to reinfestation. The objective of fumigation, therefore, is to introduce a killing concentration of gas into all parts of the grain mass and to maintain that concentration long enough to kill all stages of insects present. Fumigants may be applied directly into the fumigated space as gases from pressurized cylinders. Some gases appear as liquids under pressure but expand to a gaseous form when released. Fumigants can also be generated from solids that react with moisture and heat from the air to release the fumigant.

Regardless of formulation, all fumigants are poisons that are toxic to humans and other warm-blooded animals as well as to insects and other pests.

FUMIGANT-TYPES EFFECTIVENESS

Understanding how fumigants react in grain and what influences their behavior is an essential step in developing the know-how to effectively and safely use grain fumigants.

Sorption -- When a fumigant gas attaches itself to the surface of a grain kernel or penetrates into the kernel, it slows diffusion and disrupts penetration of the fumigant through the grain mass. However, some sorption must occur if the fumigant is to reach all stages of pest insects, especially those that develop within the kernel. The degree of sorption of individual components is the basis for selection of many of the liquid fumigant mixtures. These mixtures include chemicals which are sorbed at different rates, letting some fumigant vapors penetrate a grain mass readily while others are held near the surface of the grain mass. Some fumigants, when sorbed into a kernel, react with materials in the grain to form other chemical compounds that may be permanent, thus forming residues. Fumigants containing bromide, such as MB, are especially subject to this type of chemical reaction, which has necessitated the establishment of residue limits or tolerances for the amount of bromide permitted in grain.

Temperature -- Temperature influences the distribution of fumigants in grain and affects their ability to kill insects. At temperatures below 60 degrees F., volatility of a fumigant is reduced significantly, sorption of fumigant vapors into the grain is increased, and distribution is less uniform throughout the grain mass. Gases move more slowly and insects breath less at colder temperatures. Thus, it takes longer for the fumigant vapors to reach insects in the grain, less gas is actually available for controlling the pests, and since the insects are less active, less gas enters their bodies. Desorption may take longer at cold temperatures because grain retains more fumigants longer at lower temperatures, thus requiring prolonged ventilation periods.

Grain Moisture -- The moisture content of grain also influences the penetration of fumigant gases by altering the rate of sorption. In general, "tough grain" requires an increase in dosage or an extended exposure to compensate for the reduced penetration and increased sorption.

Grain Type and Condition -- Various grains have different characteristics that can affect fumigation. The surface area of individual grain kernels is an influencing factor in the dosage required to treat various commodities. For example, sorghum -- because of its smaller size and more spherical shape -- has higher total surface area than wheat. Increased surface means greater sorption loss, which reduces the amount of fumigants left in the space between the grain kernels and further reduces the amount of fumigant available to penetrate throughout the grain. To
compensate for this increased loss, higher dosage rates are required in sorghum than in wheat, especially when fumigants are used that are easily sorbed by the grain.

The type and amount of dockage in grain has a pronounced effect on the sorption and distribution of fumigants. When the grain mass contains large amounts of dockage such as crust, chaff or broken kernels, the fumigant vapors are rapidly sorbed by this material, and further penetration into the grain is impaired. Unfortunately, such areas are often sites that attract the greatest number of insects. When isolated pockets of dockage occur within a grain mass such as below grain spouts, fumigant vapors may pass around such pockets and follow the path of least resistance down through the intergranular area of the grain. Similar changes in fumigant distribution patterns may be obtained in grain that has settled or compacted unevenly during long storage periods or in storages vibrated by nearby traffic such as a railroad.

Insects -- Grain insect pests and their various developmental stages (egg, larva, pupa and adult) vary in their susceptibility and resistance to fumigants. Beetles and other insects that develop outside grain kernels are usually more susceptible to fumigants than certain moth and beetle species that develop inside grain kernels. The pupae and eggs, which breathe very little, are the hardest developmental stages to kill, while the young larvae are relatively susceptible.

Heavy infestations in which large amounts of dust, damaged grain, webbing, and cast skins have accumulated are harder to control because of the effect these materials have on the penetration and diffusion of grain fumigants.

Storage -- A fumigant, whether applied initially as a gas, liquid or solid, eventually moves through space, penetrates the grain, and is taken in by the insect in the form of a gas. The gas-tightness of the grain bin, therefore, greatly influences the retention of the fumigant. Metal bins with caulked or welded seams or concrete bins will still lose some gas but are generally better suited for fumigation than loosely constructed wooden bins.

Although there are often label recommendations for fumigation of grain in wooden bins, the high dosages and poor control usually achieved normally make this type of fumigation uneconomical.

The size and shape of the storage structure affect both distribution and retention of fumigants. The height of a storage bin often determines the type of fumigant used and its method of application. Some liquid fumigants will readily penetrate substantial depths of grain, but solid fumigants may be more effective if mixed with the grain during transfer into the bins.

Winds and thermal or heat expansion are major factors influencing gas loss. Winds around a grain storage structure create pressure gradients across its surface, resulting in rapid loss of fumigant concentrations at the grain surface and on the downwind side of the storage. The expansion of head-space air due to solar heating of roofs and walls followed by night-time cooling can result in a "pumping" of the fumigant from the bin. Large flat storages that contain more grain surface than grain depth are especially susceptible to gas loss due to wind and heat expansion. The greatest gas loss often occurs at the grain surface, a location that often contains the highest insect populations. Furthermore, when the grain surface is uneven, with large peaks and valleys, the distribution of fumigants through the grain will also be uneven.

Air Movement -- Successful fumigation of stored grain requires an understanding of air movement within the grain mass. It’s easy to think that the air between the kernels of grain in a bin is as immobile as the grain itself. This isn’t true and is one of the reasons that fumigation sometimes fails, even when done by professional fumigators.

Air moves along the path of least resistance, with warm air moving upward and cold air moving downward. In a bin, there is usually air movement both up and down because of temperature difference between the well-insulated middle and the grain near the edge that is affected by outside temperature. Air movement upward can carry moisture that can condense on the surface and cause crusting. The resulting crust can also interfere with air and gas movement. Air will move easier through a grain mass composed of larger kernels, such as corn, and more slowly through those composed of smaller grains, such as grain sorghum. Air may move around a hot spot and carry a fumigant gas away from the critical area. Fumigant gases can penetrate these areas better than normal air, but the air movement can affect how much gas reaches and stays at these critical stress areas.

Gas movement in a grain mass is affected by other forces such as gravity, sorption, temperature, and moisture content, but an understanding of air movement is the first step in understanding the many forces that determine gas dispersion.

Preparing Bins -- Attention to proper sealing of grain bins prior to fumigation will often make the difference between success or failure of the treatment. A high degree of gas-tightness is essential to achieve the required combination of gas concentration and time of exposure necessary to kill grain pests.

Metal storage bins are not gas-tight, since they were originally designed to hold and aerate grain. With proper sealing, they can be used for fumigation. It's important to recognize that the bins will vary in tightness, depending how well they are built. If the corrugated sections were caulked when put together and then bolted tight, they will be more effective when sealed. Loosely constructed wooden bins may have to be covered totally with a gas-tight tarpaulin to retain enough fumigant to be effective.

Remember, the goal is to try to confine a gas for a sufficient length of time at a proper concentration to be lethal to the target pests. Sealing is extremely important and demands study and work, but there are professional techniques that can make the job more effective.

There are a number of places in a bin where gas can escape. The roof-wall juncture looks tight from the outside, but examination from the inside will show a gap around the perimeter in many bins. This gap is hard to seal because it's usually dusty and may be damp. Cracks wider than one inch are even harder to seal. It's necessary to clean the dust from the surface before it can be taped or sealed with any other material.

An adhesive dispensed from a pressurized can may be used and then sealed with duct or furnace-cloth tape, since this is more effective here than masking tape. Use at least two-inch and preferably three-inch tape when sealing these cracks.

Polyurethane foams can be used to seal this gap, but they're expensive and hard to remove if the gap is needed for extra grain aeration. Insects can burrow into the foams and destroy their effectiveness, but they can provide a good seal for several years.

Another key area to seal is the gap between the bottom of the wall and the floor. Some manufacturers design the wall base to accept special sealant that can give a long-term seal. Various sealing materials have been used, including one made with polyurethane impregnated with asphalt. Plain asphalt has also been used but doesn't have as much elasticity.

Roof ventilators can be covered with plastic bags. The bags are less likely to tear against sharp edges if a burlap bag is placed over the ventilator first. The plastic bag should be gathered in at the base, then taped in place. Be very careful in this work to avoid falling.

Bin doors are not gas-tight when merely closed. They can be cleaned and sealed with masking tape, or if not used regularly, they can be sealed with foam-in plastic.

Aeration fans and their housing must be sealed to avoid gas loss. Normally, polyethylene glued to the air intake will be sufficient. However, the unit should be examined for other potential leaks.

Professional fumigators long ago found that it was hard to get tape or plastic to stick to the dusty surfaces of grain bins. Cleaning is necessary and helpful, but more is required.

An expensive but useful tool is the pressurized can of tape primer. This can be obtained from the fumigant distributor or sometimes from an auto paint store. These materials give the surface a tacky feeling and help hold the tape on much better. They can be applied to the adhesive surface of a piece of tape to improve its sticking power. Although taping of a damp surface isn't recommended, it can sometimes be done with this material.

Another alternative to taping the eaves is to cover the entire roof with a plastic sheet formed into a bonnet or cap which drapes over the top of the bin and extends down past the roof joint. An adhesive sprayed or painted in a horizontal band around the outside bin wall will provide a point of attachment for the plastic sheet. The bonnet can then be secured by rope, using the corrugation grooves on the bin to reduce slippage. Obviously, this sealing method can only be partially completed before application of the fumigant in order to provide access to the grain surface.

Level the grain surface and break up any crusted areas that have formed. When grain is peaked, the action of fumigants is similar to rain on a hillside. The heavier-than-air gases simply slide around the peak, resulting in poor penetration and survival of pests in the peaked portion of the grain. Moldy or crusted areas near the grain surface are generally caused by moisture condensation when warmer air in the grain rises to the surface and encounters cold air above the grain. These areas are sometimes hidden from view just below the grain surface. Failure to locate and break up these areas will result in uneven penetration of grain fumigants and may lead to further deterioration of the grain from mold development and invasion of the grain by insects that feed on grain molds.

APPLICATION AND DISTRIBUTION

Liquid Fumigants can be applied in two principal ways:

1. Grain-stream application.
2. Surface application.

Grain-Stream Application -- In this method, liquid fumigant is added to a stream of grain entering a storage bin or being transferred from one bin to another. A measure rate of grain flow is needed in order to apply the correct amount of fumigant. Extra dosages can be applied to the beginning of the grain movement and at the end to insure adequate distribution of fumigant at the top and bottom of the mass. Grain shouldn't be fumigated unless it's infested.

Storage condition and construction materials also determine the amount of fumigant needed and its probable effectiveness. Turning also may cool the grain, which may reduce insect activity in the grain. It's most effective during fall and winter in the temperate zones.

Insect activity will cease at about 50 degrees F. (10 degrees C.), and over time, many will die.

Solid Fumigants -- Solid fumigants may also be applied using the grain-stream method, or they can be applied by probing them into the grain mass in a checkerboard fashion.

Dosage and Time of Exposure

Because fumigants act in the gaseous state, the dosage necessary to kill an insect is related to the concentration of gas surrounding the insect, the insect's respiration rate -- which is related partially to temperature, and the time of exposure of the insect to the specific concentration of fumigant. There's a general relationship for most fumigants between concentrations and time: high concentrations require shorter exposure time and low concentrations require long exposure to achieve comparable kill.

Variations in recommended dosages are generally based on sorption differences of commodities and the relative gas-tightness of different storage structures. For example, dosage requirements for sorghum are generally higher than for less sorptive commodities such as wheat, and dosages in wooden bins are higher than in steel or concrete bins.

Calculating Dosage -- All fumigant labels provide information on the recommended dosages required to effectively treat stored grain. Using less fumigant than is recommended can result in too low a concentration of gas to be effective. Using more fumigant than recommended is illegal, adds cost, and may not increase efficiency.

Dosages found on most liquid-fumigant labels are expressed in gallons of fumigant to be applied per 1,000 bushels of grain. The required dosage varies with the formulation. Once the dosage recommended for the conditions of your fumigation have been identified from the label chart, you only need to calculate the number of bushels to be treated to determine the total fumigant dosage. The number of bushels in a bin may be calculated using one of the following formulas:

If the bin is round: Bushels = 0.6283 x diameter (ft.) x diameter (ft.) x grain depth (ft.).

Example: An 18-foot-diameter bin containing 15 feet of grain would equal: 0.6283 x 18 x 18 x 15 = 3,053.5 bushels. If the recommended dosage is three gallons per 1,000 bushels, the total dosage required would be: 3,053.5 divided by 1,000 = 3.053 x 3 = 9.2 gallons. If the recommended dosage was four gallons per 1,000 bushels, the total dosage required would be 3,072 divided by 1,000 x 4 = 12.28 gallons.

Another method of calculating the number of bushels in circular bins is to multiply the grain depth by the number of bushels per foot of grain.

Example: A bin 18 feet in diameter contains 205 bushels of grain for each one-foot depth. If the grain is 15 feet deep, the total bushels is obtained by multiplying 205 x 15 = 3,075 bushels.

Empty bins should be thoroughly cleaned and sprayed or fumigated before new grain is placed in the bin. The aeration duct and the raised perforated floor that distribute the air may be infested and are hard to reach with normal sprays.

Detection tubes are probably the most versatile tools available for measuring gas concentrations. They're available for many industrial gases as well as almost all fumigants. The equipment used with the tubes is well-built, durable, and manufactured by a number of suppliers. The initial cost of the equipment is moderate and can be amortized over hundreds of uses and many years. For most gases, they are sufficiently accurate.

The disadvantage of using these tubes is that they are designed for a single use on a single type of fumigant. Their cost of more than $2 per tube can be burdensome when many readings are necessary. They aren't available for both high and low readings for all fumigants, so other detection tools may be needed. The tubes have a limited shelf life and aren't reliable after the expiration date. In addition, they have limited accuracy with some gases.

When a given quantity of air/gas mixture is drawn through the tube, a color change occurs in the reagents inside the tubes. This change can be easily read in parts per million.

To take a reading, it's necessary to first break the tips off the ends of the tube so that the air/gas mixture can be drawn through the tube. With some gases, it's necessary to break the tube in a second place and to mix two ingredients or to attach another tube containing different ingredients to the first tube.

The glass tips removed from the tubes should be disposed of properly to avoid any chance of food contamination or personal injury. If the tubes are to be retained, the tips should be covered with tape to mask them.

After the tip is removed, the tube is inserted into the pump according to the directional arrows. Instructions on the tube give the number of pump strokes required (example: n = 3 means three strokes) for a sample. Each stroke draws one-tenth liter of air through the tube. New workers can learn to take accurate readings with a minimum of time and instruction.

If the air/gas sample is taken from a long monitoring hose, the hose line must be purged to give an accurate gas reading. Vacuum pumps are available that will speed up the purging operation. To ensure accuracy, it's better to purge too much than not enough. Naturally, readings should be taken in open air or other precautions taken to ensure that the purged air/gas mixture won't cause health problems.

With the Draeger methyl-bromide tube, it's very important that the tube is held in a vertical position when reading the ppm, or an improper gas reading may be obtained.

Most manufacturers have equipment called grab-samplers that will take a single reading of the present concentration or long-duration models designed to determine the average concentration of toxic gases or vapors a worker is exposed to over several hours.

Halide leak-detectors have found uses in several industries. They are used to detect leaks of halogenated refrigerant gases, and they have been used to give reasonably accurate estimates of the concentration of methyl-bromide-related halogenated fumigant gases.

The propane-fueled halide leak detector is the lowest-cost fumigant-detection instrument both in terms of initial purchase and in terms of cost per use. The gas is turned on and ignited, then adjusted so that the tip of the flame just pierces the copper ring. Air/gas mixtures are siphoned through the flexible tube, and a blue or green halo above the copper ring will indicate the presence of halogenated gas. It's important to keep the copper ring clean and to replace it periodically.

People vary in their ability to recognize shades of blue and green, but 25 ppm is the lowest concentration anyone could consistently recognize. This is adequate for spotting leaks in a structure but not for detecting five ppm, which is the present recommended TLV for methyl bromide. Naturally, this instrument should never be used in an atmosphere where an open flame would be a hazard.

GENERAL BIN SAFETY

The number of human suffocations in grain storage systems is increasing. There appear to be at least five basic reasons:

- Increased harvesting and handling of grains.
- Larger on-farm storage facilities.
- Faster grain-handling capabilities.
- Increased mechanization (operator working alone).
- Little knowledge of grain movement and safety precautions.

Don't make the mistake of your life. Be aware of the dangers of flowing grain.

There Are Several Reasons Why You Might Enter a Bin Filled With Grain. . .

You may enter a grain bin to visually check the grain's condition, and you may probe the bin to determine the grain's temperature and moisture content to be sure there are no developing hot spots.

Grain being removed from a bin equipped with a bottom-unloading auger may fail to flow because of clogging or bridging. You may feel that your only option is to go inside the bin and remove the obstruction or break up the bridged grain.

When drying grain, you'll check the incoming grain closely. You may feel that your wet holding bin is the best place to make your observation.

Children may find that a storage bin filled with grain is an attractive place to play.

And There Are Several Reasons Why You May Not Come Out Alive . . .

Flowing grain is dangerous. Why? To better comprehend the hazard, you should understand the way in which most farm storage bins unload. Grain-storage structures should be, and usually are, unloaded from the center. When a valve is opened in the center of the bin or a bottom unloading auger is started, grain flows from the top surface down a center core to the unloading port or auger. This is called "enveloping flow". The grain across the bottom and around the sides of the bin doesn't move. The rate at which the grain is removed is what makes the enveloping flow so dangerous. A typical rate for a bin-unloading auger is 1,000 bushels per hour. This is equivalent to 1,250 cubic feet per hour or about 21 cubic feet per minute. A man six feet tall displaces about 7.5 cubic feet, assuming an average body diameter of 15 inches. This means that the entire body could be submerged in the envelope of grain in about 22 seconds. Even more importantly, you could be up to your knees in grain and totally helpless to free yourself in less than five seconds. Also, it requires up to 2,000 pounds of force to pull a totally submerged man up through the grain.

Remember that flowing grain is like water in that it will exert pressure over the entire area of any object that is submerged in it. However, the amount of force required to pull someone up through grain is much greater than required in water because grain exerts no buoyant force and has much greater internal friction. People who have helped pull partially submerged children from grain have commented on how hard they had to pull and, often, that shoes were pulled off in the grain. This may mean that rescue efforts will fail unless the movement of grain is stopped.

Grain that bridges across a bin can be another hazard. Bridging grain may create air spaces in a partially unloaded bin. This situation presents several dangers. The first is that the person may break through the surface and be trapped instantly in the flowing grain. Another danger is that a large void may be created under the bridged grain by previous unloading so that a person who breaks through the crust may be carried under the grain and suffocate even though the unloading auger may not be in operation at the time. A third hazard is that, if the grain is wet enough to mold and bridge across a bin, there may be little oxygen present in the cavity because of microbial activity. Therefore, a person falling into this void may be forced to breathe toxic gases and microbial spores, even if his head stays above the level of the surrounding grain.

Safety hazards in grain bins aren't limited to those with bottom-unloading augers. Gravity-unloaded bins may present a similar danger through bridging or unloading. A definite danger exists with wet holding bins that feed automatic batch grain-dryers. When the dryer completes its drying cycle and reloads, a person in the wet holding bin can be drawn below the surface of the grain in a matter of seconds.

Flowing grain hazards, in addition to mold and dust health hazards, exist when working with grain that has gone out of condition or has built up in a tall pile. A wall of grain may look perfectly safe, but one scoopful could pry out the foundation and start an avalanche or "cave-off". Remember that grain is heavy. For example, a six-foot-tall man, prone and covered by one foot of corn, will be under about 300 pounds of corn. People who hear of suffocations like this are often surprised to learn that the victim was under only a shallow pile.

HOW TO REDUCE THE RISK

Rule 1 -- Ideally, anyone entering a grain bin should be fastened to a safety rope or harness that is tied to a point outside the structure. Two additional persons should be involved -- a second person who can see the one inside the bin and a third person on the ground who can (1) help lift the inside person to safety, (2) quickly go for aid without the danger of falling off the bin in a panic to climb down, and (3) ensure that no one starts the unloading equipment. Don't depend on being able to communicate from the inside to the outside of the bin. It's hard to hear under any circumstances, especially when unloading equipment or drying fans are in operation. The use of prearranged arm and hand signals is suggested under these conditions.

Rule 2 -- Never enter a bin of flowing grain. If you drop a grain probe or shovel, first stop the flow of grain, take the precautions given in Rule 1, then retrieve the lost item. Remember, no piece of equipment is worth a human life.

Rule 3 -- Don't enter a bin without knowing its previous unloading history. This is especially true if the surface appears crusty, because that may mean that the grain has bridged. Always be cautious before walking on any surface crust. If the bin has been out of condition, be sure it's well-ventilated, and enter slowly because of the danger from toxic gases, microbial spores, and a reduced oxygen content. For this situation, be sure to follow the procedure suggested in Rule 1.

Rule 4 -- If you feel you must enter the bin alone and the bin has unloading equipment, you should lock out the control circuit, tell someone what you are doing, and post a sign on the control switch informing other workers that you are in the bin. Otherwise, a fellow worker may start the unloading equipment with you inside. Likewise, check each bin before you begin to unload it to be sure that no one is in the bin. For bins that unload by gravity flow, lock out the control gate and follow the same general procedure as with bins that have unloading equipment.

Rule 5 -- Be careful in any rescue attempt to avoid being pulled into the flowing grain and becoming a second accident. Likewise, be especially cautious when trying to rescue someone who has been overcome by toxic gases or by breathing air with a reduced oxygen content. In these circumstances, it will probably be impossible for you to enter the bin and pull the individual to safety without you being overcome in the same way. To avoid placing yourself in this situation, it's imperative that the bin be well-ventilated, which you enter cautiously, and that you follow the instructions given in Rule 1.

Rule 6 -- Safety measures should include the installation of ladders and ropes on the inside of the bin. Note that you can possibly "walk down" a bin if you stay near the outside of the bin wall and keep moving, although walking in the soft grain will be very hard. However, the best preventive measure is to avoid being caught in a potentially dangerous situation by practicing the rules of safety when working with grain.

PLEASE -- BEFORE IT'S TOO LATE: Discuss the safety hazards of flowing grain with your family, employees, or fellow workers. It's the responsibility of each of us to keep informed of possible unsafe situations and take the necessary precautions to prevent their occurrence. The dangers associated with suffocation in flowing grain are no exception.

BASIC PRINCIPLES OF POTATO STORAGE

Potato "fogging" is the application of growth-inhibiting chemicals in a thermally-produced aerosol form to inhibit the sprouting of potatoes in storage. This application takes place after the potatoes are in storage, not in the field. It involves thermal creation of an aerosol form of the growth inhibitor and its circulation throughout the bin.

Originating in 1951 with the development of the growth-inhibiting chemicals, this procedure has been of great value to the potato industry. The Inspection Service in the San Luis Valley has noted that 20 years ago, their duties were complete by March. Now it's common to be inspecting shipments in August. In 1985, the average bulk price in March was $1.80 per cwt. In August, it rose to more than $8.00 per cwt.

Long-term storage allows the grower expanded marketing flexibility and provides the shippers a constant and reliable supply system. Processors benefit by having high-quality potatoes available year-round. Storage minimizes external and internal deterioration. In general, one can mostly expect the same quality of potatoes coming out of storage that were placed there. Production and harvest factors are most important in maintaining potato quality in storage.

To do a really good job, the applicator must not only know his craft but also conditions of storage such as pile tightness, air circulation, potato variety and shape, and the amount of dirt and debris in the pile. The USDA has determined that, aside from temperature, growth-inhibitor treatment is the single most important determining factor in sprouting.

Potatoes In Storage

Potato growers have known for a long time that cold storage is an effective way to prevent sprouting. Normally, a storage temperature of 38 to 40 degrees F. will prevent sprouting in potatoes for an extended period after harvest, depending on quality. Potato quality, however, is adversely affected by low storage temperatures. (It has been found that potatoes stored at 50 to 60 degrees F. have a better texture and color for use in processing.) Colder temperatures result in an increase in the sugar content of potatoes. This high sugar content causes undesirable colors during the cooking process. This is known as the Maillard Reaction.

While the potato has been growing, a series of biochemical processes have been occurring inside the potato. When the potato reaches maturity, these processes slow down, and the potato goes into dormancy.

Tubers continue to respire after harvest. Energy derived from respiration is required to support suberization and to support metabolic processes that continue in storage. Adequate storage ventilation is necessary to provide oxygen for respiration and to control humidity.

After a few weeks (if it isn't cold-stored or chemically treated), the potato tuber continues to change and breaks dormancy. Respiration (the exchange of oxygen for carbon dioxide, or a plant's form of breathing) accelerates, along with a rapid increase in starch breakdown. Other changes in pH value (acidity), enzyme activity, sugar transportation, and amino acid accumulation also occur, causing the dormancy period to end and sprouting to begin.

An untreated potato tuber will typically begin sprouting from the apical end of the potato. The length of dormancy depends on cultivar and conditions during growth and storage. In the San Luis Valley, dormancy typically ends in January. Hot weather during growth and high or fluctuating storage temperatures shorten the dormancy period. At the end of the dormancy period, the apical eye at the bud (rose) end of the tuber is dominant over the others; it's the only one that will sprout unless the tuber is cut or the apical sprout is removed. Apical dominance weakens with time after dormancy is over, until eventually all eyes will sprout. Seed tubers are generally stored at 35 to 38 degrees F. (1.70 to 3.3 degrees C.) to delay sprouting.

Pile Maintenance

After potato tubers have been properly prepared for storage (that is, field heat has been removed, and wound healing and maturation have taken place during the holding period), the pile-maintenance job is just beginning. A good storage manager will know how to properly maintain the pile. But you will encounter situations in which poor pile maintenance has made your application job harder.

On a daily basis, a good storage manager will check the pile for warning signs including:

- Wet tubers on top of a pile.
- Condensation on the ceiling.
- Depressed areas on the pile surface.
- Unusual or strong odors.

These are all signs that some factor of temperature, humidity, ventilation, or potato tuber condition has gotten out of balance and that one of the four forms of rot may have already begun. The four types of rot include:

Soft Rot -- Infected areas are initially cream-colored and later may become brown, producing a slimy tuber with foul-smelling odor. This rot spreads rapidly in the presence of free water on the surface of tubers.

Fusarium Dry Rot -- Organism enters through unhealed cuts and bruises. Rotting takes several months to develop in storage.

Pythium Water Rot -- Affects isolated tubers scattered through the pile. High temperatures and low humidity promote development in storage.

Early Blight Tuber Blemish -- Shallow, necrotic, sunken tuber blemishes appear after a period of storage. Organism enters through unhealed cuts and bruises. To control, reduce bruising of tubers by maturing them before harvest.

When a storage facility has been designed and operated to prevent deterioration of potato quality, the following will result:

- Bruises and cuts will heal rapidly; maturation of tubers will result.
- Infection and spread of rot organisms will be minimized.
- White, uniform flesh color will be maintained.
- Conversion of starch to reducing sugars will be minimized.
- External and internal sprout development will be minimized.
- Weight loss will be minimized.
- Deterioration of texture will be prevented.

Tuber Condition

Proper management of a potato storage includes providing and maintaining the correct temperature, humidity, and air circulation so that stored tubers retain maximum appearance, internal texture, quality, and food value with a minimum loss from rot, shrinkage and sprouting.

The quality of potatoes being brought out of storage has a direct relationship to the condition of the crop when it's put into storage. Potatoes which are relatively free of frost damage, mechanical damage, bruises, diseases, and other factors store much more favorably and result in significantly less weight loss than potatoes affected by these factors.

Storage guidelines should be interpreted as generalized guides rather than hard-and-fast rules based on the fact that specific potato conditions will dictate their management. Storage rules which apply to a given set of conditions may not apply to another set of conditions. For example, several assessments must be made relative to the condition of the potatoes being managed, including these:

- Are the potatoes mature?
- Is any frost damage apparent?
- Are various diseases present?
- Have the vines been thoroughly killed prior to harvest?
- How much mechanical damage resulted during harvest?
- What is the sucrose rating?
- What is the fry color?
- What extent of potato bruising occurred during harvest and handling?
- Environmental conditions prior to storage -- implications?

Many common-sense considerations come into play in storage management when considering the implication of the answers to the above questions. While the presence of diseases and frost damage is covered separately later in this section, the remaining factors must be assessed when
applying the storage guidelines presented below. Certain conditions can prevent normal storage periods.

The Pre-Suberization Period

Pre-suberization, the period immediately after potatoes enter the storage pile, involves considering potato temperature factors. Are the potatoes warm, cold, wet, dry, etc.?

During harvest conditions of warm weather and dry soils, run the fan and humidifier continuously after the first day of harvest. However, modulate the air entering the pile in compliance with local recommendations. Consult your Extension Service for specifics. The objective under these harvest and soil conditions is to lower the potatoes' temperature to 60 degrees F. and provide humidity to potentially dehydrated potatoes.

During harvest conditions of warm weather and wet soils, run the fan continuously with the humidifier off until all free surface moisture is removed. Potatoes covered with a wet film are prone to anaerobic rot. After all free moisture has been removed, use a continuous fan operation with the humidifier on until the potato temperature reaches 60 degrees F. Again, moderate the air relative to pump temperature. The objective under these conditions is to remove free moisture and cool the pulp to 60 degrees F.

During harvest conditions of cool weather and dry soils, if the pulp temperature is 50 to 60 degrees F. at harvest, run the fan and the humidifier intermittently until the storage is filled. Use a fresh-air intake temperature no lower than three degrees from the pulp temperature. If the daytime temperature exceeds pulp temperature, shut the fan off unless refrigeration is being used. Operate the main fan on a schedule of about two hours on and ten hours off.

During harvest conditions of cool weather and wet soils, once again the potatoes must be dried. It may be practical to add supplemental heat to the fresh air intake to accelerate the dry-off process. During the continuous day/night drying process, it's necessary to modulate the fresh air and return air until it's only one to two degrees below pulp temperature. Once the drying process is complete, the humidifier should be operated with the main fan.

During harvest conditions of cold weather and dry soils, the main fan operation in storage is mainly to provide essential oxygen and maintain or prevent the pile temperature from increasing due to the heat of respiration. Following the second day after harvest, operate the main fan and humidifier intermittently. Continue this operation until the storage is filled and closed.

During harvest conditions of cold weather and wet soils, the primary management consideration is to dry the potatoes. Cold weather infers a very difficult dry-off period. If the weather remains cold and wet, supplemental heat will be required for the dry-off period. Operate the main fan continuously with the humidifier off, and turn the heat thermostat to 45 degrees F.

The Suberization Period

Suberization, the storage period when the wound-healing process takes place, is critical to storage management. It's dependent mainly on time and temperature and normally requires a minimum of two weeks. In order to maintain the very high humidities needed, it's necessary to minimize air flow. Use only enough air flow to maintain the desired pulp temperature and provide enough air to prevent oxygen starvation.

Allow seven to ten days of suberization time at 60 degrees F., 10 to 12 days at 55 degrees F., and two weeks at 45 to 50 degrees F.

Sprout-inhibitor should never be applied before healing is complete or after sprouting has started.

It's very undesirable to allow pulp temperature to rise during this period, which can easily occur if the entire pile was not down to 60 degrees F. when the suberization process began or the outside air is at or above pulp temperature.

If potatoes are harvested between 40 and 45 degrees F, they will suberize much better if warmed to 50 degrees F or above. This involves a trade-off with storage quality. However, if the potatoes are sound and free of disease, they will suberize and store better at 45 degrees F. Potatoes harvested with a pulp temperature of near 40 degrees F. shouldn't be stored with long-term intentions. Plan to market these potatoes within three to four months.

The Post-Suberization Period

Post-suberization, the period between the end of suberization and the beginning of the desired storage temperature, involves maintenance. Potatoes to be marketed early (within two to three months) should be maintained at the temperature desired for marketing.

The use for which the tubers are intended will dictate the storage temperature. For instance, tubers for seed must be kept below 40 degrees F. Tubers to be processed into French fries or potato chips must be kept at temperatures of 45 to 50 degrees F. Since potatoes kept at these temperatures will begin to sprout in a few weeks, they must be treated with a sprout-inhibitor if they are to be kept any length of time at these warmer temperatures. Results obtained by the University of Idaho show that Russet Burbank potatoes kept at 45 degrees F. with high humidity and with a sprout-inhibitor lose less weight and have a lower respiration rate than tubers stored at any other temperature. Consequently, for long-term storage with the least amount of weight loss, store Russet Burbank potatoes at temperatures no lower than 45 degrees F. and use a chemical sprout-inhibitor to prevent sprouting.

When potato tubers have been stored at 40 degrees F., the tubers should be warmed to at least 45 degrees before removing them from the storage. In all cases, careful handling must be practiced to reduce injury. Cold-brittle potatoes are easily injured.

Frost Damage and Diseases

Diseased or frozen potatoes decompose rapidly in storage piles. Bruises; diseases such as soft rot, wet rot, dry rot, late blight lesions, and other pathogens; and frozen ends contribute greatly to potato losses during storage. Tubers adjacent to these diseased potatoes easily become infected, with the result of rapid-spreading potential.

Detecting excessive rotting of potatoes in storage before major losses occur in time to implement corrective measures is a primary goal of storage management. Several early detection methods are used to help reduce excessive rot losses.

Rot organisms can't grow or germinate without the presence of free water. Likewise, eliminating condensation and free-water formation is important in managing frost-damaged potatoes.

There's a close relationship between the healing process and the penetration of rot. Storage temperatures should be kept between 40 and 45 degrees F. and, at the same time, humidities throughout the pile should be kept low. While high humidities are advocated under normal storage conditions, this is the exception to the rule.

It's hard to get low humidity with warm air, but it can be done. A heater placed in the return air duct will open the outside louver and allow cold air to enter. Although the air will be high in humidity at that temperature, as it warms or as it mixes with the inside recirculated air, it will lower the humidity before being blown through the potato pile. Good ventilation and humidity control are the keys to handling both diseased and frost-damaged potatoes.

Summary of Proper Potato-Storage Environment

A. What it should accomplish:

1. Stimulate healing of bruises, cuts, and other injuries.
2. Maintain appearance -- external quality of the tubers.
3. Maintain internal quality of the tubers (food value, processability, etc.).
4. Keep rot development to a minimum.
5. Keep weight loss to a minimum.
6. Keep quality changes (internal and external) to a minimum.
7. Retard the growth of sprouts.
8. Maintain seed potatoes in a healthy, vigorous and productive condition.

9. Provide the oxygen necessary for healing of wounds and the maintenance of normal respiration and dormancy.
10. Prevent greening.

B. What it consists of:

1. Proper temperature.
2. Proper humidity.

C. How it's provided and controlled:

1. Proper ventilation and management.
2. Correct and adequate distribution of airflow.
3. Adequate humidification system.

D. How it's evaluated.

1. Weight loss.
2. Rot loss.
3. Quality change.

E. When it should be established:

Before the first tuber is put into storage.

F. How long it should be maintained.

Throughout the entire storage period, until the last tuber is removed.

THE POTATO STORAGE STRUCTURE

Successful potato storage includes providing an adequate storage structure in which to place the tubers, providing and maintaining the proper storage environment, and following proper storage-management practices throughout the storage period. Some of the fundamental requirements necessary to provide these conditions are:

Sound Structure: Footings and structural members must withstand the weight and pressures of the dead load (rafters, insulation, roofing material, etc.) and all expected live loads (snow, wind, rain, side-wall pressures of potatoes, etc.)

Adequate Insulation: Providing adequate insulation is the first line of defense against condensation forming on the inside of the storage structure.

The ceiling and walls should have enough insulation to control heat loss or heat gain. The heat-transfer rate through the walls and ceiling should be no greater than 0.05 BTUs per square foot of surface area each hour for each degree Fahrenheit difference between inside and outside temperature (U value -- heat transfer rate -- no greater than 0.05 BTU's per square foot-hour-Fahrenheit degree, and R value -- thermal resistance -- not less than 20). This amount of insulation is equivalent to about three to four inches of polyurethane, six to eight inches of fiberglass, or 14 to 18 inches of straw.

Any movement of air within a wall or ceiling greatly reduces its insulating value (thermal resistance). To eliminate such air movement, blanket-type insulation should be flanged and thoroughly tacked to the rafter or studs so no air can flow around the edges of the insulating material and reduce its insulating value.

Outside Waterproofing: The roofing material of the storage should prevent rain or moisture from penetrating the insulating material. This is especially important with materials like straw. Insulation which has become wet is a poor insulator, allowing heat to escape through the walls and ceiling. All precautions should be taken to keep the insulating material as dry as possible.

Inside Vapor-proofing: Besides the insulating material being protected from outside moisture, it should be protected from moisture coming from the inside. Since the humidity in a potato storage is very high, the moisture which goes into the insulating material reaches a dew point and condenses into free water, which in turn reduces the effectiveness of the insulation barrier. To discourage inside condensation, the storage is usually lined inside with a vapor barrier of some type, such as polyethylene plastic, tar, sealed aluminum foil, or other suitable vapor- barrier material. In the newer storages, spray-on polyurethane insulation acts as both an insulation and a vapor barrier.

Proper Ventilation With Adequate Air Distribution: A storage which is properly ventilated and has an adequate air-distribution system will maintain a uniform temperature throughout the potato pile. However, many storages have air-distribution systems which don't give the same amount of air at each end of the duct, creating different temperatures within a pile of potatoes.

Many structures with forced-air ventilation systems having too much air with too low humidity either dehydrate or pressure-flatten potatoes on the bottom of the pile. This can be largely overcome by providing only enough air to dissipate the heat from the respiration of potatoes and to uniformly distribute temperatures within the pile. Ducts shouldn't be more than eight feet apart (closer spacing would be acceptable), and airflow should be from the bottom up through the mass to remove the heat from the respiration of potatoes.

Experiments in Idaho have shown that the amount of air needed to cool the potatoes is 0.5 cfm/cwt (ten cfm/ton). After the potatoes have been cooled to the holding temperature, as little as 0.25 cfm/cwt (5 cfm/ton) is enough if supplied through ducts placed not more than ten feet apart with a static pressure-drop across the orifices in the lateral ducts or one-half inch of water. Also, the velocity of airflow in the duct should generally be not more than 1,000 feet per minute.

A good air and airflow system is the heart of any potato-storage facility. Adequate air, excellent humidification, and good control capability are necessary to maintain potatoes in the best possible condition. These factors should be evaluated when estimating the amount of management attention the stored crop will require.

To successfully control pile temperature, the air system must be able to uniformly distribute air to the pile and exhaust the air, when necessary, or return the air to the fanhouse. Duct spacing should be no greater than eight feet on center.

The initial evaluation of airflow should consider the relative areas of each of the three major passageways for air supply:

- Total area of openings in the duct outlets.
- Total area of openings to the ducts.
- Total plenum cross-sectional area.

The reasons for making these assessments and applying them to overall management plans is to get a handle on relative air velocities in order to determine how good the air distribution really is. Ideally, the total plenum area should be greater than the total area of the ducts, and the sum of the outlet areas of the ducts should be the smallest of the above three areas. These three areas contribute to the essential final factor: that there is a higher velocity of air coming out of the ducts than air velocity in the ducts. A plenum velocity of 700 feet per minute will help assure good distribution. Actual air velocities are dependent on the total cubic feet per minute supplied by the system.

Adequate Humidification System: An adequate humidification system during the cooling period in the fall will maintain the humidity of the ventilating air at a minimum of 95 to 98 percent relative humidity. The humidifier should be placed downstream from the motors or fans in case of heat increase in the air passing over the motors. The air used to ventilate the pile of potatoes should have a minimum of 95-percent relative humidity.

Adequate Controls and Equipment: Adequate controls will maintain the temperature of the air used to properly ventilate the potatoes. For example, if the potatoes are seed variety, the equipment should be able to maintain the temperature at a range of 38 to 40 degrees F. If the potatoes are to be used for processing into French fries -- such as the Russet Burbank in the Western states -- a minimum of 45 degrees F. is recommended. Regardless of the intended use for the potatoes, after a temperature has been set and the equipment calibrated, the proper temperature should be provided and maintained

A humidification system large enough to provide the proper humidity when the outside air is at its lowest humidity should be provided.

The fan should provide the volume of air necessary to cool the potatoes in the desired length of time and maintain this temperature throughout the storage period.

As with all pesticides, READ AND FOLLOW THE LABEL for health and safety information as well as application instructions.

There is another form, an emulsifiable concentrate, which is used in applications to sizing and sorting tables. This is absolutely not to be used in an aerosol generator or for fogging. It's very hazardous to do so.

In ordinary applications, only a can- or cartridge-type respirator is required. But it's absolutely required if one is to be in the fog. Self-contained breathing apparatus is for use only in case of fires.

Smokers seem to be especially sensitive to the fog. If they are exposed to it without a respirator, severe coughing occurs, often uncontrollable. There is respiratory distress and an up-welling of phlegm from the lungs. If coughing continues, vomiting will occur. A cartridge-type respirator will prevent this. However, contact with the fog is to be avoided as much as possible.

Read the label and follow it carefully. The label dictates rates of application, as with all pesticides. But there are two especially important safety reasons for applying CPIC at the proper rate (volume/minute). For one thing, there is a residue restriction set by the Federal Food and Drug Administration for only 50 ppm residue on the potatoes. The rate on the label is the proper one to keep residues below this limit. If the residues exceed tolerance, the crop is subject to seizure and condemnation.

The second reason is to keep the amount of chemical fog below the level where combustion will occur. Not only would you have fire in the bin, but highly toxic chemicals -- chloroanilins and isocyanates -- would be released. If the bin were lined with urethane, a type of cyanide gas would also be released. The label rate is designed to avoid this disaster, protecting both applicator and grower.

At all times, remember that you are dealing with methanol or isopropyl alcohol as solvents and anti-freezing agents. These are extremely volatile and flammable. Be careful to avoid heat, open flame and sparks when mixing. Remember to turn off pilot lights and other open flames in the bin to be treated.

THERE SHOULD BE ABSOLUTELY NO SEED POTATOES IN THE BIN OR BUILDING BEING FOGGED. The aerosol generated is remarkably penetrating, and even a small amount could be enough to damage seed potatoes. In table stock, one doesn't want the potatoes to sprout and grow. In seed potatoes, sprouting is exactly the idea. Sprout-inhibited seed potatoes would be worthless except as table stock. The value could be reduced by 50 percent or more.

One should also pay close attention to any drift or fog escaping from the building. It's possible for it to move to other storage and have some effect there. Also, CPIC is a herbicide in general, and surrounding vegetation or desirable plants may be harmed.

Any other types of seed or feed stored in the area must be removed, as a growth-inhibitor-contaminated seed may partially or completely fail to germinate.

It's also important to clean thoroughly after the application to remove residues from fans, housings, louvers, etc. In general, CPIC must be cleaned up on any surface that could contact the potatoes or contact air moving over the potatoes. Residues retain activity for up to six months. That particular bin isn't suitable for seed storage for one year, according to most labels.

A final safety precaution is to check thoroughly that there are no people in the building being fogged. A careful check must be made. All fogging personnel must remain outside the building during actual application.

CHEMICAL CONTROL OF SPROUTS

THE EQUIPMENT AND APPLICATION

AEROSOL GENERATORS AND FOGGERS -- Aerosol generators work by using atomizing nozzles, spinning disks, and small nozzles at high pressure. Fogs are usually generated by thermal generators using heated surfaces.

Advantages: Efficient distribution of liquid pesticides in enclosed spaces, efficient distribution of liquid pesticides in dense storage, and some devices automatic in operation.

Limitations: Aerosols and fogs extremely sensitive to drift, and repeated application needed to maintain effectiveness.

In general, use and care for an aerosol generator as you would a sprayer. They do require special precautions. Be sure that the pesticides used in them are registered for such use. Keep them on the target. The operator, other humans and animals must be kept out of the fog or smoke cloud.

STARTING THE JOB

Before beginning an application, one should consider the following:

- How long will the potatoes be in storage? This will help determine whether a second application will be necessary.
- What is the size and type of storage facility? This helps you determine the application rate, how much chemical you will need, and how long the job will take.
- What type of ventilation and fans are present in the facility? Where are the fans located? You should check locations of all ducts and fans to be certain proper dispersion is attained.
- What condition are the potatoes in? They should be free of dirt and frost, and cuts and bruises should be suberized.

Once these assessments are made, you are ready for the application process.

TIMING OF APPLICATION

Timing is important in the successful use of a sprout-inhibitor. Applications may be made anytime after the suberization period but before sprouting. The best time to apply is before the pile settles. Since you are actually putting a coating over the potatoes, piles should not have settled so much that the chemical can't reach the potato eyes.

Application shouldn't take place until bruises and cuts have suberized. Suberization is dependent on time and temperature. This period normally takes a minimum of two weeks from the time the potatoes were originally stored. This point is important in determining application rates.

Check to see if seed potatoes are stored, or are going to be stored, in the same facility. SPROUT-NIP SHOULD NEVER BE USED ON SEED POTATOES. Remember, the chemical is considered effective in inhibiting sprouts for up to one year . . . even if the potatoes are removed from storage. Six months should elapse before using a treated storage facility for seed potatoes, and it should be thoroughly and meticulously cleaned beforehand.

The two application challenges are preventing leakage on the suction side of fans and controlling air velocity. Extra air results in air displacement, causing loss of fog and reducing the effectiveness of Sprout-Nip. Concentrate your pre-application planning on solving these problems. However, it's impossible to shut off all leaks. It's normal for the storage area to vent a volume of air equal to that supplied by the fogging machine. Also, high air velocities can cause plugging of the air-distribution systems.

STORAGE-FACILITY CHARACTERISTICS

While most storages are well-maintained and safe, you need to be aware of potential hazards while conducting your on-site inspection.

- Be careful around fans, vents, and electrical equipment.
- Watch your step through doorways and narrow passageways, on ladders, and across catwalks.
- Be careful around stacked containers if you encounter this type of storage facility.
- An indispensable piece of safety equipment for storage inspection is a flashlight. Be sure you have a backup light and plenty of fresh batteries.

Handling the Chemical Safety

Like most agricultural chemicals, Sprout-Nip is safe when properly handled and applied. ALWAYS READ THE LABEL BEFORE USAGE.

The danger and poison statements are printed prominently. This is due to the methanol solvent used in the product, rather than the sprout-inhibitor chemical active ingredient, isopropyl-m-chlorocarbanilate (CIPC). Methanol is found in many household products you may be familiar with, like windshield-washer solvent At all times, SPROUT-NIP SHOULD BE STORED OUT OF CHILDREN'S REACH.

Note that the aerosol formulation of sprout-inhibitor is fatal if swallowed, again due to the methanol solvent. Emergency measures to treat accidental exposures are also listed on the container label. Become familiar with them, and know where they are located in case you should need to find them in a hurry. As a matter of practice, it's wise not to expose yourself to such agricultural chemicals at any time. Avoid exposure during handling and application. Rubber gloves, splash-proof goggles, a long-sleeved shirt and long pants are recommended.

During application, properly adjusted over-the-head hearing protection should be worn because of the noise of the application equipment.

If you splash the chemical on yourself, TAKE IMMEDIATE ACTION TO STOP THE EXPOSURE. As soon as possible, remove exposed clothing. Don't let the liquid soak through to your skin. Wash thoroughly with soap and water IMMEDIATELY.

Sprout-Nip aerosol is applied as a fog. It's vaporized, then condensed and temporarily suspended in the air circulating through the stored potatoes. Remember, the fog is a dispersion of combustible material. If the concentration is high enough, the dispersion can burn. EXPOSURE SHOULD BE MINIMIZED.

When exposure to fog is necessary for short periods, the only way to protect yourself is to wear a respirator. An example of this is where sprout-inhibitor is applied inside a storage containing chipping potatoes, and fans and blowers accidentally stop during application. GOOD VENTILATION IS THE SECRET TO SUCCESSFUL AND SAFE APPLICATION. ALWAYS USE YOUR RESPIRATOR WHEN EXPOSED TO FOG.

The ideal application temperature range is 70 to 90 degrees F. If the temperature of the product is below this range, the best and safest method to warm the vented cans is in a hot-water bath. NEVER HEAT CPIC OVER AN OPEN FLAME. The potential for injury and loss of application equipment and the storage facility due to fire is high. Don't heat the chemical above 140 degrees F. At 140 degrees F., the formulation will lose methanol, the vapors of which are flammable. Disposal recommendations for Sprout-Nip are much like other agricultural chemicals. Follow disposal recommendations presented on the label.

Making the Application

Once you have scrutinized the site and the storage, it's a good idea to double-check the application rate. Again, the label is your best source. Then consider the air-circulation layout.

1. Shut off all heaters and pilot lights.
2. Introduce the fog to the storage facility properly and according to label directions.
3. Make use of supplemental fans on top of the potato pile and on top of the bins, if necessary.
4. Apply the chemical at labeled rates.
5. Set storage fans in the "recirculate" position. You should make sure the fans are running continuously during the application process.
6. Just before you begin, check that all doors and louvers on the suction side are sealed. For air-cooling systems without refrigeration, pay particular attention to any outside entrances that may be open. For storages equipped with refrigeration, protect the refrigeration coils to prevent Sprout Nip from flowing through the coils and accumulating there.
7. Monitor the flow of sprout-inhibitor formulation from the container during the application process. This can be done by using a simple dipstick in the formulation itself.

The Cleanup Process

Once the application is complete, the cleanup process begins. This is an important part of the application. First, the fog must settle, which may require several hours.

1. Wait for fog to settle.
2. Remove all protective coverings.
3. Remove residue from fan blades.
4. Brush or scrub fan area. Hot water (100 degrees F. or hotter) with soap may be necessary.
5. Reset the control panel and fans to the original positions.

FIRE HAZARDS OF STORAGES AND "FOG"

In 50 to 75 percent of the bins constructed in the last ten years in the San Luis Valley, for example, the principal insulating component is polyurethane (urethane, as it's commonly called). This is an extremely valuable material, not only for insulation but for potato storage. It holds up in extreme cold the best of the insulating materials. It's also soft against the potatoes, helping to reduce bruising. In addition, it resists moisture penetration and degradation in the humid bin climate. Practically speaking, it's one of the few materials that can be used to insulate the newer types of half-round storage bins. Fires are not normal in urethane insulation.

Since 1976, there have been only three major fires involving urethane in the San Luis Valley. None were fogging-related. In two cases, it's believed that the fires started from external sources and spread to the urethane. Urethane simply won't burn in the normal sense of lighting a match to it. Its flame-spread is less than wood. Simply holding a cigarette to it won't cause it to ignite, as opposed to wood or paper.

The property of urethane that poses a hazard in potato fogging is that it will flash at only 700 degrees F. The fog, on the other hand, is generated at 1000 degrees F. If it flashes in an enclosed place, then temperatures can rise and promote fire. A feedback system is established where temperatures rise, flashing more urethane and creating higher temperatures.

In a urethane fire, there's a great deal of dense black smoke produced. In addition, a form of cyanide gas is produced, much as carbon dioxide is produced in wood smoke. In an enclosed space without protection, there's a very real danger of suffocation and poisoning.

A cartridge-type respirator is inadequate. It's absolutely essential to have a SELF-CONTAINED BREATHING APPARATUS to enter into the smoke. The technical safety data also states that, in case of fire, A SELF-CONTAINED BREATHING APPARATUS IS ABSOLUTELY REQUIRED. DON'T ENTER THE BUILDING OR SHED WITHOUT ONE.

Indeed, the best advice is to leave any fire-fighting to the experts. If it's possible, it would be best to cut off the oxygen, cut the fogger off, and close intake louvers or cut off external power to the interior circulating fans (but only if the breakers are on the outside). This all works to cut oxygen supply to the fire. DON'T ENTER THE BUILDING UNDER ANY CIRCUMSTANCES.

Remember, too, which bin-fogging safety is on your side. In more than 20 years in the San Luis Valley, there has been only one very minor incident reported involving fire. For the millions upon millions of sacks of potatoes that have been treated, that's a very good safety record. The odds are on your side if, and only if, you'll take all precautions and proceed carefully and with prudence.

The key point to keep in mind is that urethane flashes at 700 degrees F. Thus, a welding torch or perhaps a fogging gun can set it off.

One must be extremely careful, not only personally but product-wise. Average storage in the San Luis Valley can run from 50,000 to 200,000 cwt. at a cost of $200,000 or more. A good year for bulk-shipped potatoes might bring $6.00 per cwt. Thus, a total loss of a 50,000 cwt. storage would be $200,000 for the building and up, and a minimum of $300,000 for the potatoes, if everything were lost.

Surprisingly, in an enterprise with so much potential risk, there has been little or no loss to property or product over the last 20 years. Hopefully, this high standard of professionalism will continue in the future as well.

INTRODUCTION

A fumigant is a chemical vapor or gas that, when released, penetrates objects or enclosed areas in concentrations that are lethal to pest organisms. This definition excludes aerosols, which are particles suspended in the air, often referred to as smokes, fogs or mists. It's important to make this distinction, since it emphasizes one of the most important and useful properties of fumigants: as gases, they diffuse as separate molecules. This allows them to penetrate into the material being fumigated and to diffuse away afterward.

Some insecticides, when sprayed on leaves or other surfaces as contact or stomach poisons, sometimes give off a gas. This gas may account for part of the toxic action of these applications. This is called the fumigation effect. This study guide won't deal with this effect; the guide is limited to fumigants that are dispensed so that the poison is present as a gas soon after application and reaches the pest as a gas.

Fumigation techniques have great adaptability in pest control. They can be used to control wood-destroying insects in structures and furniture where liquid or dust formulations are ineffective or where these materials may cause damage. Under some conditions, fumigants can be applied to control burrowing rodents that can't be reached with other types of rodenticides. Most commonly, fumigants are used in Utah to control insects or mites in fresh and stored food products such as grains, fruits, vegetables, nuts and dried fruit. Fumigation may take place at a home or storage facility, or it may occur in a carrier, such as a truck or railway car.

Controlled-atmosphere storage of certain food products is a unique form of fumigation. In a controlled atmosphere, most of the air in an enclosed storage area is replaced with a gas such as carbon dioxide.

Before performing a fumigation, the applicator needs to understand clearly the hazards and problems associated with the use of fumigants. Most fumigants are highly toxic to all forms of life, including humans, animals, plants, and even microbes. Fumigation is a highly specialized operation that requires equipment, techniques, and skills not generally used for applying other types of pesticides. Applying a fumigant may be time-consuming and expensive, usually requiring more labor than other pest-control methods.
Structural fumigation is disruptive, since it requires that tenants and other occupants leave the building. Because of the special hazards and conditions of fumigation, strict legal restrictions exist concerning its use.

HOW FUMIGANTS WORK

Fumigants kill by interfering with the respiratory function of the target pest. Molecules of some fumigants (for instance, carbon dioxide or inert gases) replace oxygen molecules in the air, so the pest-control action involves smothering (asphyxiation) due to lack of oxygen. Other fumigants enter tissues and disrupt enzymes used in the respiration of animal or plant cells.

The killing action of a fumigant is influenced by its concentration in the atmosphere, the length of time it stays in the atmosphere, and the temperature and humidity of the area at the time of fumigation. Fumigants are designed to enter cracks, crevices and other areas where target pests may occur. They must be applied in enclosed areas. Fumigation has no residual effect, and re-infestation may occur after the fumigant has diffused from the area.

Advantages of Fumigation

Fumigation has several advantages over other methods of pest control:

- Fumigants are usually quick-acting and can result in total eradication of the pest.
- Because fumigants are gases, they diffuse through all parts of the structure or commodity being treated and can reach pests that couldn't be reached with conventional pest-control materials or techniques.
- For certain commodities, fumigation is the only practical way to control pests.

Disadvantages of Fumigation

There are several reasons why fumigation sometimes may not be the best means of pest control. These are:

- The control achieved through fumigation is temporary -- there's no residual action from fumigants. Where untreated populations of the pest remain, re-infestation of the treated site can take place quickly.

- Fumigants are toxic and often highly hazardous to the applicator, requiring special precautions during
- Fumigants must be retained in the gas form for a period of time to be effective, often calling for extra supervision.
- Fumigation must never be done by just one person, which requires added labor.
- Some commodities or pieces of equipment may be damaged by certain fumigants and must be removed or otherwise protected.
- Fumigant activity may be greatly affected by temperature and humidity.

HOW TO CHOOSE A FUMIGANT

If the need for fumigation has been proven, the right fumigant must be chosen. To decide on an effective fumigant, it's important for the applicator to know the habits of the pest, the characteristics of the fumigation site, and environmental conditions that may influence the fumigation process. He or she also needs to understand the chemical and physical characteristics of the fumigant.

When choosing a fumigant, consider such factors as these:

- Toxicity to the target pest
- Volatility and ability to penetrate
- Corrosive effect, flammability, and potential for explosion
- Warning properties and detection methods
- Effect on seed germination and finished-product quality
- Residue tolerances
- Availability
- Ease of application
- Cost.

CHEMICAL AND PHYSICAL CHARACTERISTICS

Important physical and chemical characteristics of a fumigant include volatility, molecular weight, boiling point, vapor pressure, specific gravity, diffusion potential, water solubility, latent heat of vaporization, The vapor pressure of the fumigant affects the atmospheric concentration of the gas in the air. When a volatile liquid or solid is confined in an area,

application.

flammability, and chemical reactivity. **Read the product information** supplied by the manufacturer to be sure that the material you select is appropriate to the commodity, treatment site, and pest control needs. The label must list the commodity and target sites.

Volatility

Volatility is the tendency of a chemical to evaporate and become a gas or vapor. Volatility increases as temperature rises. Some "gaseous-type" fumigants, such as methyl bromide, are normally a gas at room temperature. Other fumigants exist as a liquid or solid (paradichlorobenzene, naphthalene) at room temperature. Also, many of the "solid-type" fumigants, such as aluminum and magnesium phosphide, are not fumigants themselves but react with moisture to form a fumigant gas (phosphine or hydrogen phosphide).

Molecular weight

Molecular weight is a measure of the weight of the atoms that form the fumigant molecule. More complex molecules have greater molecular weight because they have more atoms. Larger molecules are often less suitable as fumigants, since they are less volatile.

Boiling point

The boiling point of the chemical is the temperature at which the liquid stage boils under specific atmospheric conditions to become a gas. Some materials used as fumigants, such as methyl bromide, have low boiling points so they are gases at normal temperatures and atmospheric pressure. These types of fumigants are usually stored as liquids under high pressure.

The boiling point of a fumigant may influence the type of application equipment required. For example, fumigants with low boiling points usually require heaters to warm the gas as it's being released. This is because these materials may freeze on release into the atmosphere, since much heat is lost as fumigants turn from a liquid to a gas.

Vapor pressure

equilibrium gradually takes place between molecules in the gas and liquid phases. Once the gas molecules reach a saturation point, further volatilization won't increase the number of molecules in the vapor phase. Although volatilization may appear to stop, what actually happens is that every molecule evaporating from the liquid is replaced by a gas molecule condensing back to the liquid form. Since vapor pressure determines the concentration that can be maintained during fumigation, materials of high vapor pressure will be more concentrated and therefore have better fumigant qualities.

Specific gravity

The specific gravity of a chemical compound is a measure of its weight in a given volume. With fumigants, it's important to know if the gas is lighter or heavier than air. Most commonly used fumigants are heavier than air. A heavy gas in a confined area will tend to concentrate in low areas and mix slowly with the air.

These fumigants usually require mechanical mixing with a fan to distribute the molecules evenly through the fumigated area. However, once the fumigant is thoroughly mixed with the air, settling takes place very slowly. As a result, the problem of stratification -- or layering -- of heavier-than-air fumigants doesn't have much practical meaning for the exposure periods usually required in fumigation work.

All gases become lighter as they become warmer. This is because warm molecules take up more space, so fewer molecules can be contained in a given space at the same pressure.

Diffusion potential

Diffusion potential is a measure of how fast gas molecules disperse through the atmosphere. After a while, the molecules become evenly distributed. The speed with which molecules disperse is affected by the molecular weight of the gas. Gases that are heavier diffuse more slowly, and it may be important to disperse these types of gases with fans or blowers.

Water solubility

The water solubility of a fumigant becomes an important consideration if items in a fumigated area contain even small amounts of water. The water will tie up water-soluble fumigant molecules, reducing the fumigant concentration in the atmosphere. Toxic molecules also may be incorporated into the water of fumigated materials and may remain as undesirable residues. Suitable fumigants for most applications are those that are insoluble or only slightly soluble in water.

Latent heat of vaporization

Latent heat of vaporization (the extra heat required to change the liquid to a gas) must be considered when using fumigants that have boiling points below room temperature. Unless sustained by warming from an outside source, the temperature of an evaporating liquid constantly drops. This is shown by the cooling effect of evaporating water on the skin.

The factor of latent heat has important practical significance. High-pressure fumigants, such as methyl bromide, volatilize and lose heat rapidly on release. Unless the lost heat is restored, the temperature of the fumigant may fall below its boiling point, causing the gas to no longer evolve. Also, as the liquid changing to gas is led through metal pipes and tubes or rubber tubing, the drop in temperature may freeze the fumigant in the lines, preventing further passage.

In many applications, it's wise to apply heat to the fumigant as it passes from the container into the fumigation space. Fumigants that are liquids at normal temperatures and are volatilized from evaporating pans or vaporizing nozzles also lose heat. These applications may require a source of heat, such as a hot plate, so that full concentrations will take place rapidly.

Flammability

Flammability of a fumigant is another physical characteristic that is very important in its safe use. Fumigants that are flammable gases are usually combined with a non-flammable gas (such as carbon dioxide) to reduce the danger of fire or explosion.

Chemical reactivity

Chemical reactivity of some fumigants with other chemicals in the environment may limit some fumigant uses. For example, methyl bromide combines with sulfur-containing compounds (such as rubber, leather and other animal products) and gives off a strong, foul odor that is hard to eliminate. Phosphine gas reacts with copper (used in electrical wiring, motors and plumbing) to cause serious corrosion. High temperatures around an open flame may cause some fumigants to form corrosive acids. Certain fumigants may make photographic film and paper unusable because of chemical reaction.

TYPES AND NATURE OF FUMIGANTS

Many of the active ingredients in fumigants used earlier have either been canceled entirely or had their uses restricted. All space-fumigation products and several soil- fumigant products (especially those containing chloropicrin and/or methyl bromide) are now restricted-use pesticides.

Active ingredients that are still legal to use include:

1. Methyl bromide
2. Chloropicrin
3. Aluminum phosphide
4. Magnesium phosphide
5. Sulfuryl fluoride
6. Carbon dioxide

Methyl Bromide

Methyl bromide readily penetrates many materials and is in wide use for space fumigation. Methyl bromide is also used in agriculture as a soil fumigant to control fungi, weeds, nematodes and insects. Methyl bromide is sold as a liquid under pressure. Upon release, it vaporizes to form a gas that is about 3.3 times heavier than air.

Methyl bromide is a colorless, odorless and tasteless gas, but it’s highly toxic as a respiratory poison and can cause serious eye and skin damage. It’s usually formulated with a small amount of chloropicrin as a warning agent. Early symptoms of overexposure are dizziness, headaches, nausea and vomiting, weakness, and collapse. Fluids in the lungs and heart irregularities may develop two to 48 hours after exposure. These effects can result in death.

Methyl bromide is retained, at least for a short time, in body tissues. Repeated small over exposures can cause symptoms such as blurred vision, staggering walk, and mental imbalances, with probable recovery after a period of no exposure. If trapped inside tight clothing next to the skin, methyl bromide can cause severe skin burns.

Methyl bromide reacts chemically with sulfur products and should not be used to fumigate materials such as fur, leather, rubber, wool, and feathers.

Chloropicrin

Chloropicrin fumigants include products marketed under the names Chlor-O-Pic, Lavacide 100 and Quasar. These products contain nearly 100-percent chloropicrin and are marketed as liquids. Chloropicrin volatilizes to form a dense gas that is about 5.7 times heavier than air.

Chloropicrin is highly toxic to insects, vertebrates, and many soil microbes, such as fungi. It’s highly irritating to eyes and is a powerful "tear gas." Concentrations as low as 1.0 parts per million (ppm) cause intense eye irritation, and prolonged exposures cause severe lung injury. Chloropicrin can cause severe injury upon skin contact. Uses of chloropicrin on foodstuffs have been restricted in recent years. Right now, use is prohibited on most food, and direct-grain treatment uses are under review.

Aluminum Phosphide

Aluminum-phosphide fumigants include products marketed under the trade names Detia, Fumitoxin, Gastoxin, Phostek and Phostoxin. These products contain aluminum phosphide in combination with inert ingredients such as ammonium carbamate and urea. The formulated material is a solid molded into pellets or tablets. The active ingredient, aluminum phosphide, reacts with atmospheric water to produce hydrogen-phosphide gas. This gas is also known as phosphine. Phosphine is a colorless gas with an odor that smells different to different people. The odor is often described as similar to garlic, commercial carbide, or decaying fish. Phosphine is only slightly heavier than air, about 1.2 times as heavy. Fumigators can't rely on the gas moving through a solid storage such as a grain bin, so they need to set up one or more fans to mix the fumigant with the air.

Aluminum phosphide is used commonly to fumigate grain-storage facilities. Phosphine gas is highly toxic to all forms of animal life. Early symptoms of poisoning can be severe, but these symptoms are reversible if exposure stops. Initial symptoms of overexposure include "tightness" in the chest, faintness, dizziness, nausea, vomiting and diarrhea. Severe poisoning leads to coma and death. Phosphine (hydrogen phosphide) gas isn't absorbed through the skin and it's not stored in body tissues. Aluminum phosphide may explode on contact with water.

Magnesium Phosphide

Magnesium phosphide is similar to aluminum phosphide, releasing hydrogen-phosphide gas in reaction with water. Release of the gas is faster than occurs with aluminum phosphide.

Common magnesium-phosphide products contain the solid magnesium-phosphide material attached to a strip or blanket that can be put in place very quickly. Because this application method may not provide good distribution of the gas in a grain mass, it isn't usually used in grain- storage fumigation. Magnesium-phosphide fumigants can be used effectively for warehouse and processing-plant fumigations.

Sulphuryl Fluoride

Sulphuryl fluoride, sold under the trade name Vikane, is a colorless, odorless gas. It's sold in canisters as a liquid under pressure that volatilizes readily. It's non-corrosive and unreactive to most materials. Sulphuryl fluoride also can provide good penetration of wood products and fabrics, but it needs fans or blowers to mix well with air. Sulphuryl fluoride is non-flammable, but in the presence of an open flame, it forms a very corrosive gas. It's highly toxic to humans.

Carbon Dioxide

Carbon dioxide (CO_2) is a colorless, odorless and taste-less gas that is about 1.5 times heavier than air. It's non-combustible and is used as a fire-extinguishing material. It's usually found in the air at concentrations of about 0.03 percent. However, carbon dioxide is poisonous at higher concentrations and is used for fumigating food products at about 60-percent concentration.

Using carbon dioxide is desirable because no toxic residues stay in treated materials. Also, CO_2 doesn't change the germination potential of treated grain and leaves no objectionable odor or flavors. However, fumigation with carbon dioxide requires fairly long exposure periods to be effective. Effectiveness is greatly reduced by low temperatures, so if temperatures are below 60

Hydrogen-phosphide (phosphine) gas is reactive and very corrosive to metals, especially copper, silver, gold, and platinum.

degrees F., fumigation periods may be too long to be practical (three to four weeks or more).

DETERMINING A NEED FOR FUMIGATION

Several criteria should be considered in determining the need and suitability of fumigation for pest control. These include:

1. Characteristics and habits of the pest
2. Life stages of the pest
3. Characteristics of the treatment area
4. Hazards located in the treatment area
5. Available pest-management alternative
6. Established pesticide-residue tolerances

TARGET-PEST CONSIDERATIONS

Fumigants used in pest control tend to affect all forms of life. Almost any pest in an enclosed area can be destroyed when exposed to an adequate concentration of a fumigant. Fumigations are most often used to treat pests that infest harvested commodities such as bulk grain, greenhouse insects, etc. Inaccessible pests, such as wood-boring beetles and drywood termites, are also targets for fumigation. Fumigation may sometimes be the best choice for controlling heavy infestations of insects such as cockroaches, especially when it's hard to gain access to all of the pest's hiding places. Fumigation is also useful to avoid toxic residues associated with application of other pesticide formulations to food, clothing, and similar materials.

Habits of the Pest

Pests that are reclusive or hard to locate can often be treated successfully with fumigation. However, it's important to understand the habits of the pest before choosing fumigation. For example, colonies of drywood termites, very uncommon in Utah, nest in structural wood above ground and are good targets for fumigation. The far-more-common subterranean termites nest underground and are not killed by fumigation. Situations where large reservoirs of the pest will remain outside the treated area can allow quick re-infestation, wiping out the benefits of fumigation.

Life Stages of the Pest

An applicator should also consider how various life stages of the pest respond to fumigation. For instance, many insects are relatively non-susceptible to fumigants or other insecticides during their egg and pupal stages. Insects may also be dormant during certain periods and not be susceptible. Be sure to check the fumigant label to see what stages of the target pests the manufacturer claims the product will control.

SITE-SUITABILITY CONSIDERATIONS

Fumigation may be used in several types of situations, including structures, bulk-storage facilities, specially designed chambers, rail cars and trucks.

However, fumigants should only be used in enclosed areas, because the molecules of the fumigant penetrate throughout the area and escape through openings. Fumigants can't be used in localized areas of a building unless it's possible to completely seal and control access to the treated area throughout the fumigation and aeration period. Fumigants should never be used in any areas that can't be fully secured to prevent entry or contact by people or animals.

The fumigation site also must have the proper environmental conditions to allow successful use of the fumigants. This includes correct temperature, humidity, and air-circulation conditions required for effective pest control.

Sites should also be thoroughly surveyed to identify and protect items that may react with or be damaged by the fumigant. This may include such items as furnishings, floor coverings, foodstuffs, wall hangings, finishes, plumbing and electrical devices, and moisture sources.

Structural Fumigation

Fumigation may be used to control certain pests within existing buildings such as grain-storage bins and homes. Since typical construction isn't sufficiently airtight, these require sealing. In relatively airtight structures, taping may be sufficient. However, many buildings require tarping the entire structure.

Fumigants used in grain storage are very useful for control of stored-product insects such as weevils and various "bran bugs." Household fumigations can help control pests such as drywood termites, powder-post beetles, and other wood-boring beetles that are hard to control with other methods.

Chamber Fumigation

Since environmental conditions can be carefully controlled and monitored, chamber fumigation is a superior method for fumigating many materials. Using a chamber will allow only small amounts of a commodity to be fumigated at a time because of the limited size of the chamber. However, the limited space can be an advantage, because the fumigant is confined, saving the time it takes to fumigate and the amount of fumigant used. The ability to carefully control environmental conditions in a chamber also allows fumigation to be used to control pests on fragile commodities such as fresh fruits or vegetables without damage.

Chamber fumigation can also be used to disinfect fresh produce, packaged foods, bagged or baled agricultural products, museum specimens, furniture, high-value garments, and similar items.

Chambers used for fumigation may be either the **atmospheric** or **vacuum** type. Vacuum chambers provide the quickest and most thorough fumigation and are best for finely divided items, such as flour. Applying a vacuum increases the penetration of a fumigant and shortens fumigation time. However, some materials may be damaged by vacuum and require special precautions. Atmospheric chambers are useful for fumigating materials that might be damaged in a vacuum chamber.

Tarpaulin Fumigation

Tarpaulin fumigation involves placing a gas-tight material over the commodity or structure to be fumigated. The tarps must be specially made for fumigation, such as impregnated nylon or sheet polyethylene. (Waterproof canvas tarpaulins are not satisfactory.) Polyethylene tarps can be used in thickness from four to six mils. Use gas-impervious adhesive tape to join various sections of polyethylene film.

The tarpaulin method provides thorough protection from insect damage at a practical cost. Done in place, it Tarpaulin fumigation may be done in the open, on loading docks, or in areas of buildings that allow safe aeration when the tarpaulin is removed. However, sites must also be checked for possible hazards in securing the fumigated area from humans and animals as well as for adequate sealing.

Rail-Car and Truck Fumigation

Items shipped in rail cars or in large truck trailers are often fumigated after they are loaded into the vehicle. This prevents pests from being transported to other locations and protects shipped products from pest damage during transport. Most vehicles, depending on their condition and on the type of commodity being fumigated, require tarping or other sealing to confine the fumigant.

Pests controlled by rail-car and truck fumigation include beetles and moths that infest flour, grains, nuts, dried fruits, and other agricultural products. These insects usually are brought into the vehicle on the commodity being shipped. Some insect pests may hide in empty vehicles, feeding on residues from previous cargoes. Unless controlled by fumigation or removed by thorough cleaning, these pests can infest future loads.

Fumigation of rail cars and truck trailers must comply with the regulations of state and local highway departments and departments of transportation as well as fumigant-label instructions. In some cases, loaded rail cars can be fumigated in transit. However, regulations prohibit truck trailers from being moved until fumigation and aeration have been completed. When performing a truck or boxcar fumigation, the pesticide applicator must post warning signs on all entrances to warn of the hazards.

Because fumigated boxcars or trailers may contain residues of a fumigant after aeration, the vehicles need to be monitored with appropriate detection equipment once they reach their destination and before they are unloaded. The person opening and monitoring fumigated loads must wear respiratory protection and

permits fumigation without the expense of moving huge stores of commodities. Tarpaulin fumigation can effectively and economically free materials such as bagged grain, dried fruit, stacked lumber, and other commodities from insects.

any other protective equipment required by the fumigant label.

FACTORS AFFECTING FUMIGANT PERFORMANCE

For a fumigant to work effectively, the correct concentration of gas molecules must be present in the atmosphere surrounding the target pest. Molecule concentration may be affected by several factors. Some important ones are:

1. Sorptive quality of the treated commodity, either through absorbing (taking fumigant into the commodity) or adsorbing (fumigant condensing on the surface of the commodity).
2. Temperature and humidity during treatment.
3. Speed of diffusion of the fumigant through the commodity.
4. Reactions of the fumigant with other chemicals or articles in the treated area.
5. Amount of fumigant applied.
6. Susceptibility of the target pests.
7. In fumigation chambers, the pressure of the gas in the chamber.

Sorptive Qualities

Surfaces or items within the fumigated area may affect the concentration of fumigant molecules. For instances, cardboard boxes that contain produce or other food items will absorb some of the fumigant. Foam rubber used in upholstery or as carpet padding is also sorptive. Building insulation has large surface-areas and therefore will sorb fumigant molecules.

Molecules can be either absorbed or adsorbed. (See No. 1 in above list.) When absorbed, fumigant molecules dissolve into another material, such as water, oil, or other liquid. Absorption may not always be reversible, Adsorption is a molecular attraction between gas molecules and the surface of something in the environment. The rate of adsorption is influenced by temperature. Fumigants applied while temperatures are low will adsorb more rapidly than when applied under higher temperatures. Adsorbed molecules may be released (desorption) as the temperature rises and as the concentration of the gas molecules in the surrounding atmosphere decreases. Fans and blowers that force air through the commodity can further speed the reversal of fumigant adsorption.

Temperature

Temperature at the treatment site affects both the fumigant and the target pest. Low temperature increases the sorption rate of the fumigant so that the concentration of the fumigant is reduced, but desorption is slowed by cooler temperatures. Fumigants also volatilize and diffuse more slowly at cooler temperatures.

Insects and other target pests may be less sensitive to effects of fumigants at lower temperatures. During cooler conditions, respiration of the target pests is slowed, making them less susceptible to poisons that affect respiration. Preferred fumigation temperatures usually range between 50 and 95 degrees F. Check the label of the fumigant being used for its optimum temperature and acceptable temperature range. Also remember that during the course of a fumigation application, the temperature of the treated area can decrease or increase due to fluctuations in outside temperatures and also due to the cooling action of the fumigant being released (latent heat of vaporization).

Humidity

The concentration of water vapor in the atmosphere -- humidity -- can affect the performance of fumigants that are water-soluble, such as methyl bromide. The water-soluble fumigants become unavailable when dissolved in water, reducing their concentration. Fumigants may not be able to penetrate wet areas, allowing insects in those areas to survive.

High humidity can also create moisture condensation in the fumigated area. Condensation can cause spotting of treated surfaces. In stored grains, condensation can therefore resulting in greater problems with chemical residues.

Adsorption

cause wet spots that allow molds and storage heating to develop.

Diffusion

For a fumigant to be effective, it must penetrate the entire treatment site quickly and must be in the proper concentration. Factors that slow the diffusion rate include heavier fumigant molecules, low diffusion potential, and cool temperatures. Diffusion may also be hampered by dust in the fumigated area, a common problem in fumigating grain-storage structures. A fan or blower will increase diffusion.

Reaction with Other Chemicals

Materials in the treatment area, including food products being treated, may react chemically with a fumigant. Higher temperatures may further speed reaction processes. For instance, the flame from a pilot light or heat from a glowing electric heating element may cause fumigant molecules to react with other gas molecules in the air. Chemical reactions of this type are not reversible under normal conditions. If fumigant molecules react chemically, new chemical compounds will be formed. This may include corrosive acids, such as result from heating sulfuryl fluoride. Possible residues of newly formed chemicals may also stay in the fumigated area or on treated food products. For example, inorganic bromide compounds are found as residues on some food items that have been fumigated with methyl bromide.

In addition, chemical reaction of fumigants may lower the concentration of the fumigant enough to reduce the effectiveness of the fumigation. Check the fumigant label for precautions, and inspect the fumigation site thoroughly to eliminate materials or conditions that may allow reactions to occur.

Concentration and Time

How well a fumigant works depend both on the amount that has been applied and how well the concentration of gas molecules is maintained after application. The amount of fumigant applied is usually expressed in weight per volume (for example, pounds per 1,000 cubic feet or grams per cubic meter). The concentration of a fumigant is the amount of gas present in a given volume (for example, ounces per 1,000 cubic feet or milligrams per liter). Concentration is influenced by sorptive qualities, temperature, chemical reactions, and how well the fumigated area is sealed.

When fumigating grains, the applicator needs to adjust the dosage for the intergranular space (the amount of It's also important to maintain the critical amount of gas in the area of the target pests for a certain period of time. Although most fumigants are fast-acting, effective concentrations need to be maintained for several hours to days or weeks to allow control. For example, in order to kill 99 percent of the cadelle-beetle larvae in stored grain, a concentration of 33.2 milligrams per liter must be maintained for five hours.

Susceptibility of Target Organisms

Target organisms can react very differently to the effects of fumigants. This variation may be due to species differences. It can also be acquired, by development of populations that are genetically resistant to the treatment. Variation in susceptibility also is affected by the life stage of the pest.

In addition, the way a fumigant is applied can sometimes influence pests' susceptibility. For instance, some insects can tolerate a higher concentration of fumigant if they are first exposed to a low concentration for a short time. To avoid this problem, bring the fumigant level to the lethal concentration quickly, then maintain the level throughout the fumigation period.

Pressure

In an airtight chamber, the penetration rate of fumigants may be controlled by using positive or negative (vacuum) pressure. Too much pressure or vacuum may cause structural changes in the commodity being fumigated.

Therefore, care must be taken to prevent damage to the commodities. To prevent undue expansion of tightly sealed packaged goods while a vacuum is being created, the pressure should be lowered slowly and/or the decompression process should be stopped for two to five minutes after each one-inch fall of mercury in a pressure-measuring device.

SAFETY PRECAUTIONS AND PROTECTIVE DEVICES

space between individual grains). This factor varies with the type and condition of the grain. Read the fumigant label for dosage information about these sites.

Using Two Trained Applicators

Recent regulations and changes in warning statements on labels now require the presence of two trained applicators during hazardous stages of fumigant application. This strengthens long-standing recommendations to always work in pairs. Two applicators are to work together whenever the application or gas-monitoring requires entry into or work within the confined space where a fumigant is applied.

Aluminum-phosphide and methyl-bromide labels do allow an applicator to work alone if the fumigant is applied outdoors to a moving grain-stream (aluminum phosphide) or in recirculation systems where methyl-bromide concentrations don't exceed five ppm in the work area. Even so, the presence of two trained applicators is always a wise investment for safety in the event of accident or emergency.

Exposure Levels

Respiratory protection is required for certain phases of most fumigant applications and other times when the airborne concentration exceeds a set value. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends following established exposure limits known as **Threshold Limit Values** (TLVs). A TLV is the airborne concentration of a fumigant in parts per million that nearly all workers may be repeatedly exposed to on a daily basis without adverse effect. A TLV is usually established for each fumigant as a guide to prevent health hazards, but it should not be considered the distinction between safe and unsafe fumigant concentrations.

Two types of TLVs are recommended by the ACGIH as guidelines for protecting persons handling toxic vapors, including fumigants. These recommendations are not enforceable standards, although they contribute to better worker safety. The two recommended TLVs are:

1. TLV-TWA, the **threshold limit value-time-weight average**, is an airborne concentration, in parts per million, of a fumigant (or other toxic gas) that most workers can be exposed to during an eight-hour workday or 40-hour workweek without developing

health problems. Typically, the TLV-TWA value is the concentration referred to on fumigant labels that must not be exceeded without appropriate respiratory protection.

2. TLV-STEL, the **threshold limit value-short-term exposure level**, is the maximum allowable concentration of any fumigant that a person should be exposed to without respiratory protection. It's recommended that exposure to this concentration be for no longer than **15 minutes** at a time, with a minimum of 60 minutes between exposure periods. No more than four exposure periods should be allowed in one workday. The total exposure for any single day should not exceed the TIV-TWA level for an eight-hour work period.

If the fumigant doesn't specify a maximum exposure value, exposures must then be kept below the Permissible Exposure Limit (PEL). PELs are set forth in state or federal health and safety regulations. These limits usually represent the maximum concentration of an airborne chemical that can be present without being a health hazard to most people.

The TLV and PEL values should only be used as a guide, since these levels may not protect everyone under all types of conditions. For example, there may be a few workers who will be sensitive to effects of the chemical below the TLV or PEL. Heavy physical activity, which increases the breathing rate, increases chemical uptake of airborne chemicals. Also, the exposure levels are based solely on exposure through inhalation. Since some fumigants can be absorbed through the skin or accidentally ingested, this increases overall exposure levels.

Gas-Detection Devices

Revised labels for fumigants require the use of sensitive gas-monitoring devices during fumigant application and before warning placards can be removed from fumigated storages.

Devices that provide adequate sensitivity includes detector tubes and matching pumps manufactured by Auer, Draeger, Matheson-Kitagawa, MSA and Sensidyne. Detector tubes are sealed glass tubes filled with a specific, reactive solid. Both ends of the tube are broken off just before use, and one end is attached to a calibrated pump. Available pumps use a bellows, bulb, or piston-type syringe to draw a precise volume of air through the detector tube. Discoloration of the solid material within the tube indicates fumigant concentration; gas concentrations can be read directly from the glass tube. Tubes and pumps manufactured by different companies may be very similar, but to get accurate readings, it's necessary to match detector tubes and pumps from the same manufacturer. Don't mix separate brands of equipment.

"Low-range" detector tubes that accurately indicate low levels of fumigant concentrations are required for label-specified monitoring practices that provide information for worker safety. "High-range" tubes may be useful for detecting fumigant leaks. These tubes are scaled for measuring much higher concentrations of fumigants, and they are especially useful for monitoring gas concentrations within storages during fumigation to determine if the necessary levels were reached. Other gas-monitoring devices, such as halide leak-detectors and thermal-conductivity meters, may be used to detect leaks or determine internal concentrations of gas during fumigation. However, these devices don't provide label-required levels of sensitivity necessary for determining safety (respiratory-protection) needs. Halide detectors also should not be used around grain-storage buildings, since the flame may trigger an explosion of grain dust.

When measuring fumigant levels after fumigation, it's important to take readings from several locations. Often fumigants may become trapped in localized pockets. Different materials will also desorb at varying rates, a process called offgassing. This can allow toxic levels of the fumigant to occur in scattered locations.

Detector tubes are specific for a single fumigant. Auer, Draeger, Matheson-Kitagawa, MSA and Sensidyne manufacture detectors that offer adequate sensitivity for label-required monitoring of hydrogen phosphide (phosphine) and/or methyl bromide.

The only currently available detector that offers adequate sensitivity for label-required detection of chloropicrin is produced by Matheson-Kitagawa and is specified on the chloropicrin label.

Tubes available for measuring CO_2 concentrations are available from several manufacturers. Several types of tubes may be needed, since applicators must be able to measure low (below one percent) CO_2 levels to provide information on worker safety and high concentrations (up to 60 percent, minimum) to determine the need for continued injection of the gas into the structure.

Warning agents, such as chloropicrin, are sometimes added to fumigant gases that otherwise have little odor. Sometimes warning agents may affect the accurate reading of fumigant levels, so be sure to use detecting equipment that can reliably measure fumigant Various types of respiratory equipment are available, but their effective and safe use requires that the equipment is matched to the specific need. For example, chemical-cartridge respirators, used in applying many types of pesticides, are not suitable for fumigation work. Depending on the gases and their concentration, various types of gas masks, self-contained breathing apparatus, or air-supplied systems are appropriate.

Canister and cartridge-type **gas masks** employ a replaceable canister or cartridge that contains chemical components that absorb specific gases. Full-face canister respirators (not half-face cartridge respirators) should be used as protection where this meets label specifications.

The effective life of an individual canister varies according to fumigant concentration and the respiratory rate of the applicator. Maximum limits are stated on each canister. Under NIOSH/MSHA regulations, canisters are color- coded according to fumigant absorbency. For example, canisters approved for protection from hydrogen phosphide are coded yellow with an orange stripe. Canisters effective for methyl bromide and chloropicrin are color-coded black. Always double-check the color code with written specifications that indicate the canister is effective for the fumigant.

As a canister <u>empties</u>, it becomes hot. Breathing hot air or encountering high resistance to breathing provides a warning that the canister is about to become ineffective for protection.

When this occurs, or when the applicator smells or tastes the fumigant or experiences poisoning symptoms, the applicator should **immediately** leave the fumigated area. An empty canister should be crushed before it's discarded so that no one will mistakenly use it in the future.

Canister respirators are inadequate for use in oxygen-deficient (less than 19.5 percent) environments, such as that produced by CO_2 fumigation. Although canisters may absorb the toxic fumigant in this environ-

concentrations in the presence of the warning agent. (Note: Commodity fumigators must not use chloropicrin as a warning agent, since this material isn't permitted for use on most food items, and it would result in an illegal residue.)

Protective Equipment

ment, they don't supply necessary oxygen. In these situations, a self-contained breathing apparatus (SCBA) or a combination air-supplied/SCBA is needed.

General Rules on Canister Use

1. Discard any canister that has been used for more than 30 minutes (total time) in a fumigant atmosphere.
2. Discard any canister whenever an odor of fumigant is detected as coming through. (The absorption material isn't working).
3. Discard any canister used for less than 30 minutes if it's more than one year old.
4. Discard canisters with expired expiration dates or that have been manufactured more than two years earlier (even if unused), unless the instruction sheet specifically says otherwise.
5. DON'T use a canister-type gas mask to enter a recently fumigated or oxygen-deficient area.

The self-contained breathing apparatus (SCBA) common-ly used for fumigation is the air pack. Air packs comprise a full-face mask attached to a tank of air carried on the applicator's back. An air pack supplies up to 25 to 30 minutes of air supply and allows work in an oxygen-deficient environment. This time period may be considerably shorter if overexertion increases the rate of breathing. A warning bell can be set to signal the depletion of the air supply.

In a fumigant-laden storage, safe exits may require uninterrupted respiratory protection. For this reason, carrying an approved canister respirator when using an air pack is recommended for situations where oxygen concentrations remain adequate. The canister respirator will allow emergency escape if the SCBA expires or malfunctions.

Methyl-bromide and chloropicrin label directions concerning respiratory protection include reference to combination air-supplied/SCBA respirators. Air-supplied respirators employ an outside air source pumped to the applicator through an air line. The major advantage of the air-line system is that the air supply doesn't expire in a limited time. Disadvantages include the need to tow the air line throughout the storage. Air-pump failure or a constriction of the air line can shut off the air supply. The air pump must also be located in a fumigant- free area. In combination with an SCBA, an air-supplied respirator does offer an unlimited work period with backup respiratory protection provided by the SCBA, if for any reason the outside air supply is cut off.

Air passage between the mask and the face indicates an unsatisfactory fit. The release of irritant gases near the edges of the mask can also indicate an improper fit. Detection of the irritant within the mask signals a poor seal between the mask and the face.

None of the respiratory-protection equipment provides protection from skin absorption or skin injury by fumigants. When using fumigants that have potential to injure the skin or be absorbed by it, such as chloropicrin, be sure to wear additional protective clothing.

Respiratory-Protection Requirements

Fumigant labels require the use of specified types of respiratory-protection equipment during most fumigant applications. Labels specify maximum fumigant concentrations in which applicators can work without respiratory-protection equipment. Gas concentrations greater than the label specifies signal a need for exposed workers to use respiratory-protection equipment. These levels include the following:

- Workers exposed to hydrogen phosphide (phosphine) at levels above 0.3 ppm must wear a canister-type gas mask or self-contained breathing apparatus (SCBA).
- Workers exposed to concentrations of hydrogen phosphide above 15 ppm, or where levels are not measured, must wear an SCBA.
- Workers exposed to chloropicrin concentrations above 0.1 ppm must wear a canister-type respirator, an SCBA, or a combination air-supplied/SCBA respirator.
- Workers exposed to methyl-bromide levels above five ppm must wear a SCBA or a combination air-supplied/SCBA respirator.
- Workers exposed to carbon-dioxide concentrations exceeding 1.0 percent must wear an SCBA or combination SCBA/air-supplied respirator.

Symptoms of Exposure to Fumigants

One final respiratory-protection topic concerns the fit of a face mask. If a face mask doesn't seal tightly against the face, it cannot provide protection from a fumigant gas. An applicator must select a mask that fits his or her face; facial hair must be cleanly shaved to allow a tight fit. Fit can be tested by closing off the breathing tube and trying to breathe in or blow air out.

Most reactions to fumigant poisoning differ from those of exposure to other pesticides. For instance, many fumigant reactions simulate drunkenness. Symptoms of fumigant exposure can include:

- Slowed body movements
- Slurred/slowed speech
- Dizziness
- Numbness of hands or feet
- Coughing
- Sneezing
- Dryness/irritation of nose and throat
- Breathing difficulty
- Nausea
- Abdominal pain.

CALCULATING USE RATES

The first step in deciding how much fumigant must be released to achieve the desired concentration is to measure the length, width and height of the area to be treated and figure its volume. (Volume measurements on fumigant labels are given in cubic feet.) If the commodity, container or structure to be fumigated is to be tarped, the total volume inside the tarp must be determined, not just the volume of the structure or commodity. This must account for spaces caused by overhangs, eaves, and other irregular shapes.

Fumigant labels are the best source of information on calculating the proper amount of fumigant to use for specific situations. **Always read and follow label instructions.**

Physical or environmental conditions may influence the amount of fumigant that must be applied to achieve the required dosage. Factors that must be considered include:

1. Temperature and temperature fluctuation during fumigation.

2. Sorption qualities of the commodity or items in the target site.
3. The type and condition of the sealing method.
4. Texture and moisture content of the soil beneath the fumigation site.
5. Wind velocity during the fumigation period.
6. The volume of the area being fumigated. Some fumigant manufacturers furnish calculators, charts, or slide rules to help figure dose adjustments for these factors.

Sorption of fumigant molecules by commodities or surfaces in the treatment area reduces the concentration. Little can be done to change sorption qualities. Therefore, the applied dose of fumigant may need to be increased. Whenever fumigation takes place over soil, such as outdoor bulk-commodity fumigation or structure fumigation, the texture of the soil and its moisture content will influence fumigant concentration. Soils made up of fine clay or loam have less space between particles. Coarser soils, such as silt or sand, are much more porous and hold more fumigant. Increasing soil moisture by wetting will lower fumigant loss.

The way a fumigation site is sealed influences how fast fumigant molecules escape. Poorly sealed seams or holes in the tarp allow a quicker drop in concentration. Wind may increase the amount of air exchange between the fumigation site and the external environment, speeding fumigant loss.

As the size of the fumigated area increases, a smaller dose per unit of volume is usually needed to achieve the desired concentration.

SEALING

In most cases, the only way to achieve a sufficiently high concentration of fumigant is to seal the treatment area with a gasproof barrier. The best possible seal should be at the lower sections of the fumigated space, since most fumigants are heavier than air. Leaks in the lower portion of the fumigated space will allow more fumigant to be lost than leaks in upper areas.

Sealing can be accomplished in several ways. One method is to cover the treatment site with four- or six-mil polyethylene sheeting or an impregnated gasproof tarpaulin. Some containers, such as storage bins, may be sufficiently airtight and may only require taping around openings or vents. Seams or cracks can sometimes be sealed with a liquid that expands to form a

Low temperatures may affect dispersal of the fumigant in a treated area. Also, insects are generally more resistant to a fumigant when the temperature is low because their metabolism slows. If a fumigation lasts over a lengthy period, there also may be important temperature fluctuations. Heating the fumigated area and increasing air circulation can overcome most low-temperature-related problems.

solid foam after being applied. Sealants that come into contact with food must be approved food-grade sealants. Fumigation chambers are built to be airtight, so they usually need no additional sealing.

It may be necessary to wet the soil around the foundation when doing structural or outdoor fumigations. This will reduce the amount of fumigant that will pass into the soil and will help achieve a good seal. Concrete or asphalt surfaces provide a satisfactory seal.

In structural fumigations, look for potential problems associated with tarping, such as landscape plants. Plants can interfere with sealing, and they may be damaged by the fumigant. Fragile roofs or roof-mounted structures can also be damaged in the sealing process unless special care is taken.

Structural fumigation may also require sealing of areas within the structure. Materials that may be damaged by the fumigation and that can't be removed should be sealed off to exclude the fumigant gas. Drains and other conduits for the fumigant may also need to be blocked. However, it should be recognized that these areas may also provide refuges and, if not exposed to the fumigant, allow some of the target pests to survive the treatment.

Seal seams and holes in the tarp with durable tape or clamps. Cover sharp edges of a vehicle, container, or structure with protective material, such as foam rubber, to keep them from tearing the tarp.

Moisture may condense inside the tarp or on surfaces or commodities being fumigated. Condensation is greatest during periods of high humidity or falling temperature. High humidity may be due to a recent rainfall or because of high humidity of the commodity. Condensation can cause several problems, such as interfering with the fumigant and damaging commodities by staining, spotting, and surface corrosion. If possible, dry out commodities or areas having high moisture before beginning a fumigation. Drying can be quickened by heating, exposing the materials to sunlight, increasing air circulation, or -- in closed buildings -- running air conditioners before and during tarping to remove moisture.

With tarpaulin fumigation, careful consideration must be given to the method of obtaining a ground seal. If concrete and asphalt surfaces are smooth, they are Occasionally, a stack may be too close to a wall to obtain a good ground seal. If the wall is well-sealed, the solution is to seal the tarp directly to the wall with adhesive tape.

APPLYING THE FUMIGANT

Before applying any fumigant, notify local fire and police authorities and other security personnel as to the location, the chemicals to be used, proposed date and time of the fumigation, type of protective equipment required, and fire hazard rating. If necessary, provide authorities with pertinent safety literature on the materials to be employed. In addition to normal equipment needs, also arrange for standby equipment, replacement parts, and an alternate plan of action.

The release of a fumigant into an enclosed area is referred to as "shooting" or "shooting the fumigant." Methods of application, or shooting, vary according to the type of fumigant used, what is being fumigated, and where the fumigation takes place. The way fumigants are applied in any situation, however, influences the degree of control of the target pests. Incorrect application techniques can damage the area, damage the commodity, or injure people.

Gas Fumigants

Gas fumigants come packaged under pressure in large steel gas-cylinders or small metal cans. When using fumigant from a large cylinder, suspend the cylinder from a scale and monitor its weight change over time to calculate the rate of application. The total weight of fumigant used will determine the dosage applied.

Gas is injected into the treatment area through one or more hoses or shooting tubes. Rate of application is influenced by the diameter and length of the shooting hose. Nozzles attached to the shooting hose further affect the fumigant release rate. Cylinder pressure also controls the rate of release, the pressure in the cylinder

satisfactory. Wood surfaces are not suitable. With wood and most soil surfaces, it's necessary to place a section of the tarp material beneath the commodity as well as over it.

There are several methods of getting a good ground seal. Allow enough tarp material to skirt outward to at least 18 inches from the stack. Loose sand, sand snakes, or water snakes can then be used to hold the skirt to the ground surface.
being influenced by the remaining gas and cylinder temperature. Obtain charts from the fumigant supplier to calculate the optimum release rate for the fumigant being used.

Releasing fumigant too fast may cause rapid cooling of the fumigation site and result in poor fumigant distribution. Rapid cooling will also promote condensation of water vapor. Releasing the fumigant too slowly may cause icing of the shooting tube and possibly restrict the flow of fumigant. As the ice melts, it may spot or stain. Slow release may also prevent the fumigant from reaching the effective concentration quickly enough to control the target pests.

Fans or blowers should always be used when the fumigant is heavier than air. Continue the use of fans or blowers until the desired concentration of fumigant is achieved uniformly throughout the fumigated space. Discontinue their use after this point to reduce potential leaking.

Pelleted Fumigants

Aluminum phosphide for use in protecting bulk grain needs to be evenly distributed to provide adequate fumigant levels. Pellets should be inserted deeply within the grain mass, at least five feet, and no more than 50 pellets or 20 tablets should be inserted per probe. Applicators should also wear cotton gloves so that perspiration doesn't contact the aluminum phosphide, releasing the phosphine gas. The applicator not making the probes should periodically monitor fumigant (hydrogen-phosphide/phosphine) levels.

Since hydrogen-phosphide gas doesn't provide adequate and uniform concentrations more than 30 feet below its application site, supplemental insertions may be needed in larger structures. These may sometimes be able to be inserted through the aeration or drying fan. Within grain-storage facilities, it's best to tarp over the surface of the grain mass. If the grain isn't tarped, the fumigant rate must be increased to provide adequate concentration in the bin headspace as well as within the grain mass. Eaves and roof hatches must be tightly sealed if the grain surface isn't covered.

Liquid Fumigants

Liquid fumigants volatilize rapidly into a gas. The gas then penetrates through the commodity being treated. To Use of carbon dioxide as a fumigant requires special application, since the gas must displace much of the existing air to achieve the necessary concentration, usually 60 percent. This requires introducing large amounts of the gas and venting the structure to allow the normal atmosphere to be expelled. A top-down purge involves allowing the CO_2 to be introduced at the top of the structure, displacing air as it settles downward. Bottom injections of carbon dioxide are sometimes used in storages with leaky roof or eave areas. Following the purge, complete sealing will result in the most successful fumigation. Additional injections of small amounts of CO_2 should be made when measurements indicate that concentrations have dropped below 50 to 60 percent.

POSTING AND SECURING A FUMIGATION SITE

Before fumigating, fumigated areas must always be clearly posted to direct others to stay away. Individual fumigants include detailed instructions for the posting of warning placards on fumigated structures. Labels specify the wording (including some information in both English and Spanish) and content that must appear on warning placards. Placards must be placed around the perimeter of the treatment area and at all entrances.

On structures, all entrances should be locked during fumigation and access allowed only to authorized persons, and even then only in an emergency. Use secondary locks on all doors to further guard against unauthorized entry.

Areas that cannot be locked or secured must have someone present throughout the fumigation and aeration period to block unauthorized entry. Always make sure to inform janitors, watchmen, and other persons who regularly use the building about the fumigation.

Warning placards may not be removed and the commodity may not be processed or fed until a certified assure even distribution, apply liquid sprays to commodities as they are being loaded into a storage container or storage building. Consult the fumigant label to determine protective clothing and equipment needs for these applications.

Carbon Dioxide

applicator uses an appropriate gas-detection device to determine that gas concentrations have dropped below specified levels for the fumigant. This follow-up monitoring is a practice recently required under newer regulations.

AERATING

When fumigation is completed, the fumigant must be completely dissipated by aeration before allowing access to anyone or before vehicles can be moved.

Bulk Grain and Other Commodities

Wear respiratory equipment to aerate bulk items that have been covered with a tarpaulin. First, pull the tarp up from the sides for about 30 minutes, then remove the tarp completely. If this fumigation was made inside a building, open doors and windows and use fans to exhaust the fumigant. The air being exhausted from the building must be directed away from work areas, sensitive plants, and neighboring property. Make sure downwind areas in the vicinity are kept clear to prevent people or animals from contacting the fumigant as it disperses.

Wear respiratory protection, if entering the building. Check the fumigant level to determine the level at which it's safe to allow re-entry without protective equipment. Take measurements at several locations.

Continue to keep people away until monitoring equipment confirms that the fumigant level is below the harmful stage. Continue to aerate for several hours, and leave the building or commodity unsealed; this will prevent a fumigant buildup by desorption.

Vehicles

Roll back the tarp that covers boxcars or truck trailers, and open the doors and ventilators for 30 to 60 minutes; then remove the tarps. Measure the fumigant level before entering the fumigated area, and wear protective equipment until the fumigant has dispersed. To prevent injury, notify people who will open the vehicle at its destination that they must wear respiratory protection.

Instruct them not to unload the vehicle until fumigant levels have been monitored again and are determined to be in the safe range.

Buildings

Wear the label-recommended respiratory protection when beginning the aeration of structures. Use fans to force the fumigant out of the structure. Fans should be installed during tarping and before the fumigant is applied. Connect electrical cords to a remote power source so the fans can be started without entering the fumigated area. Be sure the exhaust from the fans is directed away from work areas, sensitive plants, and neighboring work areas.

Begin by starting the fans, which will pull the tarps up against the sides of the structure. When the tarps have drawn up tight, slightly open a seam on the opposite side of the building from the fans. Wearing respirator equipment, enter the structure and close outside doors and most windows to prevent fumigant inside the building from getting into the space between the tarp and the building's exterior.

Next, remove the bottom seal, working in both directions away from the exhaust fans. Open all lower tarp seams before opening roof seams. Pull tarps up or peel them away from the sides of the building rather than dropping them to the ground. As soon as tarps are being removed, the exhaust fans can be shut off and all doors and windows opened.

After tarps have been removed, use an atmosphere-monitoring device to determine when the fumigant has been dissipated well. Check for pockets of the fumigant in low areas and in corners, closets, or other areas where there is poor air circulation. Areas where there are porous materials may have sorbed quantities of fumigant that will be more slowly dissipated. Longer aeration periods will be needed under these conditions. To hasten the desorption process, increase the temperature inside the structure and maintain good air circulation. Be sure to ventilate refrigerators and freezers as well as attics and crawl spaces.

SPECIAL CONSIDERATIONS FOR FUMIGANT AND CONTAINER DISPOSAL

Fumigants are hazardous materials; empty containers and any excess or unused fumigants must be handled appropriately. The correct method of handling fumigant containers differs among fumigant products. Empty canisters or tanks that were used to hold methyl bromide or CO_2 under pressure should be returned through the original shipper to the manufacturer for refilling. Some chloropicrin containers should be handled in the same manner, while others should be triple-rinsed, punctured, and disposed of in landfill. Consult specific container labels for instructions.

Unused aluminum-phosphide pellets or tablets in opened flasks should not be disposed of. Once flasks are resealed, these tablets or pellets can be stored safely (as long as the label remains intact) for future use. Don’t store flasks at sub-zero temperatures, as doing so will increase the likelihood of ignition (flash) when they are opened.

If aluminum-phosphide tablets or pellets are spilled or flasks are punctured, hydrogen-phosphide gas is released. Persons cleaning up the spill or working in the contaminated area must wear an SCBA unless gas-detection equipment is used. If gas concentrations are measured and if hydrogen-phosphide concentrations range between 0.3 and 15.0 ppm, a canister respirator should be used. At higher concentrations, an SCBA is required. Cleanup personnel should wear cotton or neoprene gloves while handling spilled material. If a spill can be cleaned up immediately, spilled pellets or tablets should be used immediately or transferred to an empty flask with an intact label. If such a container isn’t available, tablets or pellets can be placed in a sound, DRY metal container that should be sealed and labeled as aluminum phosphide. Keep the original product label with the substitute container.

If spilled material has begun to react and decompose, or if it’s contaminated by other substances so that it can't be safely stored, it should be gathered and placed into open-top, perforated gallon cans and processed immediately. Don’t use water to clean up an aluminum-phosphide spill.

Water will react with tablets or pellets to rapidly release hydrogen-phosphide gas, and the rapid production of gas can result in spontaneous ignition and explosion.

To deactivate unreacted or partially reacted pellets, transport them by hand or in an open vehicle to a location in the open air away from occupied structures. Fill a drum two-thirds full of water, and add one-fourth cup of low-sudsing detergent or surfactant for each gallon of water. Mix each flask of tablets or pellets with no less than one gallon of the water-detergent mixture. Wear respiratory-protection equipment, and slowly add the aluminum-phosphide product to the drum while stirring. Stir occasionally thereafter for at least 36 hours. Disposal of residual dust from reacted pellets or tablets is necessary following a space fumigation. Residual dust is grayish-white, and it contains a small amount of unreacted aluminum phosphide. (Tablets or pellets that are only partially reacted remain slightly greenish in color and should be disposed of in the manners described above for spills.) Residual dust from up to five flasks can be disposed of by on-site burial or by spreading over the land surface in a secure area away from inhabited buildings. This amount of dust may also be disposed of at a sanitary landfill or an approved pesticide incinerator. For larger amounts of residual dust, a detergent slurry disposal method, described above, is recommended. See product labels for additional directions.

Residual dust from up to three flasks can be held in an open one-gallon bucket pending disposal. Larger amounts of dust should be held in a porous cloth bag during any storage or transport before disposal. Don't put the residual dust from more than eight flasks of tablets or ten flasks of pellets in any one bag before disposal. Greater amounts may generate enough gas to risk explosion. Don't pile bags. Don't confine, dispose of, or store residual dust in closed containers such as dumpsters, drums, or plastic bags. Don't dispose of dust in toilets.

Empty flasks that contained aluminum phosphide may be recycled or disposed of in a landfill after they have been properly processed. To adequately clean flasks before disposal, flasks and stoppers may be triple-rinsed and then punctured. A small number of empty flasks may be punctured and held outdoors in an open and secure area away from occupied buildings to allow complete reaction of aluminum phosphide. Where

DON'T COVER THE CONTAINER! Covering the container will confine the hydrogen-phosphide gas that is generated, and the resulting high concentrations may explode. This wet method of deactivation is preferred when five or more flasks of materials must be deactivated. The resulting slurry may be disposed of at an approved landfill.

An alternative to slurry deactivation is dry deactivation (for small quantities not exceeding five flasks). Pellets or tablets can be spread out in an open, secure area away from occupied buildings and deactivated by atmospheric moisture.

triple-rinsing is used, rinsate may be disposed of in a landfill.

USE COMMON SENSE

It's essential that fumigators understand and follow the technical instructions that promote safe and effective fumigation of stored grain. It's just as important that fumigators remember to use good common sense when planning and carrying out a fumigation. Although it may be impossible to "teach" good common sense by writing instructions in study materials, the following comments are offered as reminders to exercise good judgement and to think ahead.

- Read and understand label directions. Demand information from the manufacturer and distributor. Don't use a fumigant without adequate training and confidence in your ability to do the job properly.
- Supply local medical personnel with fumigant and poison-treatment information before using the fumigant.
- Preplan the entire job. Think through every step, and plan your reactions to possible problems and emergencies.
- Always work in pairs.
- Use, or have available, proper safety equipment. Make sure all equipment fits well and that all applicators are trained in and familiar with the use of necessary safety equipment.
- Don't take shortcuts; follow through with well-planned and thorough application practices.
- Don't become complacent. Each job is a new challenge and a new situation in which an emergency may require rapid and proper reaction.

DOMESTIC (Commensal) RODENTS

Domestic (commensal) rodents have coexisted with man in his habitats for centuries. They have eaten man's food and wastes and have shared his living quarters. They have become man's chief vertebrate pest because of their great reproductive capacity and their ability to adapt to new environments. Aside from eating man's food, the domestic rodents are involved in contamination of foods by defecation, destruction of building structures by their gnawing habits, and transmitting diseases and harboring parasites of medical and veterinary importance. Some of the diseases that rodents are directly or indirectly involved in conveying to man are plague, murine typhus, infectious jaundice, ratbite fever, food poisoning, poliomyelitis and rabies.

The three main domestic rodents found in Utah are the Norway rat, the house mouse, and the deer mouse. The roof rat is common in other regions, and a brief discussion of it is also included.

NORWAY RAT

The Norway rat is the common domestic rat in Utah. It has coarse hair and close-set ears, and its muzzle is blunt. Its tail is dark on the top and light on the underneath side. The tail is shorter than the combined length of the head and body. The fur is gray-brown on the back and gray-white on the belly. The adults weigh between 12 and 20 ounces and are 7.5 to ten inches in head-and-body length. The tail length is between six and 8.5 inches. The feces are capsule-shaped and about three-fourths inch long.

Norway rats can be found in warehouses, farm buildings, houses, sewers, rubbish, dumps, woodpiles, and building foundations. They are good climbers. On their hind legs, they can reach a height of 18 inches, and they can jump 24 inches vertically. Rats are good swimmers and stay afloat for 72 hours. The Norway rat has relatively poor vision but keen senses of smell, touch, taste and hearing. The sense of touch is served by long whiskers on the snout. (Domestic rats and mice run close beside a wall where these sensory hairs touch to give the animals information about their surroundings.) The home range is often 100 to 200 feet.

Norway rats and other domestic rodents are mainly nocturnal, but they may go about in undisturbed places during the day. They feed on virtually anything edible. Norway rats are unable to vomit. They must drink water to survive.

ROOF RAT

The roof rat is smaller than the Norway rat. Serious pest populations of roof rats are confined along the southern and western coastal areas of the country. Roof rats have large, membranous ears and a sharply-pointed muzzle. The unicolored tail is usually longer than the head and body combined. The adult head-and-body length is between six and 8-1/2 inches, while the tail ranges between seven and ten inches in length.

The adult weighs from eight to ten ounces. The feces differ from those of the Norway rat in that they are about one-half-inch long and are spindle-shaped.

HOUSE MOUSE

The most common household rodent is the house mouse. This mouse resembles the roof rat in that they both have large ears, pointed muzzles, and slender bodies. However, the house mouse is a great deal smaller. The tail is unicolored, has little hair, and is about as long as the head and body combined. The adult mouse can be distinguished from a young roof rat because the head and feet of the mouse are distinctly smaller in proportion to its body size. Adults weight one-half to three-fourths ounce and are 2-1/2 to 3-1/2 inches long in head-and-body length. The tail measures between three and four inches long. The feces are one-eighth to one-fourth inch long and are rod- shaped.
Although house mice are commonly found living in man-made structures, they are also well adapted to living outdoors. They are common inhabitants of grassy fields and cultivated grain crops. These wild populations often move into buildings when weather becomes severe. The house mouse has poor vision and is colorblind. However, the mice have keen senses of smell, taste, hearing and touch.

Mice use their sense of smell to locate food items and recognize other individual mice. More research is needed on the value of repellent and attractant odors, but taste appears able to override most odor effects. House mice have acute hearing. They readily respond to unusual noises as a means of detecting and escaping danger. However, house mice become accustomed to repetitive, ordinary noises, and, as a result, their activities may be more visible than those of rats.

An important sensory factor is touch. Mice use their long, sensitive whiskers on the nose and above the eyes as tactile sensors. The whiskers and guard hairs enable the mice to travel easily in the dark, along runways close to walls. House mice feed on a wide range of foods, although cereals seem preferred over other items. In particular, the germ of grains is favored by most mice. As supplemental diet items, mice often show preference for foods high in fat and protein, such as lard, butter, nuts, and dried meats.
House mice are sporadic feeders, nibbling bits of food in various locations throughout their range.

Small amounts of food often are taken many times at many places. Mice have two main feeding periods, at dusk and just about dawn. Because of their small size, The deer mouse is the most common host of the Hantavirus, but other small animals may carry the disease. Hantavirus is a viral illness transmitted from saliva, stool or urine of infected animals. Once these waste products dry, the virus can become airborne. Infection usually results when the virus is inhaled. The illness is described as a severe respiratory illness that results in death for about 50 percent of its victims.

Use extreme caution or avoid activities associated with exposure to mouse or small-animal droppings.

DETERMINING RODENT PRESENCE

Rodents provide numerous signs that indicate their presence. These include:

Sounds -- Gnawing, clawing, climbing in the attic, and various squeaks are commonly associated with house mice and rats.
Droppings -- Droppings are left along runways, near shelters, and in other places that rodents frequent. Droppings of mice are smaller and usually harder than those produced by rats. However, insects and other rodents may produce similar droppings.
Urine -- House mice urinate at intervals along well-used runways. Occasionally, they also will form small mounds (urinating pillars) that consist of a combination of grease, urine and dirt. Wet and dry rodent urine stains will fluoresce under ultraviolet (black) light.
Smudge marks -- Dirt and oil from the fur of the rodent may sometimes leave smudge marks on pipes and

mice must feed several times during a 24-hour period. This means that they will be active day and night. Their range is normally ten to 30 feed from the nest. Their nest is lined with soft materials such as cotton or paper and may be built in walls, cabinets, upholstered furniture, or other convenient spaces. Their urine and droppings mark the trail for others. Mice are poor swimmers.

DEER MOUSE

The native deer (white-footed) mouse occasionally invades buildings adjacent to fields or woodlands. Deer mice are about the same size or slightly larger than house mice. Deer mice can be differentiated from house mice by a distinct, bicolored tail (upper portion brown-gray, lower
half white). Deer mice characteristically have small ears and eyes and a relatively short tail.

beams. Smudge marks left by rats are much more conspicuous than those produced by house mice.
Gnawing marks -- Wood chips about the consistency of coarse sawdust are produced by the gnawing of house mice. Most gnawing occurs around baseboards, doors, windows and frames, and kitchen cabinets. Recent gnawings on wood are light in color, darkening with age. The size of the tooth marks left in the wood can help distinguish the presence of rats or mice.
Pet excitement -- Pawing and excitement of cats and dogs can indicate the presence of rodents. Pets respond most commonly when the premise has been invaded only recently.
Odors -- Rodents produce characteristic odors. With experience, the musky scent of house mice can be differentiated from those produced by rats.

ESTIMATING RODENT POPULATIONS

There’s no easy or certain way of estimating rodent numbers. The techniques used most often are "reading" of signs, actual observations of rodent activity, or census of feeding. However, after considerable experience, a rat-control worker can usually detect the presence of rodents, even in fairly low numbers.

Rat sign can provide a very rough estimate of density. After a thorough search for rat sign in attics, basements, around foundations, and behind stored materials, use the following criteria:

Rat-free or low infestation -- No sign. Probably invaded by rats only recently, or the habitat won't support many.

Medium population -- Old droppings and gnawing common, one or more rats seen by flashlight at night. No rats reported observed during the day. There are probably ten rats or more in each general areas where one rat is seen at night.

High population -- Fresh droppings, tracks, and gnawing present; three or more rats are seen at night. Rats are seen in daylight.

PHYSICAL CAPABILITIES OF COMMON COMMENSAL RODENTS

The Norway rat can:

- Swim as far as one-half mile in open water, dive through water plumbing, and travel in sewer lines.
- Gnaw through a wide variety of materials, including lead sheeting, sun-dried adobe brick, cinder block, and aluminum sheeting.

The house mouse can:
- Gain entrance through openings slightly larger than one-fourth inch in diameter.
- Jump 12 inches from a flat surface.
- Jump against a wall or vertical surface and use it as a springboard to gain additional height.
- Jump from a height of eight feet without injury.
- Run up almost any rough vertical surface, including brick walls, wood, weathered sheet metal, wire mesh and cables.
- Run horizontally along insulated electrical wires and small ropes.
- Travel upside down along one-fourth-inch hardware mesh.
- Swim capably, if it needs to. House mice don't tend to dive below the surface, as do rats.
- Gain entrance through any opening that is larger than one-half inch square.
- Climb both horizontal and vertical wires.
- Climb the inside of vertical pipes that are 1-1/2 to four inches in diameter.
- Climb the outside of vertical pipes and conduits up to three inches in diameter.
- Crawl horizontally on any type of pipe or conduit.
- Jump vertically as much as 24 inches.
- Jump horizontally 48 inches on a flat surface.
- Jump horizontally at least eight feet from an elevation of 15 feet.
- Drop 50 feet without being seriously injured.
- Burrow vertically in earth to a depth of four feet.
- Climb brick or other rough exterior walls that offer footholds.
- Climb vines, shrubs and trees or travel along telephone or power lines.

RODENT CONTROL

Rodent control may involve the use of several control measures, including cleanup or sanitation, rodent-proofing, use of toxicants and traps, and other methods. Sanitation is important in a successful rodent-control program. The elimination of shelter, food and water can mean the difference between success or failure in controlling rodents. Good housekeeping practices are important. A program of routine cleaning should be set up and followed. Such areas as obscure corners, shelves, under and in cabinets, work tables, lockers and equipment shouldn't be overlooked. Eliminate rubbish piles. Keep refuse in rat-proof containers until it's removed.

Rodents need a safe place to hide. Inspect the building to identify potential harborages. Rodent-proofing within the building in such places as stairways, cabinets, lockers, machinery, double walls, false ceilings and floors, boxed-in pipes and conduits may be needed. These sites not only serve as shelter but also as nesting and breeding sites.

Proper storage practices are necessary to eliminate harborages. Rodent damage to stored materials can be greatly reduced if good storage practices are followed. In commercial storage areas, products should be on pallets at least eight inches off the floor, 18 inches from adjacent walls, not stacked more than six feet wide, and separated by an aisle at least 12 inches wide.

These practices reduce harborage areas, permit inspection and cleaning, and allow for installation of appropriate control measures. Outside, keep grass, weeds, and other vegetation near buildings closely cut. Eliminate lumber, rock piles, rubbish, and old equipment. Fill in old rat holes and burrows with earth. Store items at least 18 inches off the ground and away from walls or fences. Rodent-proofing involves the removal of all possible entrances into buildings. Exclusion practices are often hard because of the habits and behaviors of rodents. Rats and mice are quite agile and capable of entering through extremely small openings. Openings of one-fourth to one-half inch are big enough for mice and rats respectively. Rats can enter building through drains and toilets. Both rats and mice are capable of gnawing through wood, fiberboard, and many plastics. Exclusion or rodent-proofing is hard, but it can be achieved through modification of existing buildings or in the design of new buildings. In pest-control work, it isn't always possible to do extensive rodent-proofing; however, you should see that some is done so your control program will have a chance to succeed.

The bottoms and edges of doors that don't fit closely can be built up with wood so there is no opening greater than a half-inch, and covered with metal cuff. Openings around pipes, windows, holes in walls, foundation vents, and ventilating fans can be covered with screening or hardware cloth (19 gauge) or sheet metal (20 gauge or heavier). Holes in masonry walls should be cemented shut. It's impossible to list every situation or place that needs rodent-proofing. You'll need to rely on your ability to observe every possible entry to the building.

Rodent competition

There is some competition between the various commensal rodents. Partial separation between rats and mice has been reported in grain stacks, with house mice feeding in the lower areas and rats in upper portions. The smaller size of house mice gives them access to places that are not available to rats. Upon direct confrontation, rats will kill mice.

Pest-control operators have observed that when a building is freed of rats, house mice often move in or increase in numbers. This may be due to reduced competition, but it often results from mice being able to enter and colonize areas that have been made rat-proof, since potential mouse
infestations may follow rat-control activities. This should be anticipated by the pest-control operator. House mice are highly competitive against deer mice. Where house mice are present, deer mice will rarely be found.

Rodenticides

Both single-dose and multiple-dose anticoagulant rodenticides are available for rat and mouse control. Although finished baits are available in a wide variety of types, some persons trained in rodent control prefer to mix their own baits with rodenticide concentrates.

When possible, finished baits should be used because they don't require that the applicator handle the concentrate, a more hazardous material.

Pre-baiting

Mice and rats are cautious feeders and may reject new foods or eat only small amounts for the first several days. Acceptance of a toxic bait can be increased by conditioning rats to feed on a non-toxic version of the same food or "pre-bait."

Pre-baiting is highly recommended before using a single-dose toxicant. After the untreated baits are being eaten regularly, begin the use of treated baits. Pre-baiting may be necessary for two to five days to achieve maximum benefits. The amount of pre-bait eaten helps to determine the amount of toxic bait needed. All uneaten pre-bait should be removed when the toxic bait is applied.

If acceptance of pre-bait is poor, toxic bait should not be applied. Poor acceptance may be corrected by changing bait material or its placement.

Single-dose rodenticides

Single-dose rodenticides will give a quick knockdown of rat and mouse populations, and they may be preferred where rats and mice are abundant or where it's hard to get rats and mice to accept a bait for several days in succession because of competing food items. When rats or mice consume a sublethal amount of an acute toxicant such as zinc phosphide, red squill or ANTU, "bait shyness" or "poison shyness" may result. Because of this bait-rejection problem, these three single-dose poisons shouldn't be used more than twice a year at a given location, and preferably only once. Strychnine acceptance in baits is very poor, usually giving inadequate control.

Multiple-dose rodenticides

Multiple-dose anti-coagulant rodenticides are generally considered much safer than single-dose rodenticides, although red squill has a good safety record. Bait shyness doesn't occur when properly formulated anti-coagulant baits are used. With the exception of brodiafcoum, anti-coagulants cause death to mice and rats after they are fed on for several days. These latter rodenticides are capable of causing death after a single feeding, however, death doesn't occur for several days.

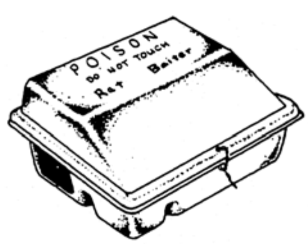
When anti-coagulant rodenticides are used, fresh bait must be made available to rats and mice continuously for at least two weeks or until all signs of feeding cease.

Bait selection and placement

Anti-coagulant baits are available in several types. Grain baits in a meal or pelleted form are often available packaged in small plastic, cellophane or paper packets. These "place packets" keep baits fresh and make it easy to place baits into burrows, walls or other locations. Rats and mice will readily gnaw into these bags to get at an acceptable bait.

Anti-coagulant baits that have been formulated into paraffin blocks are available from various

Use of bait stations (boxes) protects rodenticides from weather and provides a safeguard to people, pets, and other animals. Bait stations should have at least two openings about 2-1/2 inches in diameter for rats or one inch in diameter for mice. The bait boxes should be large enough to accommodate several rats or mice at one time, depending on the problem-rodent species. Bait boxes should be placed next to walls, with openings close to the wall, or in places where rats or mice are active. Rats usually feed in one place, so relatively few bait stations may be needed if correctly located. On the other hand, mice feed in many places and won't travel

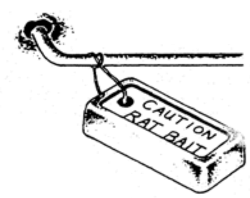


great distances.

Many bait stations may be needed for mice. Space them no farther than ten feet apart, and preferably closer. Baits or traps need to be placed where mice are living, such as in wall spaces, on pallets of feed, etc. All bait boxes should be clearly labeled "Rat Bait" or "Mouse Bait," as the case may be.

Write down the locations of all bait stations so that inspections can be made rapidly and baits replaced quickly. At each inspection, smooth the surface of the granular baits so that new signs of feeding will show

manufacturers. These blocks are especially useful in sewers or where moisture may cause loose-grain baits to spoil. Acceptance by rats and mice of paraffin-block baits is usually less than acceptance of loose-grain baits. Sodium salts of anti-coagulants are available to be mixed with water. Since rats require water daily, they can be drawn to water stations in some situations. Although mice require little water to survive, water baits used where moisture is scarce can be an effective



supplement to other control measures.

readily. Examine paraffin bait blocks for signs of rodent-gnawing. Replace moldy, wet, caked or insect-infected baits with fresh ones. Maintain records of activity indicating where baits have been disturbed, dead rodents found, and droppings or tracks observed.

Tracking powders

Tracking powders are toxicants in dust formulations that are placed in the rodent's runway, near their harborages, or in their burrows, where they travel through them. The dust is picked up on the feet, and the rodent swallows the tracking powder when it grooms itself. Tracking powders can be useful when other toxicants, such as baits, are not accepted or when there is a surplus of food.

Don't use tracking powders where the rodent or air currents may carry the powder onto human-food surfaces or food-preparation areas. Use bait stations in these situations. Tracking powders can be applied with a shaker on runways, with a dust pump in burrows, or with a duster on wall voids.

Fumigants

Fumigants are often used to control rodents in their burrows in outdoor situations, and sometimes in rail cars and on ships. The operation can be expensive, if the structure has to be tarped. Fumigants are highly toxic to people and animals, and they must not be used in any situation that might expose the occupants of a building to the vapors. Because of the hazards involved with fumigants, only persons licensed for fumigation pest control should use fumigants in any situation involving buildings or other structural enclosures.

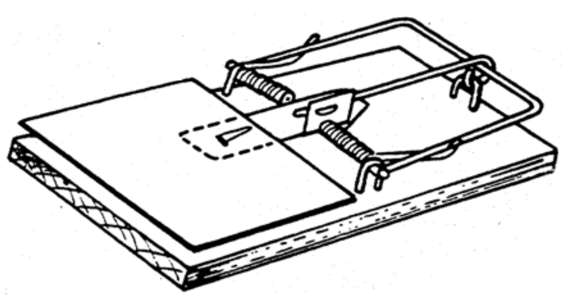
Resistance to rodenticides

When genetically immune individual rodents survive a rodenticide treatment, they pass the resistance ability to their offspring. Since many rodent populations have a rather high number of individuals that are less susceptible to most rodenticides, the development of resistance has been a serious problem.

The development of resistant rodent populations is related to the amount of selective pressure that is applied to them. As a result, more thorough rodent control programs can be expected to develop the greatest problems with rodenticide resistance. Pest-control operators should constantly be aware of resistance as a source of control failures. Where rodent-control efforts are regularly applied, periodic shifting of different baits (active ingredients) is advisable.

Rodenticide safety precautions

Certain general safety precautions should be followed besides those appearing on the labels of products. Follow the label directions on all rodenticide products carefully. Pick up all dead rats and mice after a



poisoning program. Handle the carcasses with tongs or rubber gloves. Dispose of large numbers of rats and mice by incineration or burial. With only a few, especially mice, place them in a plastic bag, close it tightly, and dispose of it with other refuse.

Remove and destroy all uneaten bait at the end of the poisoning period. Never leave single-dose baits exposed for more than three or four days.

Consider all rodenticides dangerous, and place baits where only rodents can get them.

There are no known rodenticides that don't present some degree of hazard to animals other than rodents. Persons who formulate rodent baits for their own use should use extreme care in handling the materials. Rubber gloves, an apron, and a proper respirator should be worn. Wash thoroughly after preparing baits, using soap, a brush, and plenty of water. Clean all bait-mixing utensils thoroughly, and use them only for bait preparation. Whenever possible, it's best to buy prepared or ready-to-use baits, thus reducing risks involved in handling concentrated toxicants. Label all bait containers and stations clearly with appropriate warnings. Store unused bait and concentrates in a locked cabinet, out of reach of children or animals.

Traps

Trapping can be an effective method of controlling rats and mice, but it requires more skill and labor than most other methods. Trapping is recommended where poisons seem inadvisable, and it's the preferred method to try first in homes, garages, and other small structures where there may be only a few rats present. Trapping has several advantages:

1. It doesn't rely on inherently hazardous rodenticides.
2. It permits the user to view his success.
3. It allows for disposal of rodent carcasses, thereby eliminating odor problems, which may occur when poisoning is done within buildings.

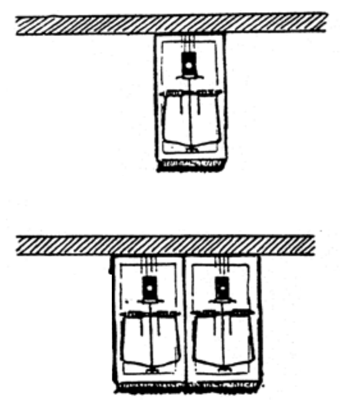
Snap-traps are generally more effective than cage traps. Simple, inexpensive, wood-based snap-traps are readily available. For rats, bait the traps with peanut butter, chocolate candy, dried fruit, or a small piece of bacon tied securely to the trigger. For mice, use bacon, nuts, hard sugar-candy, gumdrops, or peanut butter. Leaving traps unset until the bait has been taken at least once reduces the chance of rats or mice becoming trap-shy.
Place traps close to walls, behind objects in dark corners, and in other places where rat and mouse activity has been seen. Place the traps so that the rats and mice following their natural course of travel (usually close to a wall) will pass directly over the trigger. Traps can be set on ledges or on top of pallets of stored materials, if

mice are active in such locations. To determine whether rodents are present in a particular area, lightly dust the area with talcum powder. If rodents are present, their tracks will be visible in the dust. Cover all areas of escape with traps. Record the number of traps placed on each job. In food plants, map the location of each trap. This enables someone else to follow up an account, if necessary.

Use enough traps to make the campaign short and decisive. Since mice seldom venture far from their shelter and food supply, traps should be placed from three to ten feet apart in areas where mouse activity is noted. Place them within 20 feet of each other for rats.

Glueboards

Glueboards are an alternative to traps. Glueboards catch and hold mice and rats trying to cross them in much the same way flypaper catches flies. Like traps, glueboards need to be placed along walls where mice and rats travel. Don’t use them where children, pets, or desirable wildlife can contact them. Glueboards lose their effectiveness in dusty areas, and temperature extremes may affect the tackiness of the adhesive.



Although rats and mice are easily frightened by strange and unfamiliar noises, they quickly become accustomed to regularly repeated sounds and are often found living in grain mills and factories. Ultrasonic sounds, those above the range of human hearing, have very limited use in rodent control because they are directional and don't penetrate behind objects. Also, they lose their intensity with distance. There is little evidence that sound of any type will drive established mice or rats from buildings. Several types of electromagnetic devices have also been marketed recently with claims of repelling rodents effectively or causing them to behave abnormally.

Scientific tests of many such devices have shown that they failed to control rodents as claimed by their advertising.

THREATENED AND ENDANGERED SPECIES

The Endangered Species Act (ESA) was passed by Congress to protect certain plants and wildlife that are in danger of becoming extinct. This act requires EPA to ensure that these species are protected from pesticides.

Formulation of the Utah Threatened and Endangered Species/Pesticides Plan is a cooperative effort between federal, state, and private agencies and producers/user groups, and is a basis for continuing future efforts to protect threatened and endangered species from pesticides whenever possible. Furthermore, this plan provides agencies direction for management policies, regulations, enforcement and implementation of threatened and endangered species/pesticide strategies.

EPA has therefore launched a major new initiative known as the Endangered Species Labeling Project. The aim is to remove or reduce the threat to threatened and endangered species from pesticide poisoning. EPA has the responsibility to protect wildlife and the environment against hazards posed by pesticides.The ESA is administered by the U.S. Fish and Wildlife Service (FWS) in the U.S. Department of Interior. The Fish and Wildlife Service will determine jeopardy to threatened and endangered species and report to EPA. EPA and FWS will work cooperatively to ensure that there is consistency in their responses to pesticide users and to provide necessary information. The Utah Department of Agriculture is acting under the direction and authority of EPA to carry out the ESA as it relates to the use of pesticides in Utah.

Maps will show the boundaries of all threatened and endangered species habitats in affected counties. The maps identify exactly where, in listed counties, use of active ingredients in certain pesticides is limited or prohibited. Product labels will be updated as necessary. The updated labels will reflect any additions or deletions to the project. Because EPA's approach to the protection of threatened and endangered species was in the proposal phase at the time this guide was published, any and all of the above information on threatened and endangered species is subject to change and may not be valid.

WORKER PROTECTION STANDARDS

This final rule, which was proposed in 1988 and that substantially revised standards first established in 1974, affects 3.9 million people whose jobs involve exposure to agricultural pesticides used on plants; people employed on the nation's farms; and in forests, nurseries and greenhouses. The standard reduces pesticide risks to agricultural workers and pesticide handlers. The standard is enforceable on all pesticides with the Worker Protection Standard labeling. The provisions became fully enforceable in January 1995.

Agricultural workers in Utah now have a far greater opportunity to protect themselves, their families and others. These workers will know, often for the first time, when they are working in the presence of toxic pesticides, understand the nature of the risks these chemicals present, and get basic safety instructions.

Among the provisions of the rule are requirements that employers provide handlers and workers with ample water, soap and towels for washing and decontamination and that emergency transportation be made available in the event of a pesticide poisoning or injury. The rule also establishes restricted-entry intervals -- specific time periods when worker entry is restricted following pesticide application -- and requires personal protection equipment (PPE) for all pesticides used on farms or in forests, greenhouses and nurseries. Some pesticide products already carry restricted re-entry intervals and personal protection equipment requirements; this rule raised the level of protection and requirements for all products.

Other major provisions require that employers inform workers and handlers about pesticide hazards through safety training, which handlers have easy access to pesticide-label safety information, and that a listing of pesticide treatments is centrally located at the agricultural facility. Finally, handlers are prohibited from applying a pesticide in a way that could expose workers or other people.

GROUNDWATER CONTAMINATION BY PESTICIDES

Utah has implemented a comprehensive and coordinated approach to protect groundwater from pesticide contamination.

Formulation of the Groundwater/Pesticide State Management Plan is a cooperative effort between federal, state, and private agencies and producers/user groups; it provides a basis for continuing future efforts to protect groundwater from contamination whenever possible. Furthermore, this plan provides agencies with direction for management policies, regulations, enforcement and implementation of groundwater strategies.

While it is recognized that the responsible and wise use of pesticides can have a positive economic impact, yield a higher quality of crops, enhance outdoor activities, and give relief from annoying pests, the Utah Department of Agriculture is authorized by the U.S. Environmental Protection Agency (EPA) to enforce the protection of groundwater from pesticides. Product labels will be updated as necessary.

The Utah Department of Agriculture, in concert with cooperating agencies and entities, admonishes strict compliance with all pesticide labels, handling procedures and usage to protect groundwater in the state.

Groundwater can be affected by what we do to our land. Prevention of groundwater contamination is important, because once the water is polluted, it's very hard and costly to clean up. In some instances, it's impossible, especially if it is deep underground. City and urban areas especially contribute to pollution because water runoff that contains pesticides runs into drainage tunnels, then into a river or an underground stream that drains into the river. For more complete information about what groundwater is and where it comes from, read the study manual "Applying Pesticides Correctly." Shallow aquifers or water tables are more susceptible to contamination than deeper aquifers. Sandy soils allow more pollution than clay or organic soils, because clays and organic matter absorb many of the contaminants.

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), as amended, establishes a policy for determining the acceptability of a pesticide use or the continuation of that use, according to a risk/benefit assessment. As long as benefits outweigh adverse effects, a pesticide can be registered by the EPA. Although the intent of a pesticide application is to apply the pesticide to the target or pest, part of the pesticide will fall on the area around the target or pest. Rain or irrigation water then can pick up the part that is not degraded or broken down and carry it to the groundwater via leaching.

The major factors that influence the amount of contamination that can get into water are the chemicals' persistence in soil, retention time or time it remains in the soil, the soil type, the time and frequency of the application(s), soil moisture, placement of the pesticide, and the ability of the chemical to persist once in the aquatic environment. Each of these factors will influence the amount of pesticide that can leave the root zone or soil surface and percolate to groundwater.

Although some pesticides may have a high absorption quality, when they are applied to sandy soil, they will still migrate to the water table because there are no fine clay particles or organic matter to hold them. The management and use of pesticides is up to the individual applicator and/or land owner as to whether safe practices are used. Water is one of our most valuable resources; we must keep it as pure as possible.

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CALIBRATION INFORMATION

<u>Conversion:</u>

Units

One acre = 43,560 square feet	Example: ½ acre = 21,780 square feet
One mile = 5,280 feet	Example: ¼ mile = 1320 feet
One gallon = 128 fluid ounces	Example: ½ gallon = 64 fluid ounces
One quart = 2 pints = 4 cups = 32 fluid ounces	Example: 2 quarts = 64 fluid ounces
One pint = 2 cups = 16 fluid ounces	Example: ½ pint = 1 cup = 8 fluid ounces
One tablespoon = 3 teaspoons = 0.5 fluid ounces	Example: 2 tablespoons = 1 fluid ounce
One pound = 16 ounces	Example: ¼ pound = 4 ounces
One gallon = 231 cubic inches	Example: 2 gallons = 462 cubic inches

Weight

1 ounce = 28.35 grams
16 ounces = 1 pound = 453.59 grams
1 gallon water = 8.34 pounds = 3.785 liters = 3.78 kilograms

Liquid Measure

1 fluid ounce = 2 tablespoons = 29.573 milliliters
16 fluid ounces = 1 pint = 0.473 liters
2 pints = 1 quart = 0.946 liters
8 pints = 4 quarts = 1 gallon = 3.785 liters

Length

1 foot = 30.48 centimeters
3 feet = 1 yard = 0.9144 meters
16 1/2 feet = 1 rod = 5.029 meters
5280 feet = 320 rods = 1 mile = 1.6 kilometers

Area

1 square foot = 929.03 square centimeters
9 square feet = 1 square yard = 0.836 square meters
43560 square feet = 160 square rods = 1 acre = 0.405 hectares

Speed

1.466 feet per second = 88 feet per minute = 1 mph = 1.6 kilometers per hour (kph)

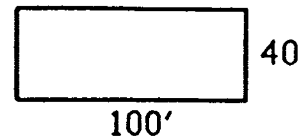
Volume

27 cubic feet = 1 cubic yard = 0.765 cubic meters
1 cubic foot = 7.5 gallons = 28.317 cubic decimeters

Area and Volume Calculations:

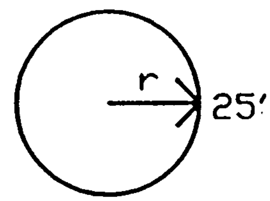
Area of Rectangular or Square Shapes

The area of a rectangle is found by multiplying the length (L) times the width (W).
(Length) x (Width) = Area
Example: (100 feet) x (40 feet) = 4000 square feet



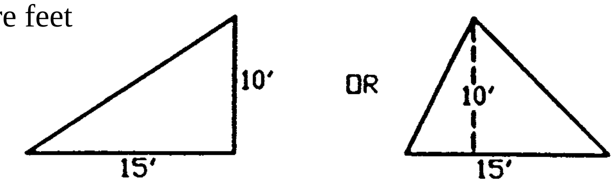
Area of Circles

The area of a circle is the radius (radius = one-half the diameter), times the radius, times 3.14.
(radius) x (radius) x (3.14) = Area
Example: (25 feet) x (25 feet) x (3.14) = 1962.5 square feet



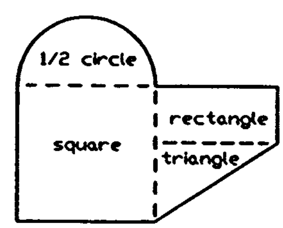
Area of Triangular Shapes

To find the area of a triangle, multiply ½ times the width of the triangle's base, times the height of the triangle.
(½) x (base width) x (height) = Area
Example: (½) x (15 feet) x (10 feet) = 75 square feet

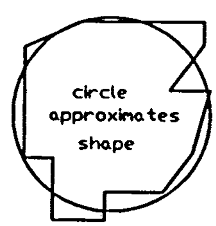


Area of Irregular Shapes

Irregularly shaped sites can often be reduced to a combination of rectangles, circles, and triangles. Calculate the area of each shape and add the values together to obtain the total area.
Example: Calculate the area of the rectangle, triangle, square, and one-half of a circle.

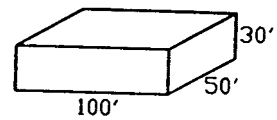


Another method is to convert the site into a circle. From a center point, measure the distance to the edge of the area in 10 or more increments. Average these measurements to find the radius, then calculate the area using the formula for a circle.
Example: Approximate the area by calculating the area of a similarly sized circle.



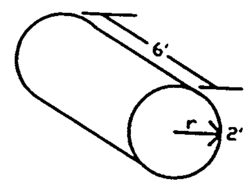
Volume of Cube and Box Shapes
The volume of a cube or box is found by multiplying the length, times the width, times the height.
(Length) x (Width) x (Height) = Volume

Example: (100 feet) x (50 feet) x (30 feet) = 150,000 cubic feet



Volume of Cylindrical Shapes
The volume of a cylinder is found by calculating the area of the round end (see formula for circle) and multiplying this area times the length or height.

Example: (radius) x (radius) x (3.14) = Area of Circle
(Area of Circle) x (Length) = Volume of Cylinder
(2 feet) x (2 feet) x (3.14) x (6 feet) = 75.36 cubic feet



Sprayer Calibration Formulas:

To Calculate Travel Speed in Miles Per Hour
The travel speed of a sprayer is determined by measuring the time (seconds) required to travel a know distance (such as 200 feet). Insert the values in the following formula to determine the miles per hour.

$$\frac{\text{Distance in Feet x 60}}{\text{Time in Seconds x 88}} = \text{Miles Per Hour}$$

Example: $$\frac{\text{(200 feet) x (60)}}{\text{(30 seconds) x (88)}} = \frac{12{,}000}{2640} = 4.55 \text{ mph}$$

To Calculate the Gallons Per Minute Applied During Broadcast Spraying
The application rate in gallons per minute (GPM) for each nozzle is calculated by multiplying the gallons per acre (GPA), times the miles per hour (MPH), times the nozzle spacing in inches (W); then dividing the answer by 5940. For small adjustments in GPM sprayed, operating pressure is changed. For large adjustments in GPM sprayed, travel speed (miles per hour) is changed or nozzle size is changed.

$$\frac{\text{GPA x MPH x W}}{5940} = \text{GPM}$$

Example: $$\frac{\text{(12 GPA) x (4.5 MPH) x (24”)}}{5940} = \frac{1296}{5940} = 0.22 \text{ GPM}$$

To Calculate the Gallons Per Minute Applied During Band Spraying
Broadcast spraying applies chemicals to the entire area. Band spraying reduces the amount of area and chemicals sprayed per acre. To use the above formulas for band sprayer applications, use the band width (measured in inches) rather than nozzle spacing for the “W” value.

Pesticide Mixing:

Terminology
The ***active ingredients*** of a pesticide are the chemicals in a formulation that control the target pests. The ***formulation*** is the pesticide product as sold, usually a mixture of concentrated active ingredients and an inert material. Restricted use pesticides are purchased in formulations requiring ***dilution prior to application***. Formulations are diluted with inert substances such as water. The ***percentage of active ingredients*** in a pesticide formulation directly affects dilution and application rates. Given two pesticides, A = 50% active ingredients, B = 100% active ingredients; twice as much pesticide A formulation is required to equal pesticide B formulation.

To Determine the Total Amount of Pesticide Formulation Required Per Tank
To calculate the total amount of pesticide formulation needed per spray tank, multiply the recommended dilution, ounces/pints/cups/teaspoons/tablespoons/etc. of pesticide per gallon of liquid, times the total number of gallons to be mixed in the sprayer. A full or partial tank of pesticide spray may be mixed.
(Dilution Per Gallon) x (Number of Gallons Mixed) = Required Amount of Pesticide Formulation Example: (3 ounces per gallon) x (75 gallons) = 225 ounces

Note: 1 gallon = 128 ounces; through unit conversion 225 ounces = 1.76 gallons

To Calculate the Amount of Pesticide Formulation Sprayed Per Acre
The calculate the total amount of pesticide formulation sprayed per acre is determined by multiplying the quantity of formulation (ounces/pounds/pints/cups/teaspoons/tablespoons/etc.) mixed per gallon of water, times the number of gallons sprayed per acre.
(Quantity of Formulation Per Gallon) x (Gallons Sprayed Per Acre) = Formulation Sprayed Per Acre
Example: (1/2 pound per gallon) x (12 gallons per acre) = 6 pounds per acre

To Calculate the Amount of Active Ingredients Sprayed Per Acre
To calculate the total amount of active ingredients (AI) applied per acre, multiply the amount (pounds, gallons, ounces, etc) of pesticide formulation required per acre, times the percentage of active ingredients in the formulation (100%, 75%, 50%, 25%, etc.), and divide the value by 100.

$$\frac{\text{(Amount of Formulation Required Per Acre) x (Percentage of AI)}}{100} = \text{Active Ingredients Per Acre}$$

Example: $$\frac{\text{(4 pounds formulation sprayed per acre) x (75\% AI)}}{100} = \text{3 pounds of AI sprayed per acre}$$

Note: 75 % = 0.75

To Calculate the Gallons of Pesticide Mixture Sprayed Per Acre
The calculate the total amount of pesticide mixture sprayed per acre is determined by dividing the number of gallons sprayed by the number of acres sprayed.

$$\frac{\text{Gallons Sprayed}}{\text{Acres Sprayed}} = \text{Gallons Sprayed Per Acre}$$

Example: $$\frac{\text{200 Gallons Sprayed}}{\text{10 Acres Sprayed}} = \text{20 gallons of pesticide mixture sprayed per acre}$$