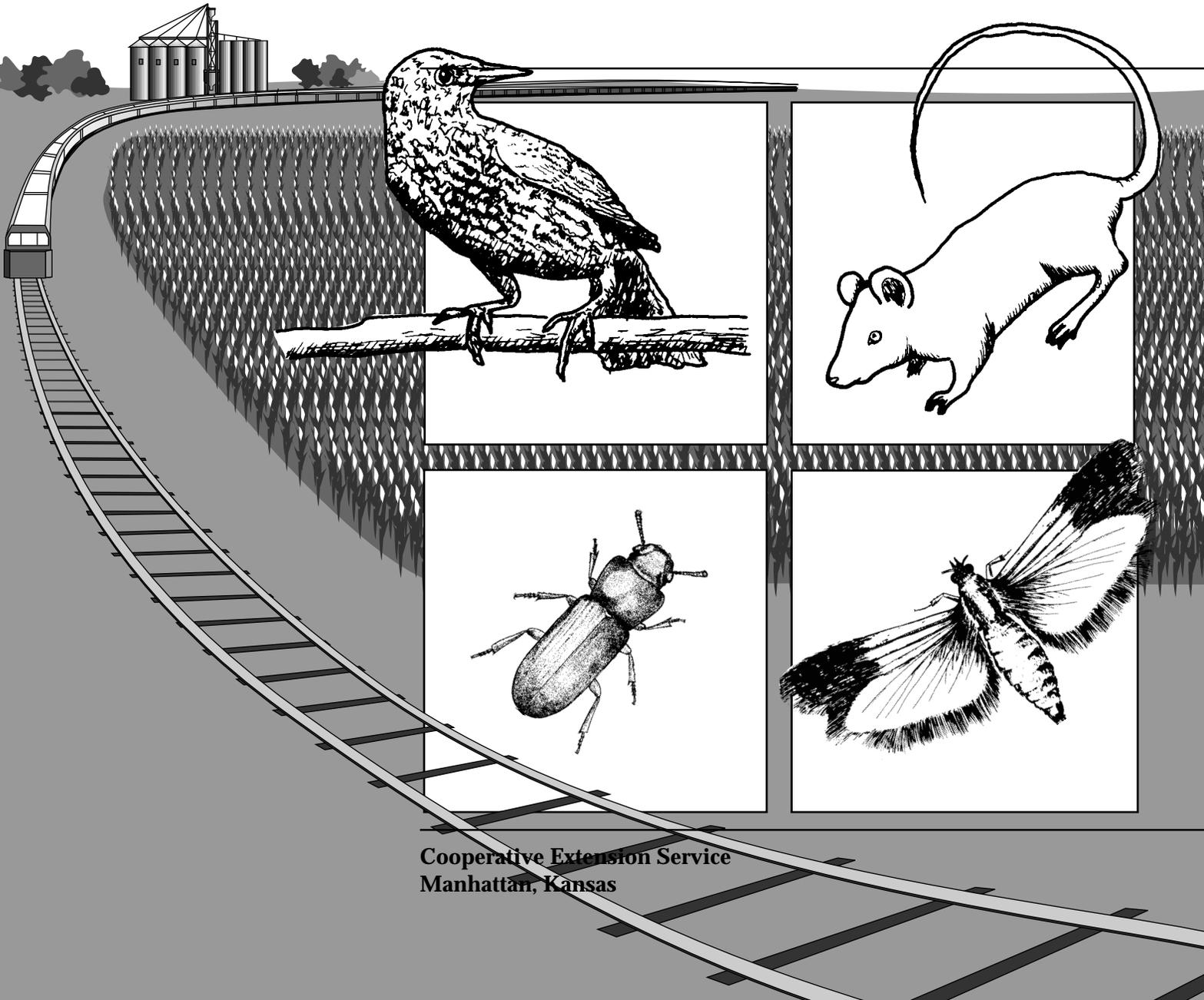


# Stored Products Pest Control



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## Directions for Using this Manual

This is a self-teaching manual. At the end of each major section is a list of study questions to check your understanding of the subject matter. By each question in parenthesis is the page number on which the answer to that question can be found. This will help you in checking your answers.

These study questions are representative of the type which are on the certification examination. By reading this manual and answering the study questions, you should be able to gain sufficient knowledge to pass the Kansas Commercial Pesticide Applicators Certification and/or Recertification examination.

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The control of pests in commodity storage (farm and commercial) and food plants (food manufacturing, processing and warehousing) requires a high degree of professionalism combined with experience and knowledge.

Pest management programs must utilize combinations of techniques that are effective, economical and emphasize prevention of food product contamination. These programs must be directed at immediate pest problems; at preventing future infestation problems; and must respond to routine daily needs, yet be flexible to meet emergency pest control situations. Integrated pest management in stored-product pest control tends to emphasize the non-chemical aspects of pest control with the judicious use of pesticides.

Unsatisfactory control of pests results in contaminated products that can cause health, financial, legal and aesthetic problems. Financial losses can result from (a) presence of live or dead insects in products and containers; (b) presence of odors, webbing and frass in products and containers; (c) loss in faith in the company by the consumer because of these conditions; and (d) direct loss in weight resulting from insect feeding.

Persons applying pesticides (chemical control measures) must be knowledgeable about the chemicals, application technique and pesticide regulations to avoid contamination of foods and/or legal problems resulting from misuse.

A variety of pests may be found in stored commodities and food processing facilities, depending upon geographic location, physical nature of the facility, and the type of food being processed.

Pests contaminate, damage and/or destroy stored raw materials and processed foods and must be controlled to maintain the quality and quantity of products. The presence or evidence of pests may result in actions by federal and state agencies includ-

ing seizure of products, fines and/or imprisonment of responsible parties.

A potential source of pests in food products is the raw material(s) from which the food is made. Not only may pests from this source be difficult to remove from the raw material, but they also may infest the processing plant and equipment, as well as products in the plant, transportation vehicles or warehouse facilities. Contamination from pests in raw materials also may pass through the processing system into finished food products.

## Why Control Stored-Product Pests?

Control of stored-product pests is necessary to prevent contamination/adulteration of human foods. Persons involved in commodity/food storage, handling and/or processing have the responsibility to prevent food adulteration. Failure to do so can result in human illness and/or death, the violation of laws, loss of good will and resulting loss of revenue.

In recent years, regulations such as those of the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA), and the Federal Grain Inspection Service (FGIS) of the U.S. Department of Agriculture (USDA) have been modified to reflect an increased emphasis on reducing the potential for pest adulteration of food products.

The Federal Food Drug and Cosmetic Act defines a food as adulterated "if it contains any filthy, putrid or decomposed substance, or if it is otherwise unfit for food (Sec. 402 (a) (3)), or if it has been prepared, packed, or held under unsanitary conditions whereby it may have been contaminated with filth or whereby it may have been rendered injurious to health (Sec 402 (a) (4))." The filthy, putrid or decomposed material may be a result of insects, rodents, birds, or micro-organisms; otherwise unfit for food may be the result of contamination by physical or chemical contamination, such as glass, metal, pesticides, etc.

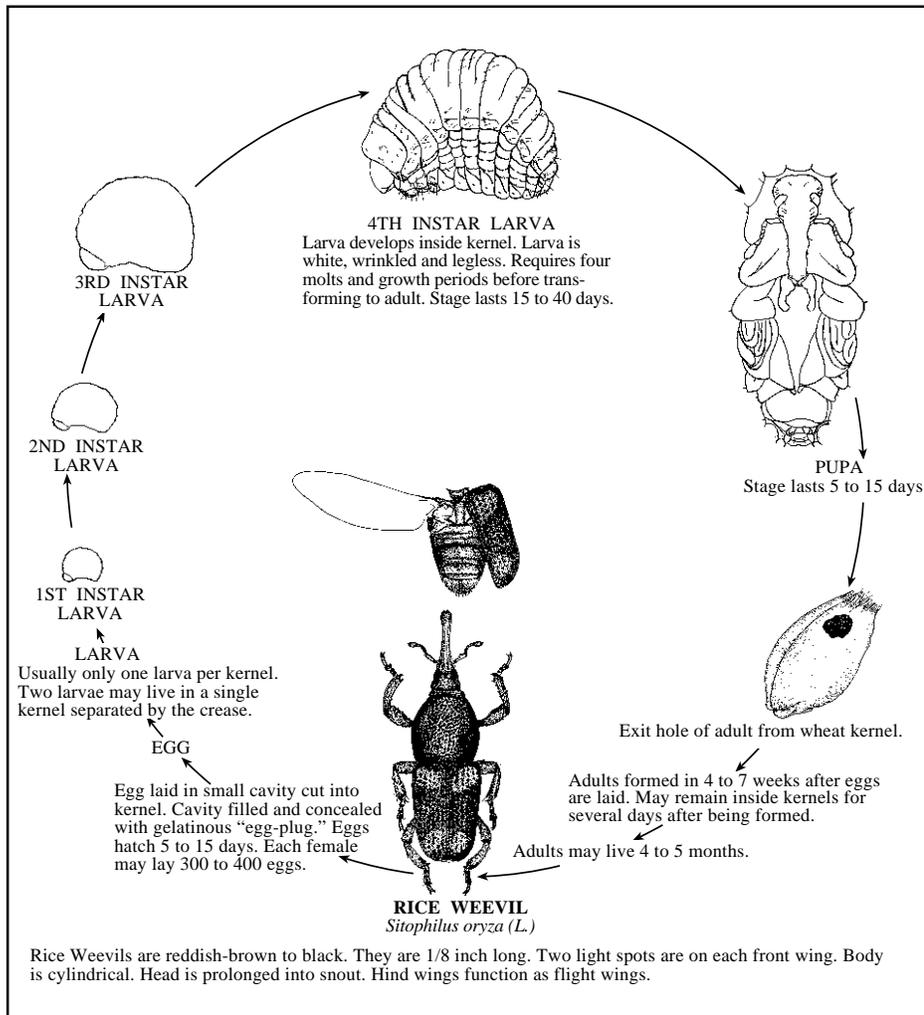
As indicated in this introduction, the control of pests in commodity storage and/or food processing facilities requires a high degree of professionalism combined with experience and knowledge. The following sections of this manual provide valuable information for applying various pest management practices.

# Stored-Product

## Insects

Insects are important pests of cereal grains and stored food. Under optimum conditions many of the species can complete their life cycles in less than 30 to 35 days and lay many eggs. This results in rapid build-up of populations that consume and contaminate various stored products.

Figure 1



Most stored product insects are either beetles or moths. Both have complete metamorphosis, i.e., they have four distinct developmental stages: egg, larva, pupa and adult. The larval stage is "worm-like" or "grub-like" and differs in appearance from the adults. Often, people do not associate the "worms" with the adults which produce them. Growth occurs in the larval stage and after transformation to the adult there is no further growth in size. (Figure 1).

Beetles are characterized by rather hard, shell-like bodies with the forewings modified into covers (elytra) which overlay the back of the insect and protect the thin membranous flight wings (if present) folded underneath. The adults of most of the stored-product beetles live and feed in the same food materials as the larvae. Both have chewing mouthparts. A pictorial key (Figure 2) illustrates the differences in appearance of several species of stored-product beetles.

Moths that infest cereal grains and stored products are similar to "millers" and have scales covering the wings and bodies. The larvae are caterpillars which do not resemble the adults—they have chewing mouthparts while adults may have coiled siphoning tubes suitable only for liquid food. Since liquids are usually not available to them, adults normally do not feed. Therefore, the moths usually only live long enough to mate and lay eggs.

## How Stored-Product Insects Multiply

Stored-product insects are small and often not noticed unless carefully looked for. Fifty rice weevils can be placed on the surface of a penny. Stored-product beetles can survive in any part of a grain mass, in small accumulations of grain or grain products in storage or processing facilities, and in "dead" areas in handling or processing equipment.

Temperature and moisture content of the food source play an important

Table 1. Number of offspring five months after 50 pairs of rice weevils were placed in wheat.

GRAIN MOISTURE	GRAIN TEMPERATURE (°F)			
	60°	70°	80°	90°
9%	0	0	0	0
10%	0	0	326	413
11%	40	87	885	984
12%	58	4,827	9,661	2,223
13%	514	8,692	10,267	3,230
14%	951	10,745	13,551	3,934

# Stored-Product Insects

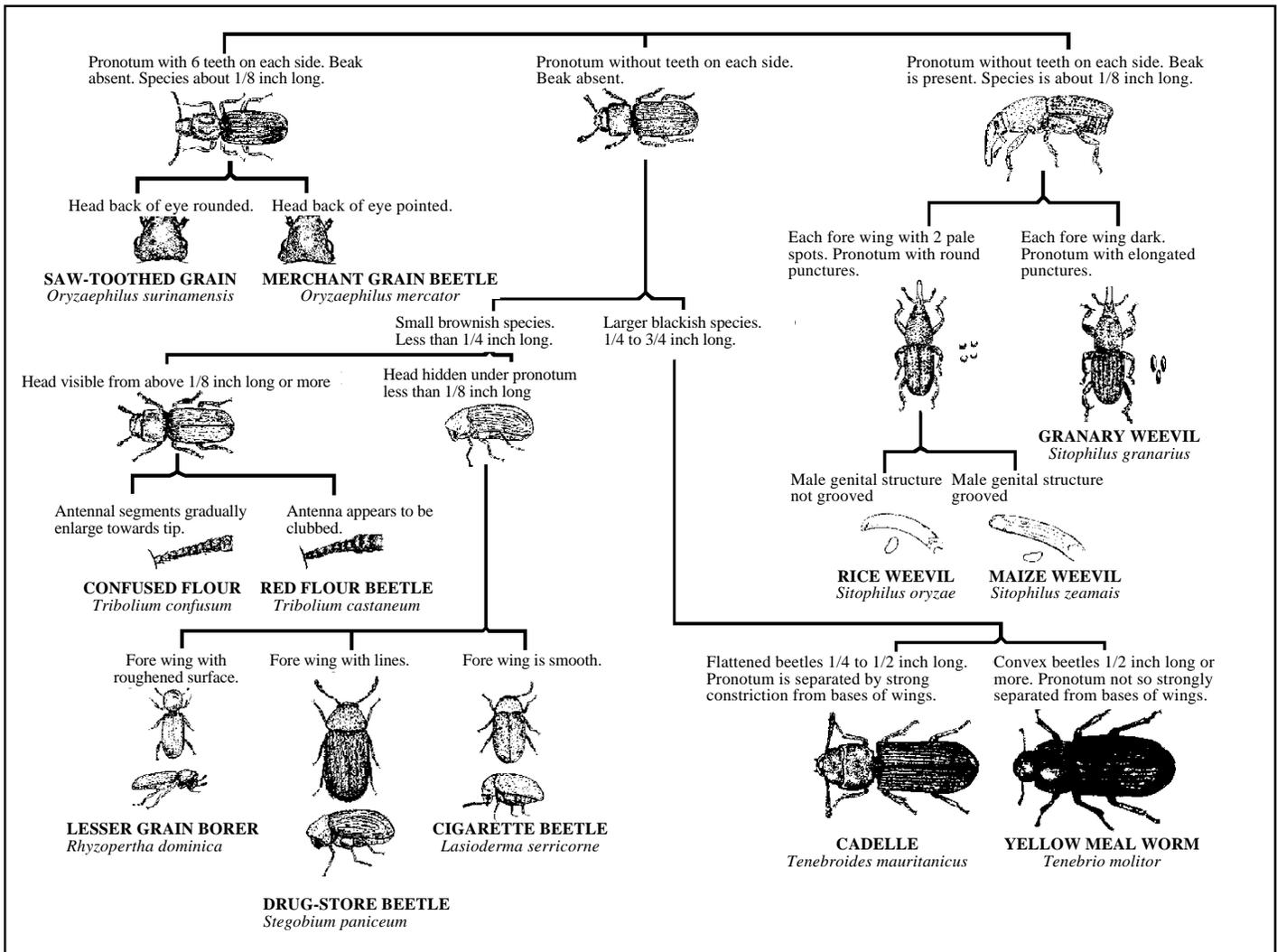
part in the speed with which stored-product insect populations increase. Stored wheat frequently retains summer heat so that temperatures in some parts of the grain mass remains above 15°C (60°F) until October through January. In general, as grain mass temperatures increase above 15°C (60°F), stored-product insects can survive and reproduce in grain of lower moisture contents. Similarly, high-moisture contents enable stored-product insects to survive at lower temperatures (See Tables 1 and 2). Similar temperatures and moisture contents are favorable for stored-product insects in food storage and processing facilities.

Over extended periods, the upper limits for survival and reproduction of stored-product insects, are approximately 38°C (100°F) and above

15 percent moisture content (mostly because molds and other microorganisms take over at moisture levels above this point). Lower limits are 15°C (60°F) for reproduction and 9 percent moisture content. Stored-product insects may survive by acclimation below 15°C (60°F) but generally die without reproducing during extended periods below this temperature. Many of the stored-product insects produce a new generation every month when temperature and moisture conditions are favorable.

Stored-product insects may be found wherever there are grain or grain products. Sources of infestation on farms are seed grains, stored grains, animal feeds or feeders, grain handling equipment and small accumulations at various locations.

Figure 2



# Stored-Product

## Insects

In grain elevators, receiving pits, bucket elevator boots, and dead spaces in other grain handling equipment, as well as dust and spillage accumulations are common sources. Food processing facilities also provide a variety of potential sources of infestation, including dead

moisture conditions within the equipment providing an ideal environment for stored-product insect development.

### Internal Grain Infesting Insects

There are five species of insects that feed and develop internally in kernels of cereal grains. Because of the difficulty of removing these internal forms, they are responsible for most of the insect fragments found in finished cereal foods, e.g., flour, corn meal, etc. Remember, using fumigants to kill these internal forms will not eliminate the fragments in the processed product.

There are three species of weevils (insects with the head elongated into a snout). They are very similar in appearance, behavior and development, but have some differences as outlined in the following description (Figure 2):

#### Rice Weevil—*Sitophilus oryzae* (L.)

- Head is elongated into a snout, at the end of which are strong teeth-like mandibles.
- Adults are about 3 millimeters ( $\frac{1}{8}$  inch) long, dark brown with two rather large, yellowish spots on each wing cover.
- Pits on the pronotum (top of prothorax, just behind head) are nearly round and are close together.
- Usually found only in whole cereal grains (wheat, corn, sorghum, rice). Not a problem in flours, meals, etc.
- Female chews a hole in the kernel, deposits an egg in it and seals the hole with a gelatinous material.
- The white, legless, grub-like larva hatches from the egg after a few days, feeds and completes development to adult inside the kernel. The adult chews its way out of the kernel and continues to feed on the grain.
- The rice weevil may fly and infest grain maturing in the field in warmer areas of the U.S.

**Table 2. Effects of grain temperature on egg laying, development, and survivorship of the confused flour beetle.**

Temperature(°F)	Eggs/Day	Days to Hatch	% Hatching
61	occasional	—	—
63–64	1.2	39	27
72	1.9	14	77
77	5.9	8.3	90
81	7.5	6.2	90
90	10.1	4.3	92
100+	All Components Decline		

spots in grain handling and processing equipment, screenings from grain cleaning, and product accumulations in cracks and crevices in the facilities.

The presence of grain dust, fines, broken kernels and other dockage permits certain stored-product insects to survive adverse temperature and moisture conditions. For instance, confused flour beetles were not able to maintain themselves in clean, low moisture (8 percent) wheat, but they at least maintained their populations when dockage was added to the same grain. Clean grain, therefore, is an important factor in controlling infestations.

Some stored-product insects, for example the cadelle, can become dormant and survive through periods of low temperatures and low moisture that exceed one year in length. For these, thorough cleaning of storage structures followed by residual insecticides is an important step in preventing infestation carry-over from one batch of grain to the succeeding batch.

Grain processing facilities are generally heated during cold periods of the year increasing the potential for stored-product insect development on a year-round basis. In addition, processing operations quite often generate heat and increased

# Stored-Product Insects

- Adults live four to five months and females lay 300 to 400 eggs. Complete life cycle may be as short as 27 days but averages about 35 under favorable conditions.

## Maize Weevil—*Sitophilus zeamais* (Motsch)

- Appearance and habits of the maize weevil are so similar to those of the rice weevil that it is unnecessary for most people to distinguish them. This insect usually is larger than the rice weevil but coloration and pronotal pits are similar. The two species may be distinguished by spatial arrangement of the pits and by differences in appearance of internal reproductive structures.
- Although it can infest any of the common stored cereal grains, it is a stronger flier than the rice weevil and is the weevil species most commonly found in corn in the field in the south. It continues infestation in storage.

## Granary Weevil—*Sitophilus granarius* (L.)

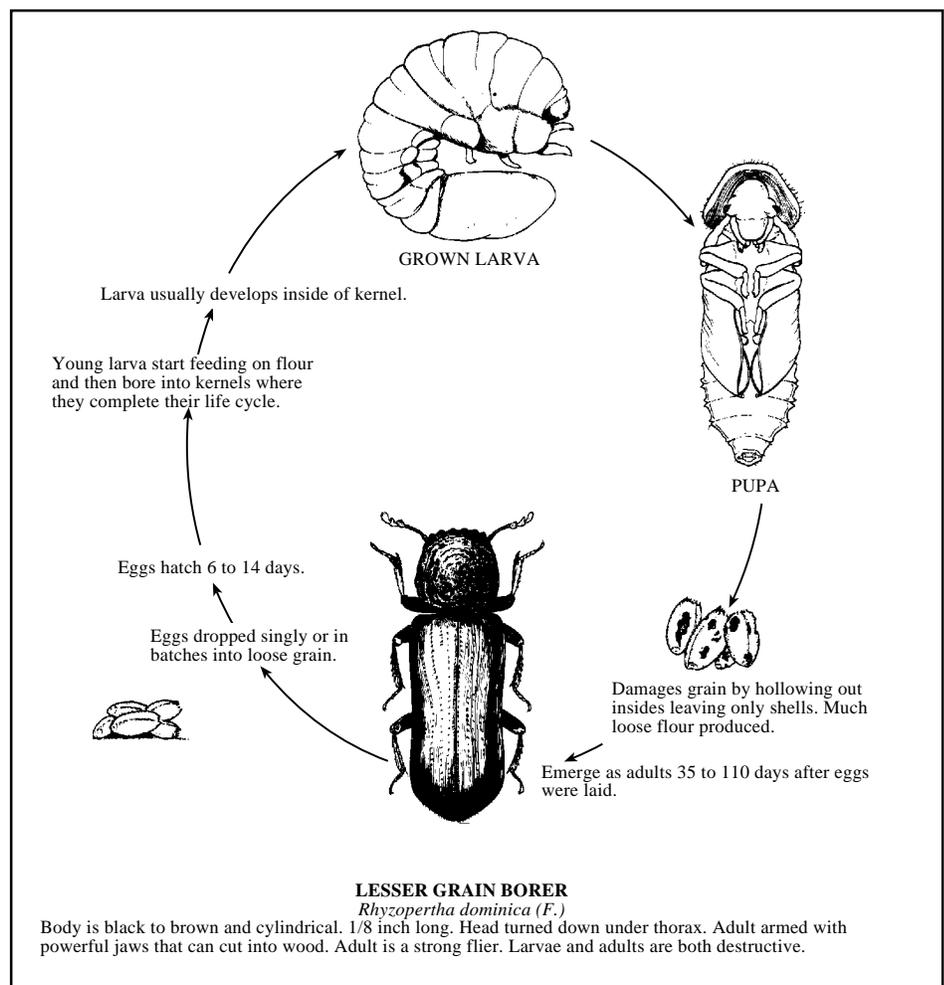
- Similar to the rice and maize weevils but is a uniform color and somewhat more shiny. The pits on the pronotum are elliptical and not as closely spaced as those of the above two species. The adult is somewhat larger than the rice weevil usually, but similar in size to the maize weevil.
- Does not fly so is dependent upon man for its distribution.
- Infests whole cereal grains, only after harvest.
- Life cycle averages about 40 days; 300 to 400 eggs per female.
- Unlike the rice and maize weevils, it has not been found in grain maturing in the field.

## Lesser Grain Borer (Figure 3)

- Small, cylindrical beetle with the head pointed downward from under the prothorax. Head usually cannot be seen from above.

- Uniformly dark brown, about 3 millimeters ( $\frac{1}{8}$  inch) long.
- Adults are strong fliers.
- Usually only infests whole cereal grains. Eggs are placed among the kernels (not inside). Newly hatched larvae burrow into the kernels where they develop to the adult stage. The adult chews its way out of the kernel, then continues to feed on grain.
- During development the larvae push "dust" out of the kernels. The dust has a sweetish, musty odor and is composed of fecal material and flour. Lesser grain borer infestations often can be identified by this odor in the grain storage.
- Although usually found in whole grain, they are capable of completing development in flours, meals or broken kernels.

Figure 3



# Stored-Product

## Insects

### Angoumois Grain Moth

- Adult is tan or buff color, similar in appearance to clothes moths and about 6.5 millimeters ( $\frac{1}{4}$  inch) long. The hind wing has a fringe of long hairs and the leading edge is extended at the tip to form a “pointing finger.”
- Eggs are laid among kernels of cereal grains. A few days later newly-hatched larvae enter the kernels where development to adults is completed.
- The mature larva prepares a thin escape “window” for the adult by chewing away all but a thin outer layer of the grain covering. These “windows” are more conspicuous on corn kernels than on wheat.
- Usually infests only whole cereal grains. In bulks of small grains and shelled corn, it infests only the top few inches. In ear corn it may infest the entire bulk. It is not a problem in flours, meals, etc.

- Adults do not feed. They live only a few days, lay 80 to 100 eggs per female, and complete their life cycle in 35 to 40 days.

### Other Stored-Product (External) Insects

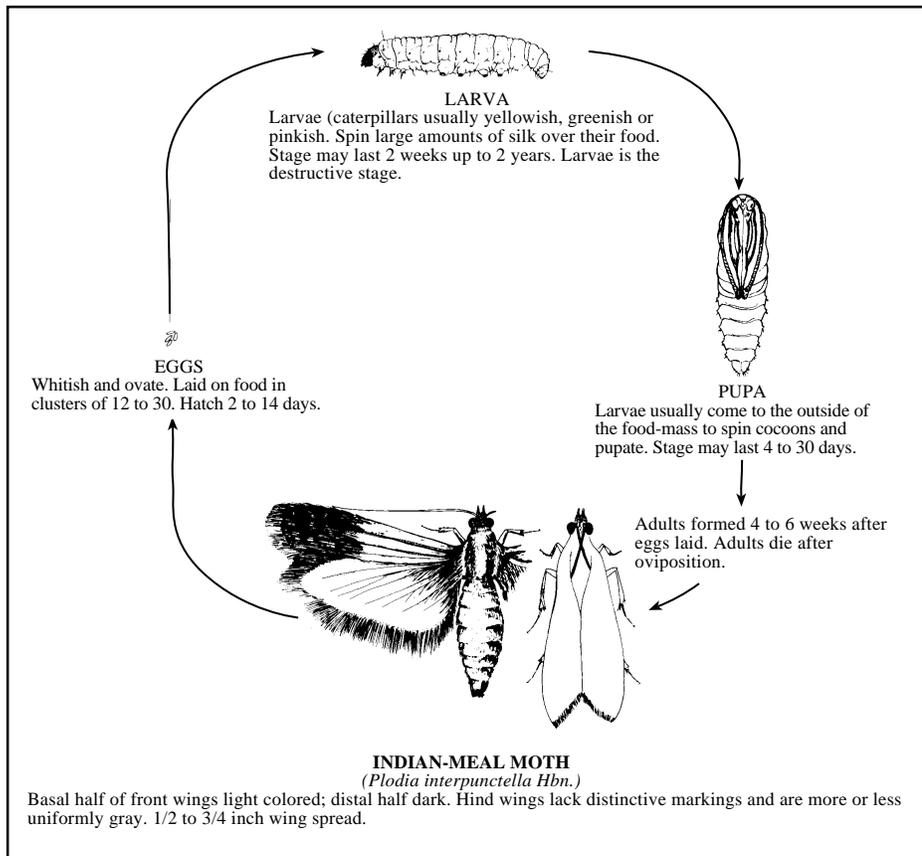
#### Indian Meal Moth (Figure 4)

- Adult moth is about 10 millimeters ( $\frac{3}{8}$  inch) long and dark, except for a conspicuous light band across the base of the wings (usually folded longitudinally over the back). When at rest, a distinctive dark-light-dark sequence is visible. The distal portion of the wings is a dark “coppery” color.
- Larvae are caterpillars that web food particles together with silk and often wander out of the food materials in search of places to pupate.
- Infest a variety of materials including cereal products, meals, feed, dried fruit, nuts and whole cereal grains.
- A common pest in grain bins. It infests just the upper few inches of the grain mass but may be so numerous that surfaces may be covered by a mat of silk webbing. Early infestations are evidenced by several kernels webbed together in clumps.
- A common kitchen and warehouse pest.
- Adults do not feed and live just a few days. Females lay 200 eggs each. Life cycle averages 35 to 40 days.

#### Red Flour Beetle—*Tribolium castaneum* Herbst

- Adults are uniform reddish-brown, shiny, about 3 millimeters ( $\frac{1}{8}$  inch) long and somewhat flattened.
- Both adults and larvae feed in a variety of materials: flour, meals, nuts, dried fruits and whole grain if moisture is sufficient and/or contains broken kernels.
- Adults can fly.

Figure 4



# Stored-Product Insects

- Outer three antennal segments of the adult are similar in size and distinctly larger than the adjacent ones.
- Adults live several months and lay 400 to 500 eggs per female. Complete life cycle averages 35 to 40 days.

## Confused Flour Beetle (Figure 5)

- Very similar in appearance and behavior to red flour beetles.
- Antennal segments enlarge gradually toward the tip of the antenna.
- Do not fly.
- Probably the most common flour mill insect, although it can infest the same foods as the red flour beetle.

## Saw-toothed Grain Beetle (Figure 6)

- Adults are slender, flat, dark brown and about 2.5 millimeters ( $\frac{1}{10}$  inch) long. Each side of the prothorax (just behind head) bears 6 pointed, saw-tooth-like projections.
- Both larvae and adults feed in cereal products, nuts, dried fruits, meals and whole cereal grains.
- This species is a common kitchen and warehouse pest and one of the most common insects in Kansas farm-stored grain (although not as damaging as internal feeders).
- Small size, especially of newly-hatched larvae, permits penetration of all but the tightest food packages.
- Adults live several months and lay up to 300 eggs per female. The life cycle may be completed in 25 days but the average is longer.

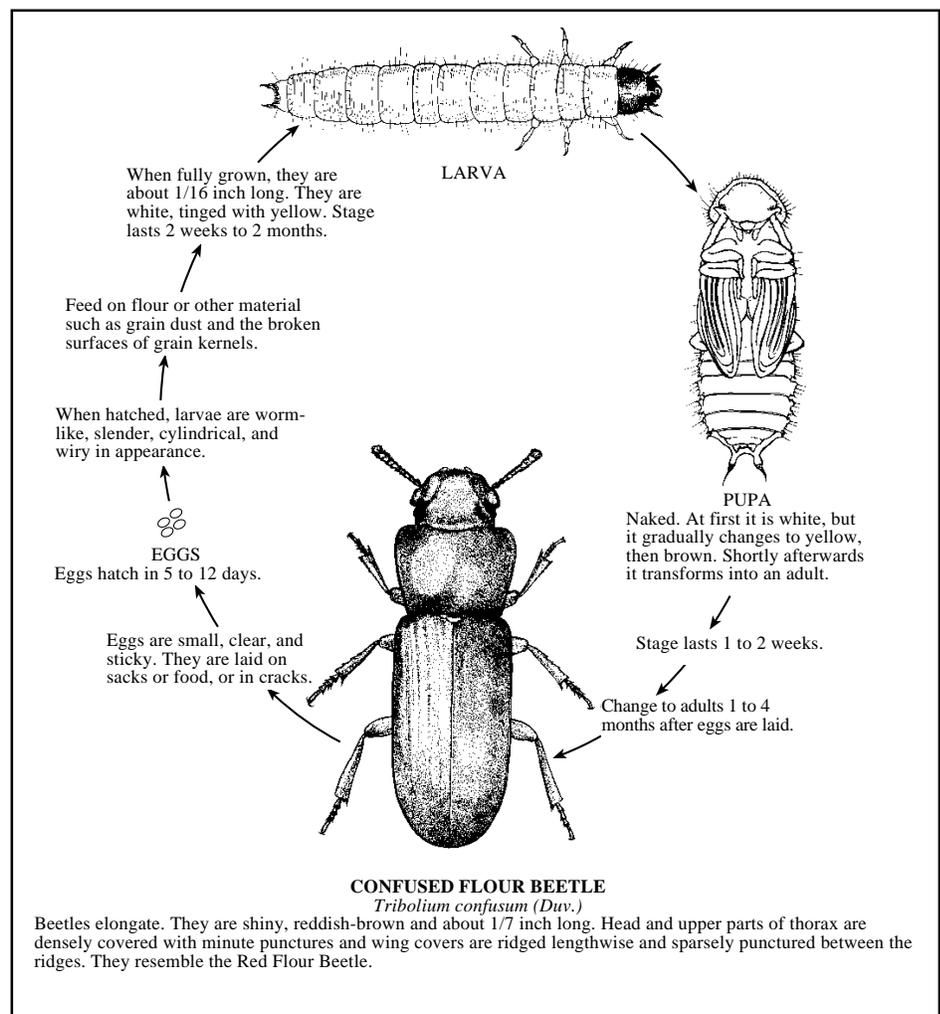
## Merchant Grain Beetle—*Oryzaephilus mercator* (Fauv.)

- Almost identical in appearance and habits to the saw-toothed grain beetle.
- Infests the same foods as the saw-toothed grain beetle, but is better adapted to oilseeds and oilseed products than the former.

## Flat Grain Beetle (Figure 7)

- Adults are flat, reddish-brown and among the smallest of the stored-grain insects (2 millimeters or  $\frac{1}{12}$  inch long). Antennae are long and slender—the female's about half as long as the body and the male's two-thirds as long. The prothorax of the female is nearly square; that of the male narrows slightly toward the posterior.
- Both larvae and adults feed in grain, cereal products, nuts and other stored products. They may infest deadstock in mills.
- They are common in grain, often abundant in grain infested with other insects such as the weevils. They cannot develop on completely sound kernels of grain, but nearly all masses of grain include damaged kernels.

Figure 5



# Stored-Product

## Insects

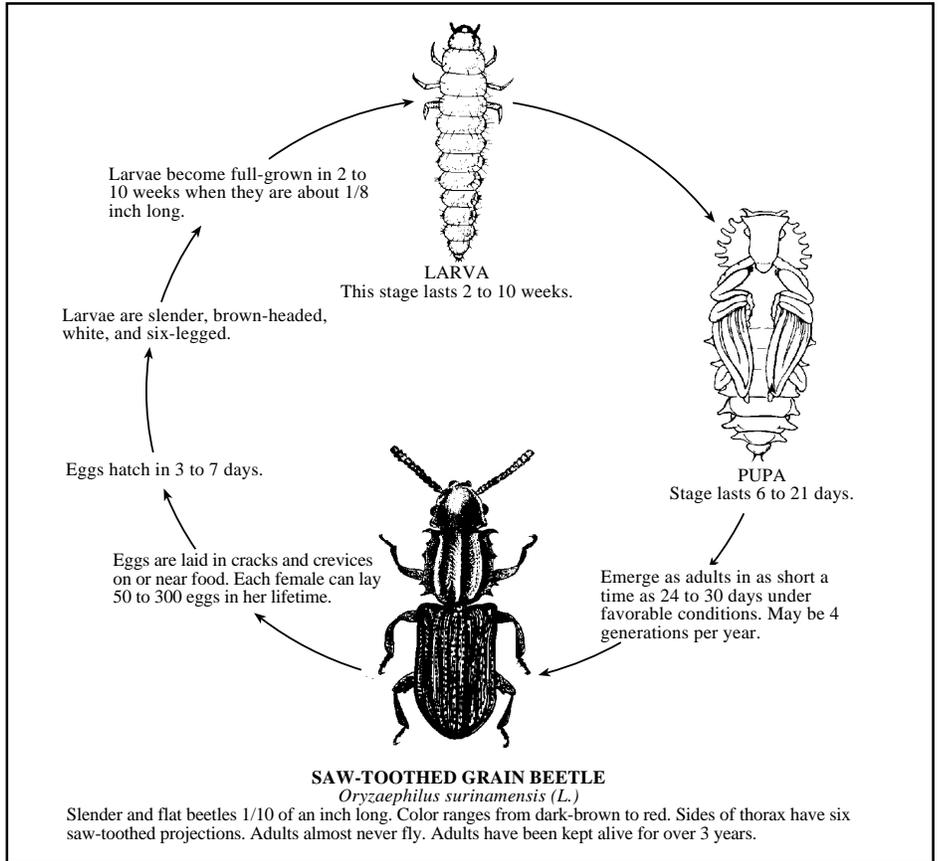
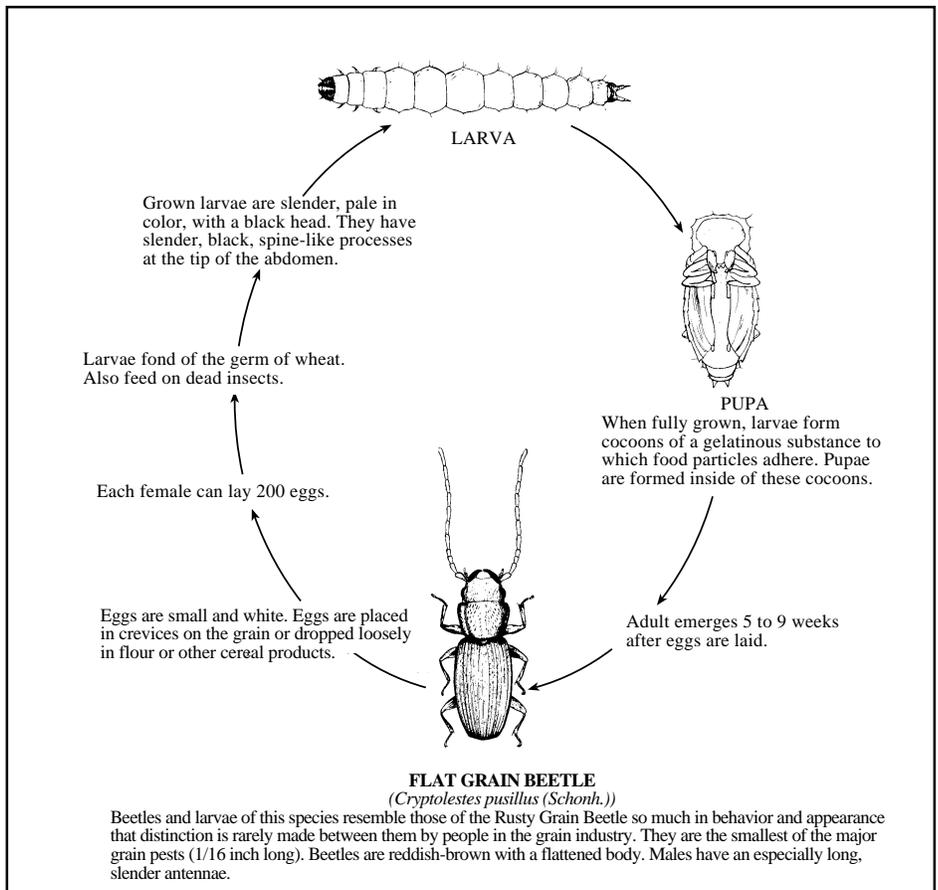


Figure 6

Figure 7



- Larvae feed principally on the germ of kernels.
- Each female may lay 200 to 300 eggs.
- Their life cycle may be completed in as few as 22 days, but is somewhat longer.

### Rusty Grain Beetle—*Cryptolestes ferrugineus* (Steph.)

- Similar to the flat grain beetle, except that antennae of males and females are the same length, about half the length of the body.
- The prothorax is slightly longer than broad and tapers toward the posterior. This is more pronounced in the male.
- Habitats and biology are similar to those of the flat grain beetle.
- Both species are common in Kansas stored grain. No doubt rusty grain beetles have often been reported as “flat grain beetles.”

### Dermestid Beetles

#### Grain Dermestids (*Trogoderma* species)

- Dark, oval beetles, from 2 to 3 millimeters ( $\frac{1}{12}$  to  $\frac{1}{8}$  inch) in length, with hairs on the wing covers (may be rubbed off, then beetle appears shiny) and rather indistinct patterns of brown and black. Females are larger than males.
- Larvae have long hairs and thick tufts of smaller brown hairs on a few of the posterior segments and have a “ringed” appearance. The width of the body is nearly uniform throughout its length.
- Infestations are revealed by cast “skins” of the larvae, which are shed at each molt, and may be numerous on the surface of the food material, sacks and packages.
- They infest many kinds of cereal products, meals and sometimes grain.
- Adults do not feed in the same food materials as larvae and are short-lived, so are not as readily

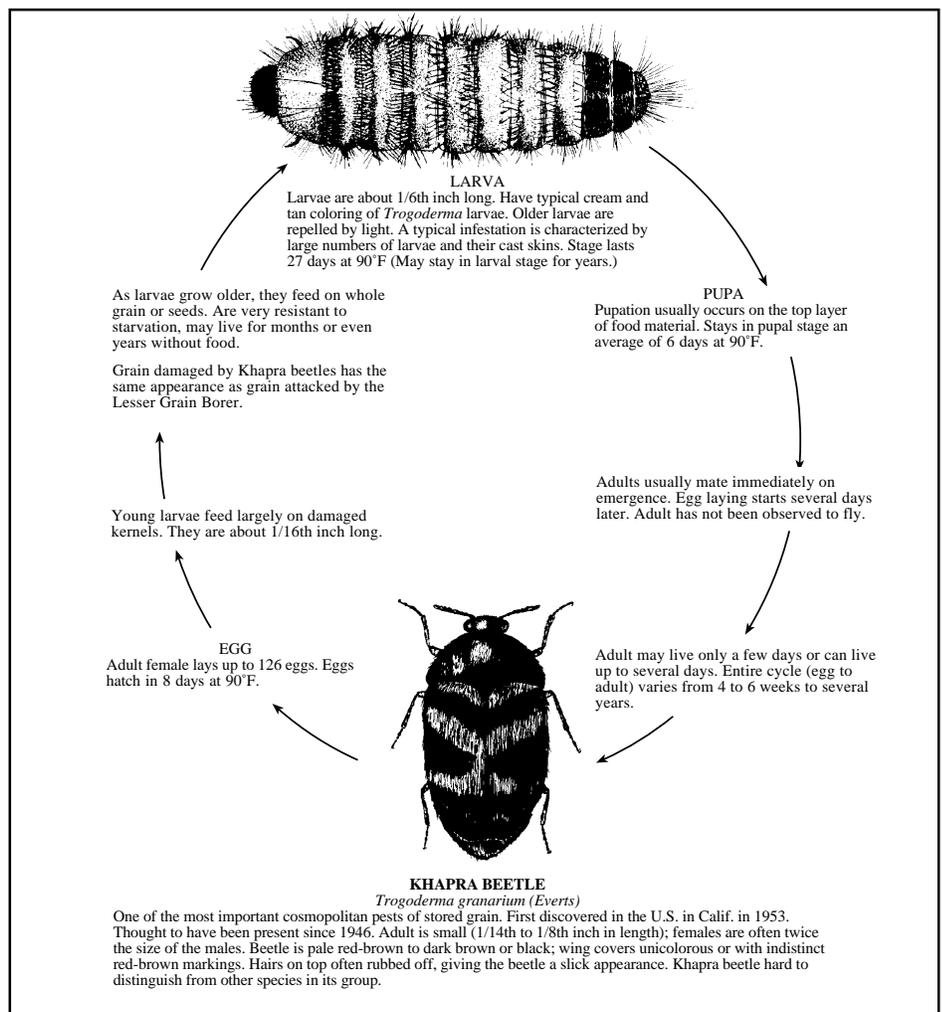
observed in infested foods as larvae.

- The life cycle may be completed in 25 to 35 days, but often is longer.
- Larvae are capable of living more than a year without food.
- Khapra beetle is illustrated (Figure 8). Sporadic accidental importations into the U.S. have occurred in the past few years but vigorous inspections and quarantines have prevented long-term establishment of this serious pest.

### Black Carpet Beetle—*Attagenus piceus* (Oliv.)

- Adults are similar in appearance to the *Trogoderma* species but usually larger and uniformly black or dark brown. Length is about 3 to 5 millimeters ( $\frac{1}{8}$  to  $\frac{3}{16}$  inch).

Figure 8



# Stored-Product

## Insects

- The larvae are darker than *Trogoderma* larvae and have a particularly long tuft of hairs at the posterior end. The body narrows from front to back which gives it sort of a cigar shape. It has a “ringed” appearance, as do the cast “skins” which are found on the surface of the food medium or in folds, cracks or crevices in sacks, packages, walls, etc.
- Infestations may occur in many of the cereal products and grain as well as in carpets, woolens, etc.

### Cigarette Beetle (Figure 9)

- Small, reddish brown, oval, hump-backed beetle about 2.5 millimeters ( $\frac{1}{10}$  inch) long. It is covered with fine hairs and

the head points downward under the hood-like pronotum. There are no striations (grooves) on the wing covers. Antennae are rather long and slender with segments resembling saw teeth.

- Larvae are white and grub-like with long hairs.
- Have been found infesting a wide range of materials such as tobacco, spices, nuts, grain, dried fish and meatmeal.
- Adults feed little, if at all, and live only a few days. Females average 100 eggs each and complete life cycle in about 35 days.

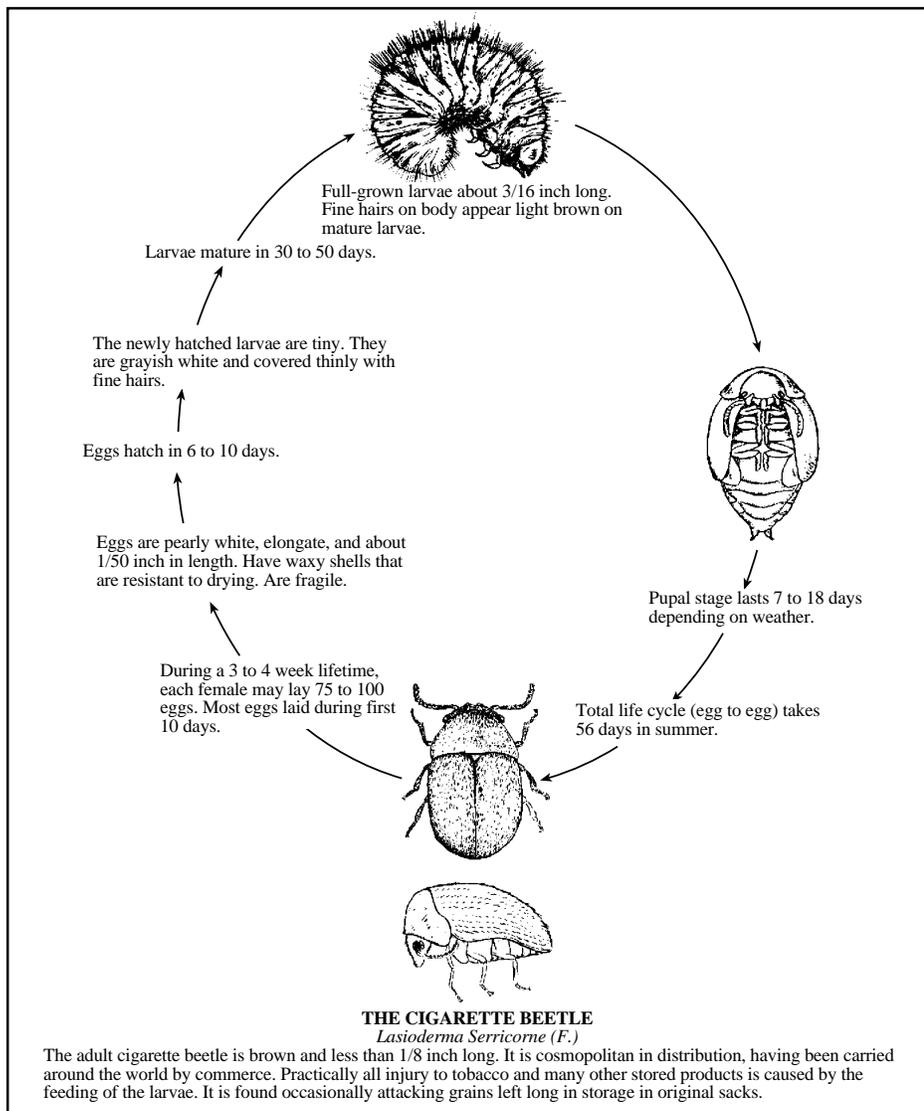
### Drugstore Beetle—*Stegobrium paniceum* (L.)

- Similar to the cigarette beetle, but less oval with striations on wing covers and with a less hump-backed appearance. The outer three segments of the antennae are distinctly enlarged.
- Although there are minor differences in larval appearance and habits, they are not considered here.
- This insect lays fewer eggs (75 per female) and has a slightly longer life cycle (40 days) than the cigarette beetle.

### Cadelle (Figure 10)

- Adult is a flattened, black, shiny beetle about 8 millimeters ( $\frac{1}{3}$  inch) in length. The head and prothorax are closely joined but appear separate from the rest of the body giving the body a divided appearance.
- The larva is white with black head and conspicuous black plates on the first segment behind the head and at the tip of the abdomen, the latter bearing two horns.
- In grain, especially in wooden structures, both larvae and adults burrow into the wood to pupate in cold weather or when no grain is in the bin.
- Both larvae and adults feed on grain, flour and other grain products.

Figure 9



- The female lays about 1,000 eggs and the life cycle is completed in a minimum of 70 days.

### Yellow Mealworm—*Tenebrio molitor* L.

- Adults are shiny black or dark brown and 14 to 20 millimeters ( $\frac{1}{2}$  to  $\frac{2}{3}$  inch) in length. These beetles are the largest found in stored products.
- The larvae are honey-yellow and attain a length of 26 to 30 millimeters (1 to  $1\frac{1}{4}$  inches). The body is heavily sclerotized and cylindrical and is similar in appearance to wireworms.
- They feed on grain and grain products, especially when it is out of condition. They may also infest meals, meatmeal, mill sweepings and other products.

### Dark Mealworm—*Tenebrio obscurus* (F.)

- Similar in size, appearance and habits to the yellow mealworm, except the adults are dull and pitchy black, not shiny.
- Larvae are much darker than the larvae of the yellow mealworm.

### Insects Associated With High Moisture Conditions

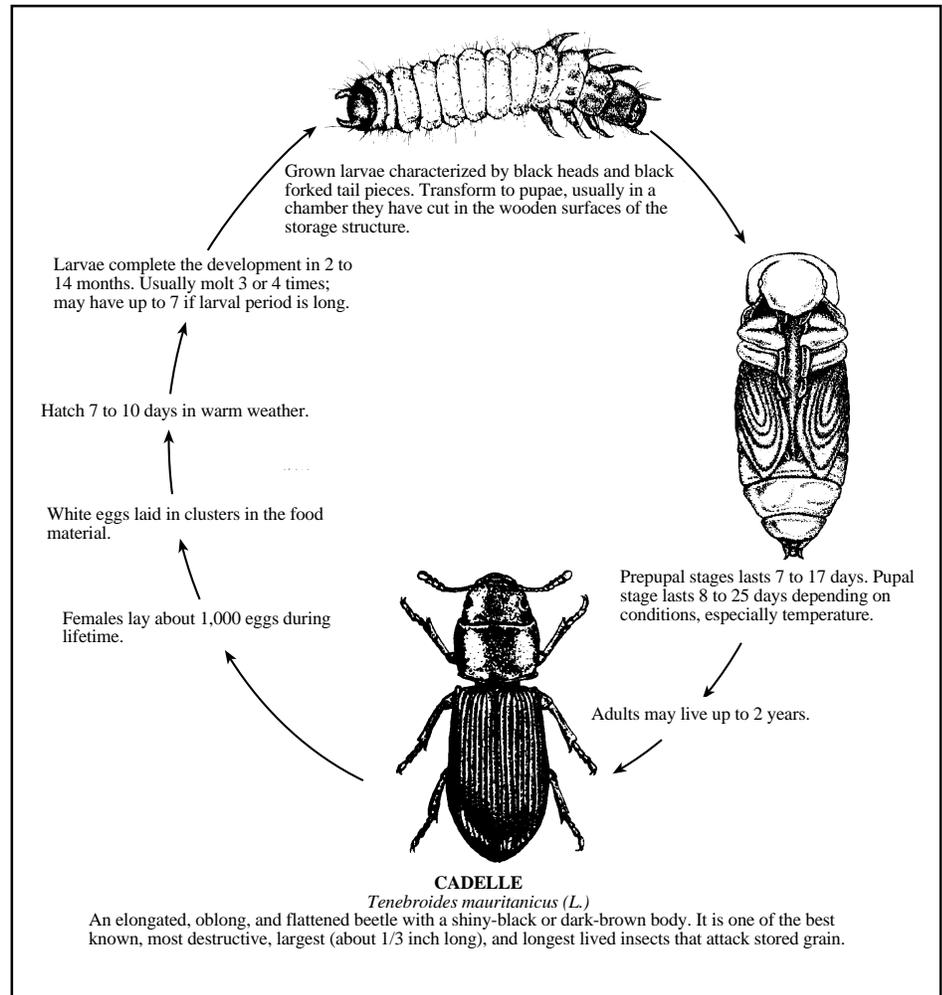
There are several other small beetles, i.e. the foreign grain beetle (*Ahasverus advena* Waltl), the hairy fungus beetle (*Typhea stercorea* (L.)), etc. which may be found in grain and grain products slightly high in moisture content. These insects primarily feed on fungi developing in these products and do not significantly damage the products.

Booklice (*Liposceles* spp.) and mites (*Acarious* spp.) (not true insects but close relatives) are microscopic in size and can be found under similar conditions (Figure 11).

### Parasites and Predators

On occasion, very tiny insects (some wasp-like) may be found in large numbers associated with infested grains. These are natural enemies (parasites/predators) of the grain infesting insects. In some instances, application of ineffective chemical treatments may destroy the parasites/predators allowing the damaging species to survive.

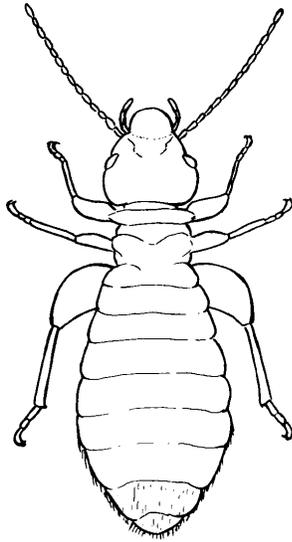
Figure 10



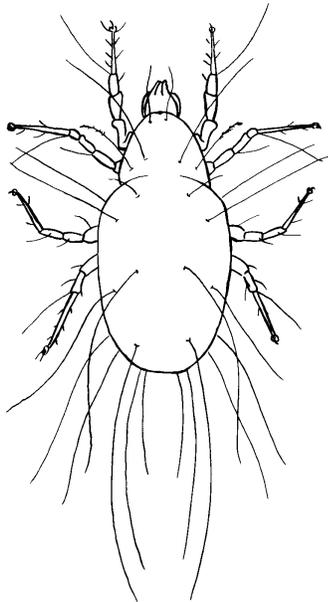
# Stored-Product

## Insects

### Questions



Booklouse  
*Liposceles*



Mite  
*Acarious*

1. (3) In recent years, regulations by what Federal government agency has increased emphasis on reducing pest adulteration of food products?
  - a. Health and Human Services (HHS)
  - b. Centers for Disease Control (CDC)
  - c. Food and Drug Administration (FDA)
  - d. Bureau of Alcohol, Tobacco and Firearms (BATF)
2. (4) Adult beetles infesting stored products are characterized by:
  - a. rather hard shell-like bodies
  - b. soft, very fragile bodies
  - c. transparent body walls
  - d. body covered with scales and hairs
3. (5) In general, stored grain mass temperatures above \_\_\_ allow insects to survive in lower moisture content.
  - a. 30°F
  - b. 40°F
  - c. 50°F
  - d. 60°F
4. (6) The cadelle can become dormant and survive low temperature and moisture conditions for over:
  - a. 6 months
  - b. 12 months
  - c. 18 months
  - d. 24 months
5. (7) This stored grain infesting weevil does not fly.
  - a. Maize weevil
  - b. Granary weevil
  - c. Rice weevil
  - d. Lesser grain weevil
6. (8) Larvae of the \_\_\_ web food particles together.
  - a. Rice weevil
  - b. Angoumois grain moth
  - c. Granary weevil
  - d. Indian meal moth
7. (9) One of the most common insects in Kansas farm-stored grain is the \_\_\_.
  - a. Saw-toothed grain beetle
  - b. Rice weevil
  - c. Angoumois grain moth
  - d. Pea weevil
8. (11) Vigorous inspections and quarantines have prevented long-term infestations of this pest.
  - a. Rusty grain beetle
  - b. Merchant grain beetle
  - c. Flat grain beetle
  - d. Khapra beetle
9. (12) The Drugstore beetle is similar in appearance to:
  - a. Yellow mealworm
  - b. Cigarette beetle
  - c. Dark mealworm
  - d. Khapra beetle
10. (13) Ineffective chemical treatments may destroy these insects and thereby allow the damaging species to survive.
  - a. Syrphid flies
  - b. Parasites
  - c. Indian meal moth
  - d. Merchant grain beetle

Figure 11

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# Monitoring for Stored-Product Insects

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Stored-product insects cause significant losses of stored grains, processed foods, fibers and animal products. In general, losses can be minimized when infestations are quickly identified and appropriate control measures implemented.

Numerous methods for detecting stored-product insects have been developed or are being investigated. The most promising technique that has been developed, and continues to be refined, is monitoring populations with insect pheromones and/or food attractants.

The incorporation of monitoring methods into existing stored-product pest management programs can lead to earlier detection of low level infestations and pinpointing location of infestations. Monitoring information can be used to justify reduction in pesticide use or the need for intensified surveillance and pest management procedures. Monitoring results also can serve as an indicator of how well integrated pest management (IPM) program components are functioning.

## Monitoring Methods

Current monitoring methods for insect infestation vary and depend on the type of insect, commodity and/or storage. They include:

### Bulk Commodity Storage

- Observation of the commodity surface and overspace for insects and/or evidence of their presence, i.e. webbing, castskins, dust, odor, etc.
- Examination of commodity samples obtained by various means, i.e. probe sampling, turning of the commodity, etc.
- Probe (pitfall) traps inserted into the surface of grain masses and left for varying lengths of time have proven useful as a means of early detection of live, free-living insects.
- Temperature monitoring in grain masses may detect

localized increases in temperature which can indicate the presence of an insect infestation.

### Warehouse Storage of Processed Commodities

#### Pheromone/food attractant monitoring

Pheromones have been identified for many of the stored-product insects. Some synthesized lures have been commercially developed and a variety of trap designs are available. Traps have been very effective for monitoring commodities that have few species of stored-product pests, e.g., tobacco. Pheromone/food attractant monitoring has the advantage of:

- continuous surveillance.
- targeting a defined area of facility.
- identification of an infested area.
- early detection of an infestation.
- reduced need for time consuming product inspection.
- providing a basis for minimum pesticide application.

Some definitions:

- Food attractant—A natural food, food extract, or synthesized scent that will attract a select group of insects. In some cases it is impregnated into an artificial medium.
- Lure—A small rubber or plastic device impregnated with or retaining a pheromone or food attractant, designed to release the attractant gradually over a designated period of time, either passively or controlled.
- Pheromone—A chemical compound produced by an organism that initiates a behavioral activity in others of the same species. Such compounds are synthesized for attracting target insect species.
- Aggregation pheromone—A communication chemical predominantly produced by males that attracts both sexes. Effective compounds have been synthesized for stored-product

# Monitoring for Stored-Product Insects

insect species with long-lived adults (e.g. Tribolium, Rhyzopertha) and species which need to feed to reproduce.

- Sex attractant pheromone— A communication chemical usually produced by females to attract the opposite sex. Effective compounds have been synthesized for stored-product insect species with short-lived adults and adults that do not need to feed to reproduce (e.g., Plodia, Ephestia).

## Pheromone and food attractant lures (Table 3)

Pheromone lures have been developed for several stored-product insects. Lures developed for species with short-lived adults have proven more effective. The lure for the lesser grain borer (*Rhyzopertha dominica*) also has produced good results. Food attractant lures for stored-product insects (predominantly an oil lure consisting of oat oil, wheat germ oil extracts and mineral oil) are used for species having long-lived adults and some larvae. These lures may be used

**Table 3. Status of pheromones for stored-product insects.**

**Codes: A = aggregation pheromone, F = food attractant, S = sex pheromone**

Genus	Duration of Adult Stage	Lure Type	Comm. Available	Duration of Lure	Effectiveness
Anagasta <sup>1</sup> (Mediterranean flour moth)	1–2 wks	S	Y	6–20 wks <sup>2</sup>	moderate–good
Anthrenus (carpet beetle)	2–4 wks	S&F	Y <sup>3</sup>	4–8 wks	good
Attagenus (black carpet beetle)	2–9 wks	S&F	Y <sup>3</sup>	4–8 wks	good
Cadra <sup>1</sup> (Raisin moth)	1–2 wks	S	Y	6–16 wks <sup>2</sup>	moderate
Cryptolestes (flat grain beetle)	3 mon–1 yr	A	N	unknown	N/A
Ephestia <sup>1</sup> Almond/Tobacco moth)	1–2 wks	S	Y	6–20 wks <sup>2</sup>	moderate–good
Lasioderma (Cigarette beetle)	2–4 wks	S	Y	6–8 wks	moderate–good
Oryzaephilus (sawtoothed grain beetle)	6 mon–3 yr	A/F <sup>4</sup>	N/Y	unknown	poor <sup>5</sup>
Plodia <sup>1</sup> (Indianmeal moth)	1–3 wks	S	Y	6–20 wks <sup>2</sup>	good
Rhyzopertha (Lesser grain borer)	6 mon	A	Y	8 wks	good
Stegobium (Drugstore beetle)	2–5 wks	S	Y	4 wks	unknown
Tribolium (flour beetle)	6 mon–3 yr	A&F	Y	7–16 wks	variable (poor–good)
Trogoderma (warehouse/Khapra beetle)	2–4 wks	S&F	Y	6–26 wks	good

<sup>1</sup> Same lure for all species, separate lure for *Cadra* under development.

<sup>2</sup> May be effective for up to 40 weeks based on USDA studies.

<sup>3</sup> *Trogoderma* traps utilizing food attractants will catch larvae of both *Attagenus* and *Anthrenus*. Commercial sex lures have been marketed (1992) for carpet beetles, their effectiveness is not known.

<sup>4</sup> Aggregation pheromone under development.

<sup>5</sup> Food lure results have been erratic. Glue boards currently are almost as effective and more economical.

*Used with permission:* Stored-product Pest Monitoring Methods. Technical Information Memorandum No. 27 Armed Forces Pest Management Board, June 1992.

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## Monitoring for Stored-Product Insects

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with or without pheromones. In general, food attractant lures have a smaller effective range than pheromone lures. They can be used to enhance the effectiveness of pheromone traps for flour beetles (*Tribolium*) and to attract *Trogoderma*, *Attagenus*, and *Anthrenus* larvae.

### **Pheromone and food attractant traps**

There are a variety of traps used to deploy pheromones and/or food attractants. Bulk grain is most effectively monitored with perforated plastic probe (pitfall) traps. Traps are usually placed in the grain near the surface at cardinal points and in the center. They take advantage of the normal movement and activity of grain-infesting insects and may include a pheromone or food attractant lure.

Traps for flying insects (wing-, delta-, and diamond-traps) suspended at various locations through-

out grain elevators or warehouses are an effective way to monitor for moth adults and certain beetles. Lures containing pheromones for either Indianmeal moth or lesser grain borer placed in the center of a glue coated surface within the trap attracts these species and traps them on the sticky surface.

Multi-layered, corrugated paper traps with pheromones and/or food attractants are used to monitor for beetles and some larvae in warehouse situations. The corrugations attract the insects by serving as harborage sites similar to crevices in floors and walls. Multiple entry points formed by the corrugations provide tactile stimuli and air chambers within the trap to provide circulation for the pheromones and/or food attractants. Traps usually lie flat to prevent spillage of food attractant, however, some may be wall-mounted. A modified pitfall trap for floor or shelf placement also has been designed.

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# Monitoring for Stored-Product Insects

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## Questions

1. (15) One of the promising techniques for stored products insect pest management is:
  - a. Monitoring
  - b. Poison baits
  - c. Spraying bin walls
  - d. Super cooling with CO<sub>2</sub>
2. (15) Monitoring of bulk commodity storage for insects may include such techniques as:
  - a. Observation of surface and overspace
  - b. Probe traps inserted into the surface
  - c. Temperature read-outs in the grain mass
  - d. All the above
3. (15) These pheromones are used in warehouse storage of processed commodities and they attract both sexes of the species.
  - a. Repelling
  - b. Sex
  - c. Aggregation
  - d. Reproduction
4. (17) Pheromone and food attractant traps may include:
  - a. Perforated plastic probes
  - b. Multi-layered corrugated paper
  - c. Wing-, delta-, and diamond traps
  - d. All the above

# Cockroaches

## Cockroaches

Cockroaches are among the oldest of insects, as indicated by fossil remains, dating to 200 million years ago. This ability to survive the many changing environments through time illustrates the capability of these insects to adapt to wide ranges of habitats and living conditions.

Cockroaches may be direct carriers of disease. They also contaminate food and kitchen utensils with excrement and salivary secretions and leave an unpleasant odor. Cockroaches sometimes produce allergic reactions in humans. The allergy is due to cockroach parts (proteins), not the odor.

## Biology and Behavior

Cockroaches develop by gradual metamorphosis through three life stages: egg, nymph and adult. Adult females produce small, bean-like capsules or oothecae which contain the eggs. These capsules usually are dropped at random near food or glued to some surface by the female soon after they are formed. (The female German cockroach carries the capsule protruding from her body until the eggs are ready to hatch.)

Nymphs which hatch from the eggs and emerge from the ootheca resemble adult cockroaches, except that they are smaller and do not have fully developed wings. Their flattened bodies allow them to squeeze into crevices and long, spiny legs enable them to run rapidly.

Nymphs molt several times before becoming mature males and females. As indicated in Table 4, the time required to complete the life cycle varies from about 2 months to nearly 3 years, depending on the species and environmental conditions. Most cockroaches are tropical or subtropical in origin and generally live outdoors. However, some species have become well-adapted to living with humans. Though it is true that cockroaches prefer poor housekeeping, they at times, infest even the

most sanitary and well-organized buildings.

Cockroaches can enter buildings in boxes and containers of all kinds. They also can enter around loose-fitting doors and windows, where electrical lines or water and steam pipes pass through walls, sometimes even in seasoned firewood and through sewer lines.

Most cockroaches are nocturnal and appear during daylight only when disturbed or where there is a large population. They prefer warm, dark, moist shelters and often are found around food-handling areas; where pipes or electrical wiring pass along or through a wall; behind window or door frames, loose baseboards or molding strips; or underside of tables, chairs and equipment.

Cockroaches feed on a variety of plant and animal products, including meat and grease, starchy foods, sweets, baked goods and other unprotected kitchen goods. They also feed on materials such as leather, wallpaper paste and book binding and sizing.

## Common Species

There are about 55 species of cockroaches in the United States, but only five species are routine problems in buildings. Most of the other species live outdoors and, therefore, escape notice; if brought into the building they either leave or die. Unfortunately, four species of cockroaches favor the buildings of people as a home—reflecting the close relationship humans have had with cockroaches since moving into the first cave (Figure 12).

### German Cockroach—*Blatta germanica* (L.)

- Light brown and 13 to 16 millimeters ( $\frac{1}{2}$  to  $\frac{5}{8}$  inch) long.
- The head shield is marked with two dark stripes that run lengthwise.
- Adults are fully winged but rarely fly.
- Immature German cockroaches are smaller and darker than adults and are wingless.

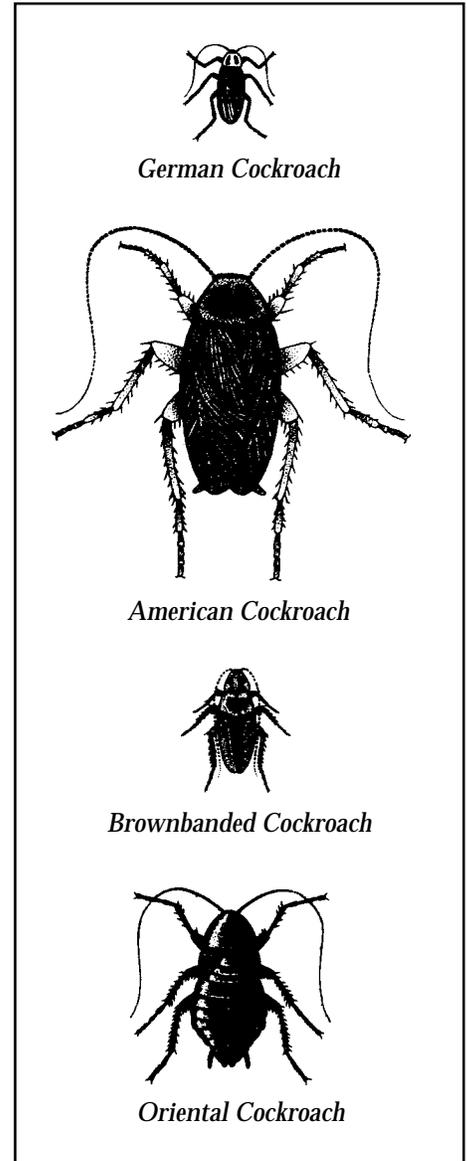


Figure 12

# Cockroaches

- The most prevalent household cockroach in Kansas and is more active than other domestic species.
- Troublesome infestations can develop rapidly after the introduction of a few individuals.
- The only domestic species in which adult females carry the egg capsules protruding from their abdomens until the eggs are ready to hatch.
- These cockroaches thrive in all types of buildings but are found most often in homes and commercial food establishments.
- Usually enter homes with bottled drinks, potatoes, onions, dried pet food, grocery sacks, corrugated cartons and even furniture.
- Usually seek dark shelters near moisture and food. However, they may sometimes be found in other parts of the building.
- Female usually drops her egg capsule within a day after it is formed. The capsule often is dropped near a food source or in locations where it can be covered with miscellaneous debris. Occasionally, the capsule is glued to some surface with secretions from the female's mouth.
- They thrive in commercial establishments and other buildings which provide favorable shelter and an ample food supply. They live mainly in dark, moist sites in basements, steam tunnels and sewers.

## Brownbanded Cockroach—*Supella longipala* (F.)

## American Cockroach—*Periplaneta americana* (L.)

- Light gold to glossy dark brown and 13 to 16 millimeters ( $\frac{1}{2}$  to  $\frac{5}{8}$  inch) long with transverse yellow bands across the base of the wings and across the abdomen.
- Wings of adult males cover the abdomen while the female's wings are shorter.
- Yellow bands are more pronounced on nymphs than on adults.
- These cockroaches are quite active. Adult males fly readily when disturbed.
- Female carries her egg capsule for only a day or two before gluing it to protected surfaces such as the undersides of furniture and equipment and
- Largest of the common species, growing to a length of 38 to 51 millimeters ( $1\frac{1}{2}$  to 2 inches). Reddish-brown with a light yellow band around the edge of the head shield.
- Adults of both sexes have well-developed wings but seldom fly. However, they are capable of gliding flights.
- Nymphal cockroaches are small, brown and not fully winged.

**Table 4. Life-history of four common cockroaches in Kansas.**

	Average number of eggs per capsule	Average number of capsules produced per female	Length of Life cycle (days)	Average longevity of adults (days)	Approximate number offspring possible per year beginning with one female
German	37	7	60–250	140	35,300
American	15	58	320–1070	440	810
Brownbanded	16	10	140–380	110	680
Oriental	14	14	210–990	100	200

sometimes to ceilings in darkened rooms.

- Egg capsule remains in place until hatching which may require several weeks.
- Brownbanded cockroaches are more likely to be found in homes, apartments, hotels, motels, nursing homes and hospitals than in restaurants, grocery stores and other commercial establishments.
- Prefer starchy foods and appear to have lower water requirements than other cockroaches.
- Nymphs and adults are frequently found on ceilings, behind picture frames, in light switches, in upper walls of cabinets and closets, on undersides of furniture and inside upholstered furniture.

## **Oriental Cockroach—*Blatta orientalis* L.**

- Glossy dark brown to black.
- Females are nearly 38 millimeters (1½ inches) long.
- Male has wings which cover part of the body. Female has rudimentary wings which are reduced to mere lobes.
- Neither sex can fly; in fact, both are rather sluggish.
- Nymphs are dark brown to black and have wing stubs which lack a definite venation.
- Female usually carries egg capsule for about a day, then it is dropped or attached to a protected surface near a food supply.
- Adults are more abundant in the spring.
- Nymphs and adults usually found near decaying organic matter.
- During warm, humid weather they inhabit lawns, compost piles, flower beds and dumps.
- In periods of drought or cool weather, there is mass movement into buildings.
- In buildings, they inhabit high moisture areas such as sewers, crawl spaces, drains, basements

and hollow spaces under concrete slabs.

- Activities restricted to the ground or below-ground levels in buildings.

## **Pennsylvania Wood Roach**

- Not a normal building dwelling species; but males are attracted to lights and will invade buildings in the spring.
- In wooded areas, the Pennsylvania wood roach is a definite, but usually seasonal problem.

## **Cockroach Control**

The control of cockroaches requires much care and planning. Taking precautions to prevent the invasion of cockroaches into a building works better than applying insecticides to control an established population. Cleanliness and elimination of favorable breeding sites will greatly lessen the possibility of cockroach infestation, but these practices will not always prevent infestation from outside. Cockroaches can survive in even the most sanitary environment once an infestation is established.

Because various combinations of cockroaches can occur in the same building, it is essential to accurately identify the species present. This will permit use of control measures that take advantage of behavioral patterns and life requirements for the particular species. For instance, for chemical control of the widely dispersed brownbanded cockroach, chemicals must be applied over greater areas of a building than for control of the more restricted oriental or American cockroaches.

## **Non-chemical Control**

Non-chemical measures include:

1. Keeping tight-fitting windows and doors; caulking cracks in outside walls, sills and foundations.
2. Sealing all openings where electrical lines or water, steam and cooling pipes pass through walls and floors to slow the movement of cockroaches into a building.

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# Cockroaches

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3. Inspecting boxes and other containers to avoid bringing cockroaches into the building.
4. Repairing plumbing leaks and sealing other moisture sources.
5. Keeping the premises clean by removing all food crumbs and placing garbage and trash into containers with tight-fitting lids.
6. Use roach traps (sticky traps) to monitor for cockroach activity.

## **Chemical Control**

To effectively control cockroaches with insecticides, it is necessary to inspect closely for their shelters and thoroughly treat these locations. Regardless of the insecticide or formulation chosen, chemicals placed in or near regular hiding places will provide much better control than those placed where cockroaches move only occasionally.

Present methods of insecticidal control generally provide temporary control within treated structures. Since some cockroach species invade buildings from outside, reinfestation can occur once the insecticide has dissipated. To solve this problem, outdoor populations also must be controlled. For example, when wood

roach become numerous in the home, use of chemicals inside will provide short-term control. Locating, treating or removing outside shelters can provide effective long-term control.

To eliminate an established infestation from a building, first remove as many routes of reinfestation as you can, then thoroughly clean the building and apply an approved chemical concentrating on cracks, crevices and hiding places. The type of chemical selected and the application method used will depend on the location and nature of the infestation. Chemicals have different capabilities and pesticide selection should be based on the species of the insect, application technique, surfaces to be treated and information on the label.

Each cockroach problem must be studied and control measures used in accordance with the location, extent and nature of the infestation. With a range of chemicals, formulations and application techniques available, it is important to select the appropriate combination to provide the desired control.

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# Cockroaches

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## Questions

1. (19) The \_\_\_ cockroach carries the egg capsule protruding from her body until the eggs are ready to hatch.
    - a. American
    - b. German
    - c. Brownbanded
    - d. Oriental
  2. (19) In the United States there are about \_\_\_ species of cockroaches.
    - a. 28
    - b. 40
    - c. 55
    - d. 63
  3. (20) The largest adult of the common cockroach species is the:
    - a. German
    - b. American
    - c. Brownbanded
    - d. Oriental
  4. (20) The \_\_\_ cockroach has yellow transverse bands across the base of the wings and abdomen.
    - a. German
    - b. American
    - c. Brownbanded
    - d. Oriental
  5. (21) The \_\_\_ cockroach appears to have lower water requirements than the other cockroaches.
    - a. German
    - b. American
    - c. Brownbanded
    - d. Oriental
  6. (21) Chemicals must be applied over a greater area of the building to control the \_\_\_ cockroach.
    - a. German
    - b. American
    - c. Brownbanded
    - d. Subslab dwelling
  7. (22) Present methods of insecticidal control of cockroaches provide:
    - a. Temporary control
    - b. Annual control
    - c. Permanent control
    - d. No control
    - e. All the above
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# Food-Plant Pest Treatment Areas

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Pests may enter storage or food processing facilities in two ways: (1) penetration through ineffective pest-proofing of walls, doors, windows and roofs, and (2) entry with commodities, ingredients or other raw materials and/or supplies.

## Areas of Concern

Food plants have five areas of activity where pests must be controlled:

- Grounds, the building exterior and the area around the plant.
- Receiving and storage area for incoming materials.
- Processing area.
- Packaging area.
- Finished product warehouse and shipping area.

Both chemical and non-chemical controls are important in these areas. Non-chemical controls include both preventive maintenance and mechanical and physical measures.

## Grounds and Building Exterior

### Non-chemical Controls

- Eliminate all exposed dirt surfaces by paving all roadways or parking areas and maintaining well-kept lawns. This will reduce contamination from dirt, microbes and other airborne particles.
- Provide good drainage to help keep the area clean and dry.
- Place outside lighting away from buildings and focus the lights toward buildings. This helps keep night-flying insects away from doors and windows.
- Screen potential bird roosting areas.
- Store equipment so it does not become a place for pests to hide.
- Remove all litter, weeds and grass clippings.
- Eliminate any waste that may accumulate near exhaust systems.
- Rodent-proof and bird-proof loading docks, doors, walls, windows and roofs.

- Use rodent, insect and bird traps as necessary.

### Chemical Controls

- Bait stations for rodents.
- Baits, fogs and sprays for insects.
- Chemical repellents or avicides for birds.

## Receiving and Storage Areas

### Non-chemical Controls

- Visually inspect all vehicles, ingredients and materials to ensure that pests are not brought into storage areas.
- Store ingredients and materials far enough away from walls to permit access for inspection.
- Use FIFO (first in-first out) rotation of incoming materials.
- Use traps or other methods for rodents.
- Use air curtains at dock and pedestrian doors to keep insects out.
- Use monitoring methods to detect insects.

### Chemical Controls

#### For insects:

- Space treatment with nonresiduals.
- Crack and crevice treatment with residuals.
- Spot treatments with residuals.
- Periodic general treatment.
- Treatment of raw bulk commodities with protectants on receipt and fumigants during storage where applicable.

#### For rodents:

- Bait stations, in non-food areas.

## Processing and Packaging Areas

### Non-chemical Controls

- Place rodent traps near doors if situation warrants.
- Screen all windows that can be opened.
- Eliminate cracks, crevices and other places where pests may hide.
- Where possible, locate equipment off the floor and away from walls for inspection and cleaning.

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# Food-Plant Pest Treatment Areas

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- Keep these areas clean and free of litter.
- Clean interiors and exteriors of equipment regularly.

## **Chemical Controls**

### *For insects:*

- Space treatment with nonresiduals.
- Spot treatment and nonresiduals.
- Crack and crevice treatment with residuals.
- Contact treatment with nonresiduals.
- Periodic general treatments.

## **Finished Product and Shipping Areas**

Use the same pest control methods in the finished products warehouse as in the materials receipt and storage area.

Vehicle inspection is essential to prevent the finished products from being placed in a pest-contaminated carrier. Vehicle inspection is difficult, particularly for boxcars and trucks with false walls or end-liners. If vehicles are dirty or infested, do not use them.

## **Chemical Controls in Vehicles**

### *Before loading, consider:*

- Space treatment.
- Crack and crevice treatment.

### *After loading, use:*

- General treatment—usually a solid fumigant—for in-transit control.

## **Forms of Pesticide Chemicals**

### **Aerosols**

#### **Advantages**

- Excellent for flying or exposed insect pests.
- Disperse well if used correctly.
- Convenient and easy to store.
- Usually leave little surface deposit.
- Store well during normal use period.
- Available for hand operations or can be installed as a timed release system.

#### **Limitations**

- No lasting protection.
- Good only for exposed pests.
- Hazardous if container is punctured or overheated.
- Usually cannot be used during food processing or when people are present.
- Hazardous around open flames and sparks.

### **Liquids—Sprays**

#### **Advantages**

- Usually provide a deposit on surface.
- Can easily be directed onto surface for treatment.
- Easy to store, transport and handle.
- Adaptable for use in many kinds of equipment.

#### **Limitations**

- May be hazardous to use around electrical outlets (water or oil sprays).
- May damage or stain wallpaper, varnish and many fabrics (water or oil sprays).
- Require agitation during application (wetable powders).
- May be hazardous around open flame (oil sprays).
- May damage or etch asphalt, plastic tile or rubber products (oil sprays).
- May make floors slippery (oil sprays).
- May damage living plants (oil sprays).

### **Vapors**

Vapors are released by supplementary heat or by inherent high vapor pressure to produce a gas. They usually are dispersed from impregnated resin strips or vaporizers.

#### **Advantages**

- Easy to apply and safe to handle.
- Can be used where fumigant tolerances may be exceeded.
- Sealed building not as essential as for fumigants.
- Effective against flying insects such as moths and flies.

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# Food-Plant Pest

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## Treatment Areas

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### *Limitations*

- Will not penetrate commodities in concentrations lethal to target pests.
- Not effective against beetles.
- Resin strips cannot be used in plant areas where food is exposed.

### **Dusts**

#### *Advantages*

- Excellent for crack and crevice treatments.
- May be purchased ready to use.
- Usually require only simple and lightweight application equipment.
- Safe for use around electrical equipment.

#### *Limitations*

- Drift easily.
- Easily dislodged from treated surface (should not be applied on equipment or above food-contact surfaces).
- Generally bulky to store.

### **Baits**

#### *Advantages*

- Often can control specific pests.
- Easily distributed.
- Easily monitored and recovered.
- Used in small amounts.

#### *Limitations*

- Can be dangerous to nontarget animals.
- Often not as attractive as natural food supply.
- Rodents must feed for 5 to 15 days on an anticoagulant rodenticide before it is lethal.
- Rodents feeding on poison baits may die anywhere and go undetected, causing sanitation problems.

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# Food-Plant Pest Treatment Areas

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## Questions

1. (24) Areas of concern for pest control at food plants include:
  - a. Exterior building and surrounding grounds
  - b. Receiving and storage areas for incoming material
  - c. Processing and packaging areas
  - d. All the above
2. (24) Non-chemical controls for exterior buildings and surrounding grounds may include:
  - a. Providing good drainage of rain water
  - b. Screening of potential bird roosts
  - c. Eliminate waste from exhaust systems
  - d. All the above
3. (24) Chemical control techniques for receiving and storage areas of food plants may include:
  - a. Space treatments
  - b. Crack and crevice treatments
  - c. General treatments
  - d. All the above
4. (25) The same pest control methods can be used in the finished product and shipping as in the:
  - a. Exterior building and surrounding grounds
  - b. Receiving and storage area for incoming materials
  - c. Processing areas
  - d. Packaging areas
5. (25) An advantage of aerosols is that:
  - a. They provide a long lasting surface deposit
  - b. They can be used in place of fumigants
  - c. They are excellent for flying insects
  - d. They require agitation during mixing
6. (25) An advantage of liquid sprays in food plants is that they:
  - a. May be hazardous around electrical equipment
  - b. Usually provide a surface deposit
  - c. Can be used in place of fumigants
  - d. Are good only for exposed pests
7. (26) A limitation of dusts in food plants is that they:
  - a. Drift easily
  - b. Are excellent for flying insects
  - c. May damage asphalt and plastic tile
  - d. Can be used in place of vapors
8. (26) A disadvantage of baits in food plants is that they:
  - a. Often control specific pests
  - b. Are used in small amounts
  - c. Are easily distributed
  - d. Can be dangerous to non-target animals



## Pre-Harvest Preparation

The following steps are necessary for proper storage in grain bins and elevators:

- Bins and adjacent structures should be thoroughly cleaned of old grain, grain residues, dust and any other material that may harbor stored grain insects and be a source of infestation of new grain.
- Clean up spilled grain outside of building such as along railroad tracks and around loading or unloading areas.
- Properly dispose of above materials so they will not infest any stored grain or products near the disposal site.
- Repair, replace, plug or otherwise correct conditions that allow entrance of rodents, birds or other pests into the buildings.
- Clean grounds of weeds, debris and other materials that may provide shelter for insects, rodents or birds. Store equipment properly.
- Train personnel in recognition of pests, safe use of pesticides, overall safety and emergency procedures.
- Install temperature monitors.
- Apply residual insecticidal spray to interior walls and ceilings of adjacent structures (that have been thoroughly cleaned). See that the insecticide gets into cracks, crevices and out-of-the-way niches. See section on Residual Sprays.
- It may be necessary to fumigate the empty structure to eliminate hidden infestations such as those below perforated floors where cleaning is impractical.
- Fumigate any grain that will remain in storage, if it has insects, when new grain is being accepted.

## Harvest Operations

During harvest, do the following:

- Keep harvesting and conveying equipment properly adjusted to minimize breakage which can open up otherwise sound grain to invasion by a broader range of stored grain pests.
- Do not store the first few bushels of grain passing through harvesting equipment. This grain scours out hidden infestations attacking residual grain left over from the last harvest.
- Visually check incoming grain for presence of stored grain insects. Be alert for previously stored grain that may come in as though it were “new grain.”
- If deemed necessary, incorporate a fumigant or grain protectant into newly received grain as it goes into storage. See section on Grain Protectants.
- Regularly clean-up around dump pits and conveying equipment.
- Separate excess dockage and fines from grain going to storage. Use distributors to spread allowable dockage and fines throughout grain mass.
- Separate dockage and fines from grain going to a dryer. Do not recombine.
- Use separate bins for “dry” and “wet” grain. Splitting of wet grain into “wet” and “very wet” may be necessary to do an orderly job of keeping grain in condition and making effective use of dryers and aeration equipment.
- Watch for evidence of rodent or bird invasion when harvest approaches completion.

## Post-Harvest Operations

Inspect grain thoroughly and regularly for signs of insect infestation. Inspect every 2 months when grain temperatures are below 55 to 60°F, and monthly when grain temperatures are warmer.

First, sample top-center of grain in the bin. Insert the probe or grain trier horizontally about or less than 4 inches deep. Then take more surface probes around the bin about 1 foot from the walls. Finally, probe vertically at various locations in the bin to as great a depth as possible.

Carefully sieve and examine each sample. Note all insects and the presence of any damaged grain, flour, or other signs of infestation. Remember, the earlier the infestation is detected, the more damage can be prevented.

- Monitor all bins of stored grain by appropriate means. Temperature increase may indicate insect activity.
- Immediately inspect grain if snow melts quickly from the roof of unheated storage structures. Heating may be caused by insect or mold growth.
- Check “hot spots” for insect activity by using sampling probes. This may not be practical for deep bins.
- Use “turning” to break up hot spots due to mold or bacterial activity. Sample grain at bin discharge for possible insect infestation.
- If insect infestation is found or suspected, use fumigants to control the infestation. See section on “Fumigation of Stored Products.”
- Inspect transport equipment before loading out grain for shipment. Railroad cars often need cleaning to prevent contamination of grain by other materials with resulting down grading and financial loss.
- Under some circumstances it may be desirable to fumigate grain in rail cars while in transit or on sidings. See “Fumigation of Stored Products” and check current guidelines on the legality of this practice.
- Have regular checks of pest bait stations and/or traps.

- Check at regular intervals for evidence of rodent, bird or pest invasion. Make regular inspections of buildings and grounds for possible access points.

## Use of Sprays and Protectants

### Residual Sprays

The purpose is to kill insects that are located in cracks, crevices and other locations which will, if not controlled, infest newly stored grain. For approved pesticides, be sure to refer to current recommendations and actual product labels. Time application one to four weeks before harvest or filling the bin.

#### Safety considerations:

- Personnel must have proper clothing and equipment so as to keep their exposure to pesticides at a minimum.
- Personnel exposed to the pesticides should thoroughly wash hands, face and exposed skin after application is completed or at the end of the day.
- A filtered air supply should be used by personnel in enclosed spaces if pesticides are being or have recently been applied.
- Be aware of accidental exposure of pets, livestock or people who may be in the vicinity of the structure.
- Solvents may be equally or more hazardous than the pesticide being used.

### Grain Protectants

Protectants are insecticides that are designed to remain on the grain as a protective shield of toxic residues and are designed to be applied directly to the grain. The purpose of these products is to **prevent** infestation of stored grain. They are not as effective as fumigants in killing stored grain insects which **already exist** in the grain mass. Fumigants penetrate into infested grain kernels but also diffuse out of grain and structure in a relatively short time leaving no protective residue.

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# Grain Handling

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For approved pesticides, refer to current recommendations and actual product labels. Time the application for immediately after harvest as grain first enters storage or during transfer from one bin to another. Protectants are most appropriate where summer-

harvested grain is stored into the next calendar year and where storage of fall-harvested grain is expected to be well into the next summer (at least).

**Safety considerations:** Same as for residual sprays above.

## Questions

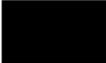
1. (28) Which statement applies to pre-harvest preparation for storage in grain bins and elevators?
  - a. If an insect infestation is found, fumigate.
  - b. Immediately inspect grain if snow melts quickly from unheated roof.
  - c. Bins and adjacent structures should be thoroughly cleaned.
  - d. Use separate bins for “dry” and “wet” grain.
2. (28) Install temperature monitors in grain bins during the:
  - a. Pre-harvest preparation of the bins
  - b. Harvest operations of the grain
  - c. Post-harvest operation after storage
  - d. Thirteenth week of storage
3. (28) When grain is in the storage bin, it should be inspected every 2 months when the grain temperature is below:
  - a. 55–60°F
  - b. 65–70°F
  - c. 75–80°F
  - d. 85–90°F
4. (29) When monitoring grain in storage bins, you should:
  - a. Be aware of grain temperature increase
  - b. “Turn” the grain break up hot-spots caused by molds and/or bacterial growth
  - c. Have regular checks of pest bait stations/or traps
  - d. All the above
5. (29) The purpose of residual sprays for stored grain is to:
  - a. Control insects that are located in cracks and crevices in the bin
  - b. Increase the moisture content of the grain
  - c. Control the level of dust associated with stored grain
  - d. Protect the structural wood in the bin from insect attack
6. (29) Grain protectant spray applications are:
  - a. Applied only to the bin wall surfaces
  - b. Applied to the space above the grain
  - c. Applied directly to the grain
  - d. Applied around the outside base of the bin to protect it from rodents entering

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# Fumigation of Stored Products

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While this manual contains considerable information, it is not all inclusive. If information in this manual conflicts with any pesticide label, the information on the label must be considered correct.

## Fumigants

Fumigants are defined as those pesticides which by themselves or in combination with any other substances are or become a gas or a mixture of gases. Fumigants will kill or control a pest and also are toxic to humans. Various aerosol space sprays (a suspension of liquid in air) are not considered fumigants.

Fumigants penetrate cracks, crevices and the commodity being treated. They must reach the target pests as gases to be effective. As soon as a fumigant diffuses from the target area, reinfestation can occur. Fumigants must be applied in enclosed areas; the gas released must reach a lethal concentration in all parts of the infested storage environment and the concentration must be held for a minimum amount of time to be effective.

### Advantages

- Toxic to many pests.
- Can be applied by various methods.
- Some may be applied without disturbing the commodity.
- Penetrate structures, commodities and equipment.
- Readily available and economical.
- Quick acting.
- Only practical method for infested commodities such as stored grain.

### Disadvantages

- Toxic to humans.
- Require trained applicators.
- Target area or commodity must be enclosed.
- May injure seed germination.
- Temperature requirements may be hard to meet, especially in northern climates.

- Control is temporary—no residual action.
- May damage some commodities and/or equipment.

## Selection of Fumigants

When choosing a fumigant, consider:

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

## Fumigation Variables

Several factors can change the efficiency of fumigants. Consider these when selecting a formulation and dosage.

### Temperature

The fumigant may not kill the pests if the product or space being fumigated is below 10°C (50°F) or above 46°C (115°F). The effect of temperature varies according to the specific fumigant being used.

### Moisture

As the moisture content of a commodity increases, it becomes more difficult for a fumigant to penetrate it. This makes fumigants less effective on insects. For some fumigants, this also increases the potential for residues exceeding legal tolerances. Adequate moisture is required for the generation of some fumigants.

### Pests

Susceptibility to fumigants depends on species, habitat and stage of development. During some stages of their life cycle, they are less susceptible than during others. Active insects are more susceptible than sluggish, diapausing forms.

### Structure

Consider the condition of the structure, the type of construction

and the product it contains. A wooden structure, even when sealed well, will not retain fumigants as well as metal, plastic, masonry or concrete. Fumigation in vacuum chambers allows increased efficiency. **Vacuum chambers must never be used for phosphine.**

## Preparation for Fumigation

### Planning

Understand fully the facility and commodity to be fumigated, including the:

- Design of the structure, as well as adjacent and connecting structures both above and below ground.
- Persons or animals expected to be at or near the area to be fumigated.
- The commodity, its history (previous fumigation, temperature, moisture), condition, and intended purpose (seed or food processing).
- Availability of emergency shutoff stations for electricity, water and gas.
- Location of nearest telephone and numbers for fire or police departments, hospitals and physician.

Select a suitable fumigant. Understand label directions, warnings and antidotes. You should notify local medical, fire and police authorities and other security personnel about:

- Chemicals to be used.
- Proposed date and time of use.
- Type of respiratory protection required.
- Fire hazard rating.
- Name and phone number of person to contact in event of emergency.

Have alternate application and protective equipment and replacement parts available. Display warning signs near points of entry and provide for security of buildings. Have necessary first aid equipment available. Before treatment is started, develop plans to ventilate the area

when the treatment period is over. Post-treatment gas concentration levels must be determined and written records maintained to document that harmful levels have dissipated. Grain cannot be legally released back into commerce until this step has been completed.

### Premises Inspection

Once you decide to fumigate, make a serious on-site inspection. You must ask yourself a number of questions and make a number of decisions. Frequently, the success or failure of the fumigation operation will depend upon what you learn, what you decide and how you plan. Some of these questions should include:

- If the structure itself is not infested, could the infested commodity be moved from the building and fumigated elsewhere?
- Assuming that removal of the infested commodity from the building is not practical, can you fumigate the commodity in place?
- Is there enough room between the commodity and walls or partitions so you can seal the tarp to the floor.
- What is the volume of the commodity?
- What is the volume of the building?
- Can the structure itself be made reasonably airtight or will it be necessary to tarp the entire building?
- From what materials is the structure built? (Fumigants will pass through cinder block with no difficulty.)
- Are there broken windows that must be replaced?
- Are there cracks in the ceiling, walls or floors that must be sealed?
- Are there floor drains or cable conduits that will require sealing? (There have been a number of fumigation failures because floor drains under stacked commodities went

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# Fumigation of Stored Products

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- unnoticed. In one instance, the fumigant leaked into a telephone cable tunnel which led to an occupied building. No loss of life occurred, but a number of people were made ill.)
- How are you going to handle air conditioning ducts and ventilation fans?
  - Will interior partitions interfere with fumigant circulation?
  - Are the interior partitions gas tight so they can be relied upon to keep the fumigant from entering other parts of the structure?
  - Are there parts of the building not under your control?
  - Can these other operations be shut down during the fumigation?
  - What are the building contents?
  - Can any of them be damaged by the fumigant?
  - Can such items be removed during the fumigation?
  - If they cannot be removed, can they be otherwise protected?
  - Where are the electrical outlets?
  - Of what voltage are they?
  - Will the circuits be live during fumigation?
  - Can the outlets be used to operate your fumigant circulating fans?
  - Look outside the building. If you tarp the entire structure, can you make a good, tight ground seal?
  - Is there shrubbery next to the building that might be damaged either by the fumigant or by your digging to make an air-tight fumigation seal?
  - Can this shrubbery be moved?
  - How far is it to the nearest building?
  - Does that building have air conditioning?
  - Does it have air intakes that could draw the fumigant inside—particularly during aeration?
  - How are you going to aerate your structure after fumigation?
- Are there exhaust fans and where are the fan switches?
  - Are there windows and doors that can be opened for cross ventilation?
  - Does the building contain any high-priority items that may have to be shipped within a few hours notice?
  - Is the structure to be fumigated so located that your operations may attract bystanders? (If so, you should consider asking for police assistance to augment your own guards.)
  - Where is the nearest medical facility?
  - What is the telephone number of the nearest poison control center?
  - Once you are convinced that you have covered everything, prepare a checklist of things to do and of materials needed.
  - Don't rely upon your memory.

The final three questions:

- Am I qualified to do this job?
- What have I overlooked?
- Is fumigation still the best method of controlling the pest problem?

## Respiratory Protection Devices

### Gas Masks

The respiratory protection devices that furnish the minimum protection are the full-face gas masks. These are equipped with canisters. The canister must be suitable for protection against the fumigant being used. The canisters contain chemicals that absorb the fumigant, and also may contain a filter.

The life of the canister is limited and varies with the fumigant used and the fumigant concentration, temperature and respiration rate. The maximum permissible limits usually are stated on each canister. Do not exceed these maximum limits. The canister color codes for the various fumigants are:

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# Fumigation of Stored Products

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Fumigant	Color Code
Chloropicrin	Black
Methyl Bromide	Black
Aluminum Phosphide	Yellow with gray and orange stripe

There are several reasons for using devices other than full-face gas masks with chemical canisters for respiratory protection. The canisters have limited life. Special canisters must be available for each fumigant. The canisters provide no protection at abnormally high (over 2.0 percent) fumigant concentrations. Refer to labeling and Occupational Safety Hazard Association (OSHA) regulations for additional guidance. They provide no protection in spaces when oxygen is deficient.

### General Suggestions on Canister Use

1. Discard any canister that has been used for more than its suggested effective use time at 2 percent gas concentration.
2. Discard any canister whenever an odor of fumigant is detected as coming through (the absorption material is not working).
3. Discard canisters kept beyond the expiration dates or more than two years after manufacture (even if unused) unless instruction sheet specifically says otherwise.
4. Do not use a canister-type gas mask to enter a freshly fumigated area. The concentration of fumigant will overpower even new absorbent material.

### Air-line Masks

These devices have face pieces similar to the canister gas masks but rather than a canister, the masks are attached to hoses which lead to an air pump. The air then passes through a filter. One air pump can supply air for several air lines. This device permits the fumigators to operate within a space being fumigated for indefinite time (**Note: There is no protection against skin absorption of some fumigants.**)

The disadvantages of air-line masks are that the fumigators must tow the air-line with them. The air-line can become caught or kinked which will shut off the air supply. The engine may fail. The air pump must be located so that contaminated air is not pumped to the fumigator. Air-line masks used in “immediately dangerous to life and health” (IDLH) atmospheres must have an escape cylinder attached.

### Self-Contained Breathing Apparatus

There are two types of these devices. One is the air pack and the other is the oxygen breathing apparatus (OBA).

#### Air Pack

With this device, the full-face mask is attached to a tank of air carried on the back of the fumigator. This device gives the fumigator the mobility of the canister mask and does not tie him/her to an air pump. Again, this does not protect against skin absorption of the fumigant.

With the popularity of SCUBA diving, it is not difficult to get the air tanks refilled. Depending upon the size of the tank, the air supply will last up to an hour. There usually is a warning bell that warns the fumigator when the air supply is running low. The disadvantage of the air pack is that the fumigator has to carry a heavy tank to complete the work.

#### OBA

The oxygen breathing apparatus is similar to the air pack but instead of a tank to carry, a special canister generates the oxygen supply. The canister is lightweight and usually is worn on the chest. To operate, the fumigator places the canister into its place, tightens the connector and blows into the air supply tube once or twice. The moisture from the breath activates the chemicals in the canister which then provide a supply of oxygen. The supply is good for about one hour.

There usually is a warning bell that can be set to warn the fumigator that the life of the canister is about to

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# Fumigation of Stored Products

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expire. Care must be taken and directions closely followed for the disposal of the oxygen-generating canisters.

Note: All respiratory protection devices must be fit-tested to assure proper protection of the person using the device.

## Physical Examinations

All new employees should have a thorough physical examination before performing any fumigation duties. The examination should include a liver function test and a respiratory capability test (or equivalents).

All persons working with fumigants should have a complete physical examination every six to 12 months, depending on the amount of exposure. Again, the examination should include liver function capability and respiratory capacity.

## Fumigant Application

Always assign at least two persons to each fumigation. Everyone involved in the fumigation should know first aid and other emergency procedures, including personal decontamination.

Prior to applying the fumigant make sure that no one is within the structure to be fumigated. This is particularly critical if the structure to be fumigated consists of several adjoining rooms or spaces and/or is a multi-level structure.

Provide watchmen when appropriate. Secure entrances by guards or locks. Current law requires placarding of structures undergoing fumigation.

Wording must meet posting requirements (including name, phone number of fumigator, etc.) and warnings must appear in English and Spanish.

Follow label directions exactly when applying a fumigant. Consider prevailing winds and other pertinent weather factors such as temperature and humidity.

Return to the storage area all unused chemicals in clearly labeled, original containers. Dispose of empty containers correctly.

Report to company-retained physician or to designated personnel any indications of illness or physical discomfort, no matter how minor they seem. These symptoms and signs may include dizziness, nausea, headaches and lack of coordination.

Do not consume alcohol for 24 hours before or after a fumigation.

## Post Fumigation

Before re-entry, use a suitable gas detector as indicated on the label to determine fumigant concentration. Do not depend on odors. Some fumigant gases are odorless. Wear correct respiratory equipment.

Passive gas detection badges, which resemble X-ray exposure badges, change color or shading to inform wearers that their exposure to the fumigant may be reaching health-threatening levels.

Turn on all ventilating or aerating fans.

Check for gas concentrations in areas that are expected to aerate slowly.

Remove warning signs when the gas concentration is within safe limits for human exposure.

Remove and dispose of packaging and waste products of solid fumigants.

On those occasions when a fumigated area must be entered, portable bottled air systems with full-face mask are the safest choice. Absorptive filter masks can be used if steps are taken to make absolutely certain that the filter cartridges are replaced before they lose their effectiveness and if the fumigant concentration is not high. The "buddy" system should always be practiced; in grain bin fumigation, one person outside the bin but within eyesight and hearing range prepared to give aid if it is necessary.

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# Fumigation of Stored Products

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## Commodities/Pests to Consider for Fumigation

Most fumigation operations are directed toward the control of insect pests of stored grain, flour, meal, egg noodles, rice, spaghetti, spices, nuts and similar foods. Control of pests in a few packages of an item can be accomplished by either heat or cold. When large quantities are involved, fumigation is the answer.

If the infestation is light, the commodity may be used after fumigation. Even if the infestation is so heavy that the commodity will have to be destroyed after fumigation, fumigation may be warranted to prevent spread of the insects to uninfested items.

### Stored Grain

Granary weevil  
Red flour beetle  
Lesser grain borer\*  
Indian meal moth (larvae\*)  
Saw-toothed grain beetle  
Angoumois grain moth  
Flat grain beetle  
Rice weevil  
Cadelle or flour worm\*

### Flour and Flour Products

These include fry and cake mixes, spaghetti, macaroni, noodles, etc.  
Flour beetles (*Tribolium* sp.)

Rice weevil  
Cigarette beetle\*  
Granary weevil  
Drugstore beetle\*  
Indian meal moth (larvae\*)  
Cadelle\*  
Mediterranean flour moth  
Saw-toothed grain beetle

### Spices

Cigarette beetle\*  
Drugstore beetle\*  
Dermestids\*

### Nuts and Dried Fruit

Indian meal moth (larvae\*)  
Saw-toothed grain beetle  
Cadelle\*  
Flour beetles (*Tribolium* sp.)

### Dried Peas and Beans

Common bean weevil\*  
Cowpea weevil\*

### Tobacco

Cigarette beetle\*  
Drugstore beetle\*  
Dermestids\*

### Dehydrated Foods

(soups, powdered milk)  
Indian meal moth (larvae\*)  
Dermestids\*

\*Pests which can penetrate paper or plastic packaging.

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# Fumigation of Stored Products

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## Questions

1. (32) To be effective, fumigants must:
  - a. Be applied in enclosed areas
  - b. Reach a lethal concentration in all areas
  - c. Be held at a lethal concentration for a minimum amount of time
  - d. All the above
2. (32) Several factors can change the efficiency of fumigants:
  - a. Corrosive, flammability and explosive potential
  - b. The temperature and moisture of the grain mass
  - c. The fumigant availability and cost
  - d. The ease of application and residue tolerance
3. (33) Knowing and understanding the commodity, its history, condition and future use are important when planning to \_\_\_ for pest control.
  - a. ship it to China
  - b. fumigate it
  - c. store it
  - d. sell it quickly
4. (33) Before a fumigated commodity can be legally released back into commerce,
  - a. it must pass a USDA inspection.
  - b. it must pass an EPA inspection.
  - c. it must pass a Kansas Department of Agriculture inspection.
  - d. written records documenting harmful levels of the fumigant have dissipated must be maintained.
5. (34) One of the final questions you should ask before doing a fumigation is:
  - a. What is the volume of the commodity?
  - b. What is the voltage of electrical outlets in the men's room?
  - c. What have I over looked?
  - d. Does the building have air conditioning?
6. (34) The respiratory device that furnishes the minimum protection is the:
  - a. Full-face gas masks
  - b. Air-line masks
  - c. Air packs
  - d. Oxygen breathing apparatus
7. (35) Use of \_\_\_ in "immediately dangerous to life and health" (IDLH) atmospheres must have an escape cylinder attached.
  - a. air pack
  - b. air-line masks
  - c. full-face gas masks
  - d. OBA's
8. (35) The air pack is an example of a type of:
  - a. Air-line mask
  - b. Full-face gas mask
  - c. Self-contained breathing apparatus
  - d. OBA
9. (36) Medical physical examinations of persons working with fumigants should include:
  - a. A hearing and taste test
  - b. A liver function and respiratory capability test
  - c. A smell and flexibility test
  - d. A sight and touch test
10. (36) Before re-entering a fumigated area, you should \_\_\_ to determine the fumigant concentration.
  - a. release a canary in to the structure
  - b. send an EPA inspector in to the structure
  - c. use a suitable gas detector as indicated on the label
  - d. send a lawyer in to the structure
11. (37) Fumigation of a heavy infestation may be warranted even though the commodity will still be destroyed because:
  - a. Fumigation leaves no residue.
  - b. Fumigation will prevent the pest from spreading to uninfested items.
  - c. Fumigation is less expensive than spraying.
  - d. Fumigation can be carried out over night in most cases.

# Fumigation

## Methods for Stored Grain

**Note:** After June 30, 1986, the traditional liquid grain fumigants (carbon tetrachloride, carbon disulfide, ethylene dibromide, ethylene dichloride, etc.) were no longer legal for use.

### General

There are several important factors common to all fumigant application procedures.

- All fumigants are restricted use pesticides and as such, applicators must be certified or under the direct supervision of a certified applicator to obtain or use them.
- A plan should be devised for application, aeration, monitoring and disposal of the fumigant so as to minimize applicator exposure to the gas.
- Provision should be made for uniform distribution of the gas throughout the storage space being fumigated.
- The condition of the storage facility and the materials from which it is constructed may determine the feasibility of obtaining a safe, effective fumigation, i.e. whether the enclosure can be properly sealed to retain a toxic concentration of gas long enough to kill target insects.
- Follow all dosage, exposure, precautionary and safety statements on the label and technical labeling. Placard fumigated structures, monitor gas concentrations and use required respiratory protection.
- When applying fumigants from within the space being fumigated, two trained individuals are required.

The following suggestions are intended to provide general guidelines for typical fumigations. They are not intended to cover every type of situation nor are they meant to be

restrictive. Other procedures may be used if they are safe, effective and consistent with the fumigant and its labeling.

### Fumigation of Farm Bins

- Leakage is the most important cause of failure in the fumigation of farm storages. Since storages often are small, the leakage is high in proportion to the capacity. Most wooden structures are too porous and should be completely covered by a gas-tight sheet for successful fumigation.
- Seal the bin as tightly as possible, especially doors, eaves, hatches, vents, and aeration/auger ports.
- Surface of the grain should be leveled and below the storage side walls. Fines should be uniformly distributed throughout the grain mass.
- Since solid forms (tablets or pellets) of phosphine are most likely to be used, provision must be made to distribute the gas uniformly throughout the grain mass. This may be accomplished (follow label directions) by:
  - probing tablets or pellets into the grain at regular intervals over the surface and to depths of 5 to 7 feet (Figure 13).
  - covering the surface of the grain with polyethylene sheeting after applying the fumigant from the surface will greatly reduce the leak rate.
  - additionally, applying no more than 25 percent of the total dosage at the bottom if the bin is equipped with an aeration system. Caution: Make sure the aeration duct or plenum is dry before adding fumigant tablets or pellets to this space. Addition of metallic phosphides to water may result in a fire. Seal the aeration opening with 4 mil polyethylene.

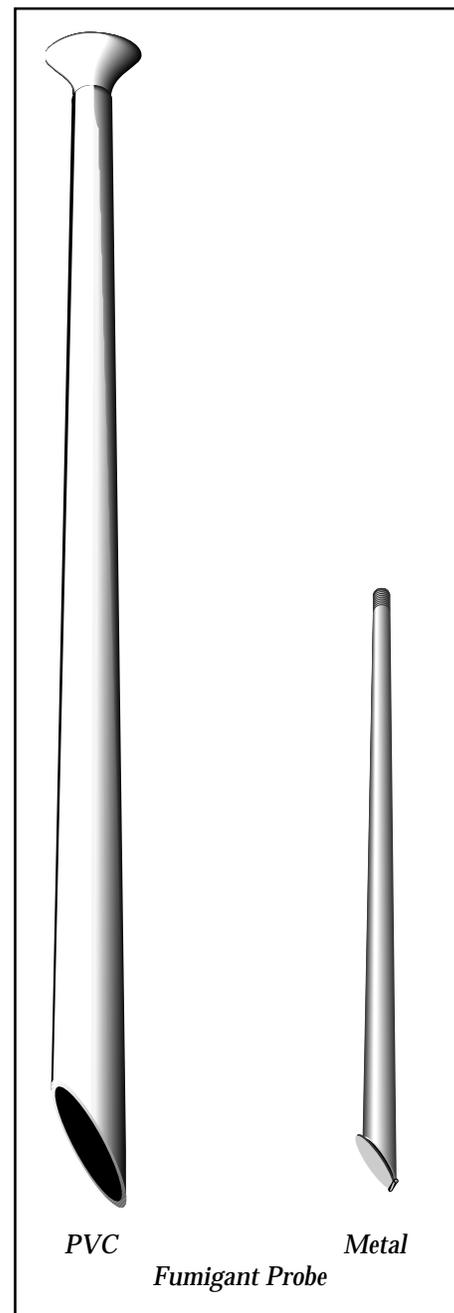


Figure 13

# Fumigation

## Methods for Stored Grain

- Larger bins that are properly sealed (bolted or welded construction) may be fumigated by applying the solid phosphine tablets or pellets over the surface of the grain and recirculating the fumigant through the grain by means of a small fan and duct system (closed loop fumigation) as in Figure 14. Gas generated at the surface of the grain is taken from the over-space and introduced into the grain at the bottom of the bin and distributed upward through the grain. For details

of this method see “Stored Product Management” available from the Cooperative Extension Service, Oklahoma State University.

- If the grain can be moved from one bin to another, uniform distribution of the gas can be obtained by adding the solid tablets or pellets to the grain as it is placed in storage.

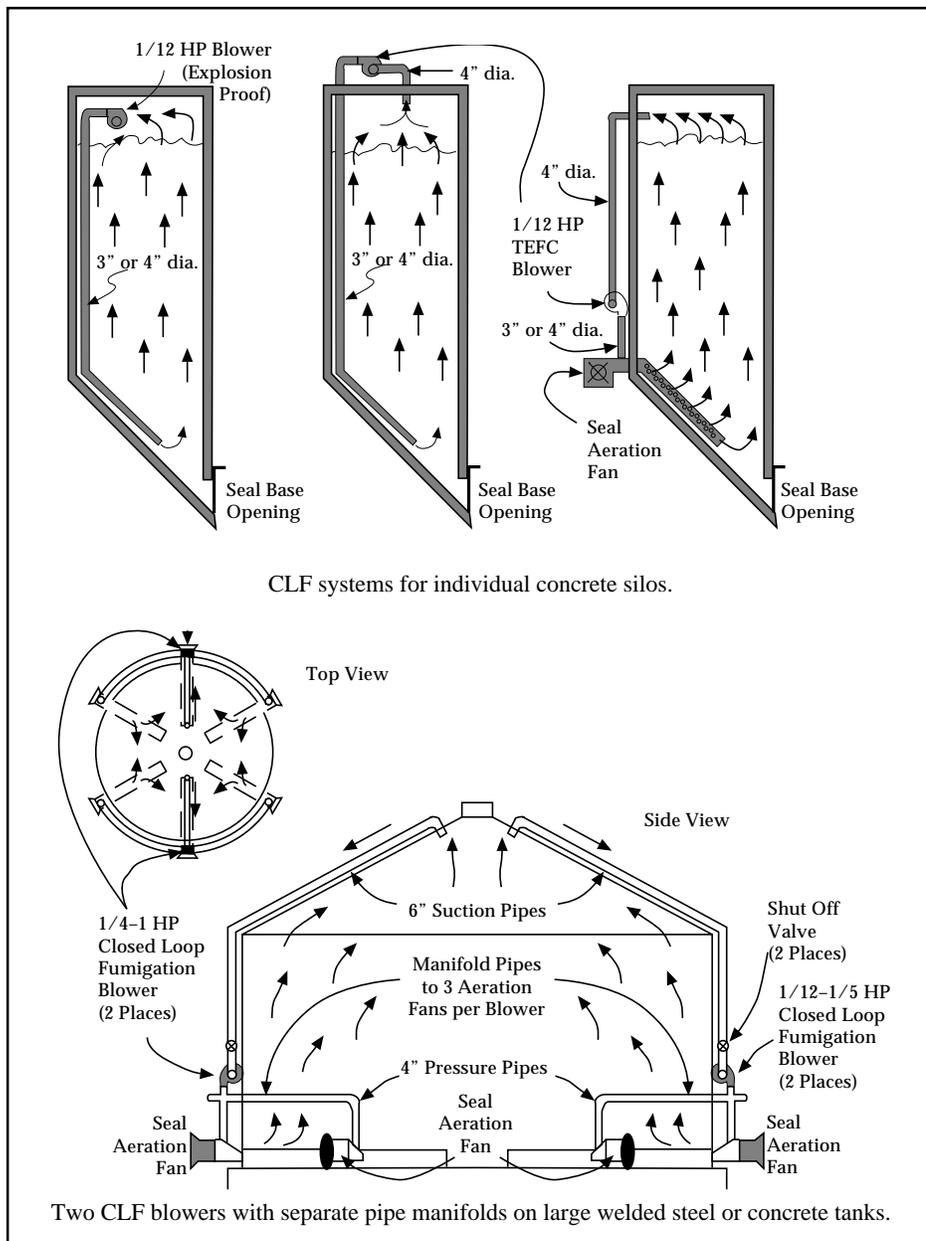
### Fumigation of Flat Storages

Fumigation of flat storages with solid tablets or pellets to generate phosphine may require considerable effort. Sufficient numbers of individuals should be available to complete the application rapidly enough to prevent excessive applicator exposure and minimum loss of gas from the storage.

- Conduct fumigations during cooler periods and employ other physical means and work practices to prevent applicator exposure.
- Seal any doors, vents, aeration ducts, cracks or other sources of leaks.
- Establish a plan for application of phosphine tablets or pellets to the grain to provide uniform distribution of the gas in the grain mass.
  - Apply phosphine tablets or pellets to the grain by probing at intervals along the length and width of the flat storage.
  - Tablets or pellets may be deposited within the grain mass by intermittently dropping them into the probe as it is withdrawn from the grain.
  - Tarp the surface of the grain as it is treated to prevent excessive loss of gas from the grain.

- It is unlikely that flat storage structures would be sufficiently well sealed to allow closed loop fumigation with phosphine or recirculation with methyl bromide (See fumigation of vertical storages).

Figure 14



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## Fumigation

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### Methods for

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### Structures and

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### Other Enclosures

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#### Fumigation of Vertical Storages

Concrete upright bins and other silos in which grain can be rapidly transferred provide the opportunity to use automated systems of fumigant application.

- Close and seal all openings to make the structure as airtight as possible. Prior to fumigation, seal the bin discharge and the vents near the bin top which connect to adjacent bins.
- Pellets or tablets may be applied continuously by an automatic dispenser or by hand as the grain is turned or loaded into the bin.
  - Application can be at various locations in the grain stream, i.e. conveying belt or conveyor to the bin, at entry to the bin, or in the up leg of the elevator by automatic dispenser.
  - Seal and placard the top hatch of the bin when the fumigant application is complete.
- Phosphine also may be applied using the “closed loop fumigation” method.
  - Pellets or tablets are placed on the surface of the grain in the bin using the headspace to generate the gas.
  - The gas is then moved by duct and fan to the bottom of the bin and up through the grain.
- Methyl bromide gas is best applied by the recirculation method in elevator silos.
  - Methyl bromide, compressed as a liquid in cylinders, is released as a vapor into a fan and duct system which includes the silo as part of the system.
  - The gas is recirculated through the grain for the prescribed exposure period to allow uniform distribution of the gas throughout the grain mass. The gas is then exhausted from the grain to

prevent damage or excessive bromide levels in the grain.

- When fumigating silos in grain elevators, adjacent areas must be carefully monitored for the presence of hazardous levels of gas.
  - Gas levels in work areas must not exceed 0.3 ppm for phosphine or 5 ppm for methyl bromide.
  - Pockets of methyl bromide may accumulate in low areas (boot pits, etc.) because it is heavier than air.

#### Fumigation of Structures, Facilities and Other Enclosures

##### Fumigation of Food Processing Plants and Warehouses

Safe, effective fumigation of entire structures requires extensive planning and preparation. This type of treatment is primarily aimed at disinfesting the structure and its equipment rather than destroying an infestation in a commodity, such as grain.

- Check with appropriate authorities to become familiar with local regulations regarding fumigations.
- Notify fire, police, medical and other local authorities (as required) of the fumigation.
- Select a fumigant that will allow effective treatment of the facility within the available time.
  - Using the labeling, calculate the dosage and exposure period based on the volume and tightness of the structure.
  - Note any physical and/or chemical hazards related to the fumigant.
- Prepare the facility for fumigation by sealing the structure to prevent gas leakage.
  - Close and seal all external openings, including windows, doors, exhaust ventilators, air intakes, drain pipes, tunnels, etc.

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# Fumigation

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## Methods for

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## Structures and

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## Other Enclosures

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- Processing equipment within the structure, i.e. bucket elevators, conveyors, hoppers, bins, spouts and other pieces of equipment should be opened to allow fumigant penetration.
- Establish a plan to minimize exposure of applicators during release of the fumigant and during aeration of the structure. Have personal protective equipment available and be aware of the maximum exposure levels for the fumigant being used.
- Immediately prior to introducing the fumigant, check that all entrances are locked and placarded and that all personnel have left the facility. In some instances, it may be necessary to post watchmen or guards to preclude persons from entering the fumigated facility.
- Apply the fumigant according to the label and technical labeling.
- Following the fumigation, aerate the facility.
  - Using gas detection equipment, monitor the gas levels to assure proper aeration and that the facility is safe for workers to enter.
  - Specific attention should be given to ventilating enclosed and low areas in the facility to assure that heavier than air gases have been removed.
- Remove any fumigant residues and/or containers and the fumigation warning placards.
- Bulk commodities to which phosphine producing tablets or pellets may be added directly are fumigated essentially the same as flat storages with the transport vehicle acting as the “storage structure.”
  - Railcars and containers shipped piggyback by rail may be fumigated in transit.
  - It is illegal to move fumigated trucks, trailers, vans, etc., over public roads until they have been aerated.
- Processed food commodities also may be fumigated in transport vehicles, with the exception that residues of tablets, pellets or other phosphine forms are not allowed in or on the processed products or their packaging.
  - Various forms of packaging for aluminum and magnesium phosphide are available to preclude or contain the dust residues that remain when phosphine gas is generated.
  - Only railcars and containers shipped piggyback may be fumigated in transit.
- Consignees of railcars and containers fumigated in transit must be aware and trained for proper monitoring of gas concentrations in the vehicle and processed commodity at time of receipt.
- Empty transport vehicles occasionally may be fumigated to assure they are not infested before use to transport processed food products.
- All transport vehicles must be properly placarded during fumigation.
- Shipboard, intransit ship or shiphold fumigations are governed by U.S. Coast Guard Regulations. Both phosphine and methyl bromide are labeled for use.

### Fumigation of Transport Vehicles

Railcars, containers, trucks, vans, and other transport vehicles, either empty or loaded with commodities, may, at times, require fumigation. Very specific conditions apply to this type of fumigation and it is suggested that the labeling be referred to for guidance. Some general guidelines are as follows:

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# Fumigation

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## Methods for

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## Structures and

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## Other Enclosures

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### Vault Fumigation

Atmospheric and vacuum vaults are chambers primarily designed for fumigation of small lots of commodities or materials. They can be small structures located well apart from other facilities or special chambers within a structure. Some are specially built for fumigation, others are modified from other structures.

- Atmospheric vaults are simple gas-tight chambers that provide a constant volume space for fumigation with either methyl bromide or phosphine.
  - Application of fumigant and aeration can be accomplished with minimum exposure for the applicator.
  - Chambers should be placarded when in use.
- Vacuum fumigation vaults are specifically designed for fumigation under reduced pressures.
  - Vacuum vaults allow fumigation of sensitive commodities and other items with reduced dosages and exposure times.
  - Application of the fumigant and aeration usually are automated. After fumigation, release of the vacuum should be followed by two changes of air in the chamber.
  - Limited uses of methyl bromide are labeled for vacuum fumigation.

### Tarpaulin Fumigation

Tarpaulin fumigation involves the placement of a gas-tight material over the commodity or structure to

be fumigated. Tarps may be specially made for fumigation, such as impregnated nylon, or they may be sheet polyethylene.

- Use of plastic sheeting to cover commodities is one of the easiest and least expensive means for providing relatively gas-tight enclosures for fumigation.
  - The volume of these enclosures can vary widely from a few cubic feet to covering an entire storage structure.
  - Plastic sheets may be sealed together to provide sufficient width of material to cover large stacks of commodity and provide for adequate sealing to the floor or other surface.
  - If the base on which the commodity rests is of wood or other porous material, the commodity should be repositioned onto polyethylene prior to being covered for fumigation.
  - The plastic covering of the commodity must be sealed to the floor. Use sand or water snakes (plastic or fabric tubes filled with sand or plastic tubes filled with water) or other means for sealing.
- Method of fumigant application will vary depending on the commodity and/or fumigant. Follow label directions.
- Place warning placards at conspicuous points on the enclosure.

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# Fumigation Methods

## for Stored Grain,

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## Structures and

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## Other Enclosures

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### Questions

1. (39) In the fumigation of farm storage bins, \_\_\_ is the most common cause of failure.
  - a. insufficient dosage of fumigant is applied
  - b. temperature of grain is too low
  - c. the moisture of the grain is too high
  - d. leakage of gas from the bin
2. (39) Provisions to distribute gases uniformly throughout the grain mass include:
  - a. Probing tablets/pellets in to grain at regular intervals
  - b. Covering the grain surface with a polyethylene sheeting after fumigant application
  - c. Apply no more than 25% of the dosage at the bottom of the bin with aeration equipment
  - d. All the above
3. (40) When fumigating flat storages, you should:
  - a. Conduct fumigations during cool weather
  - b. Seal all sources of possible leaks
  - c. Have a plan to provide uniform gas distribution
  - d. All the above
4. (41) Vertical grain storage bins and silos with rapid grain transfer systems:
  - a. provide an opportunity for automated fumigant application
  - b. can not be legally fumigated
  - c. can only utilize liquid fumigants
  - d. can only be fumigated during July
5. (41) Fumigant gas levels in work areas must not exceed \_\_\_ ppm for phosphine.
  - a. 0.3
  - b. 0.7
  - c. 1.0
  - d. 5.0
6. (41) Whole structure fumigation is primarily aimed at:
  - a. controlling pests in packaged goods
  - b. disinfesting the structure rather than the contents
  - c. controlling pests of stored wheat
  - d. controlling pests of stored corn
7. (42) It is legal to fumigate only \_\_\_ while in transit:
  - a. trucks
  - b. trailers
  - c. railcars
  - d. vans
8. (43) Atmospheric vault fumigation means that:
  - a. The fumigation is in a vault up high in the atmosphere
  - b. The atmosphere is pressurized in the vault to control the pests
  - c. The atmosphere (air) is pumped out of the vault, thereby suffocating the pests
  - d. The fumigant is released in to the vault at normal atmospheric pressure
9. (43) Vacuum vault fumigation means that:
  - a. The vault is placed in a vacuum before the gas is released
  - b. The vault is designed for fumigation under reduced atmospheric pressure
  - c. The commodity is put in a vacuum before going in to the vault
  - d. The atmosphere (air) is pumped out of the vault, thereby suffocating the pests
10. (43) The fumigation technique of covering the commodity or structure to be fumigated with a gas-tight material is called:
  - a. Atmospheric fumigation
  - b. Vacuum fumigation
  - c. Tarpaulin fumigation
  - d. Transport fumigation



## Aluminum and Magnesium Phosphides

**Properties:** Various forms of aluminum or magnesium phosphides react with moisture to evolve phosphine gas ( $\text{PH}_3$ ). Hydrogen phosphide gas is highly toxic to insects, burrowing pests, humans and other forms of animal life. In addition to its toxic properties, the gas will corrode certain metals and may ignite spontaneously in air at concentrations above its lower flammable limit of 1.8% (v/v).

Phosphine easily penetrates into products, but being only slightly heavier than air (sp. gr: 1.214) can easily be moved by convection or other air currents. To maintain toxic concentration of the gas requires tight sealing of the space being fumigated.

Tablets and pellets are formed by adding paraffin and commonly include ammonium carbonate which liberates ammonia and carbon dioxide. These gases are essentially non-flammable and act as inert agents to reduce fire hazards. Ammonia gas also serves as a warning agent.

**Human Hazards:** Tablets, pellets or dust that are swallowed, or if gas is inhaled, are highly toxic to humans. The maximum safe exposure limit (for 40 hours/week) is 0.3 ppm (0.00003 percent) in air. Garlic odor warns of toxic concentrations but may not always be present above 0.3 ppm. Gas detectors should be used to ensure safe working levels. Symptoms include fatigue, ringing in ears, nausea, pressure in chest, intestinal pain, diarrhea and vomiting.  $\text{PH}_3$  apparently is not chronic and is not absorbed through the skin in appreciable amounts.

**Physical/Chemical Hazards:** Aluminum and magnesium phosphide tablets, pellets and dust will rapidly release  $\text{PH}_3$  when exposed to moisture in the air, or to water or other liquids. High concentrations of gas may cause an increase in

temperature and may ignite spontaneously. Metals such as copper, brass and other copper alloys, and precious metals such as gold and silver are subject to corrosion by phosphine.

**Uses:** READ THE LABEL. Tablets usually are probed into grain in shallow storage structures. Pellets usually are introduced in grain by automatic applicators as grain flows into vertical storage bins. Sachets and various other forms of packaged aluminum or magnesium phosphide are used in other specialized types of fumigation. Refer to product technical labeling for specific applications and uses. Tolerances have been set for residues on raw agricultural commodities and on processed cereal products.

## Methyl Bromide (MB)

**Properties:** At normal temperatures and pressures, methyl bromide is an odorless, colorless gas. It is generally transported in cylinders under pressure as a liquid. The gas is over three times heavier than air (sp. gr: 3.27). MB quickly and deeply penetrates into grains and cereal products under normal atmospheric conditions and following fumigation the vapors dissipate rapidly. Repeated or excessively high dosage fumigations of seeds or cereal product may result in reduced viability of the seeds and cumulative increase in inorganic bromide residues in raw agricultural products and processed cereal products.

**Human Hazard:** This gas is not as toxic as some other fumigants, however, because it lacks an odor it must be handled with extreme caution. Liquid MB in contact with the skin will cause severe blisters. The maximum safe exposure limit is 5 ppm. Acute and chronic symptoms may occur. Acute exposure causes pulmonary injury and circulatory failure. Chronic exposures result in neurological symptoms (headache, incoordination, visual disturbances) which are often irreversible. Delayed symptoms and lack of odor make this fumigant hazardous to use.

# Types of Fumigants

The presence of MB gas can be detected by halide leak detectors but more reliably it is measured by detector tubes or thermal conductivity.

**Physical/Chemical Hazards:** Methyl bromide in air is considered non-flammable; however, liquid methyl bromide in contact with aluminum may result in spontaneous ignition. Certain commodities (iodized salt, sponge rubber, leather goods, viscose rayons, photo chemicals, etc.) should not be exposed to MB.

**Uses:** READ THE LABEL. MB readily penetrates flour and milled products and has been used for this purpose. However, because of potential residue problems this use has diminished. MB fumigation of grain requires gas recirculation systems which are not common in most farm and elevator facilities. Grain processing facility fumigation has constituted a major use of this gas, however, the declaration of MB as an ozone depletor is changing this situation. Refer to technical labeling for specific applications and uses. Tolerances have been set for inorganic bromides on raw agricultural and in processed cereal products.

## Chloropicrin (CP)

**Properties:** Commonly known as “tear gas,” this clear liquid evolves an intense burning vapor. Because of this property, chloropicrin has been used as a warning agent in some MB formulations. It is one of the most toxic fumigants to insects. Even though “tear gas” is over five and a half times as heavy as air (sp. gr.: 5.676), when it was used as a grain fumigant it was absorbed by the grain and was not effective in penetration to any depth in the bin. Commodities tended to release the absorbed gas slowly, making it unpleasant to handle.

**Human Hazards:** The “tear gas” effect of chloropicrin is helpful in preventing persons from staying in dangerous concentrations of the gas. A concentration of 2.4g/m<sup>3</sup> (=240 ppm) can cause death from acute pulmonary edema in one minute. A concentration as low as 1 ppm in air causes an intense smarting pain in the eyes and the reaction is to leave the area immediately. Continued exposure may cause serious lung injury. The maximum safe exposure limit is 0.1 ppm.

**Physical/Chemical Hazards:** Chloropicrin is a non-flammable liquid that may be corrosive under certain conditions. Do not use water to clean equipment or use magnesium, aluminum, or alkali metals as containers.

**Uses:** Chloropicrin is no longer labeled for direct application to grains; however, it is effective in destroying infestation in full-floor aeration bottoms or empty grain bins.

## Threshold Limit Values

Threshold limit values (TLV’s) for fumigants are listed in Table 5. They refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effects. These TLV’s are based on time weighted average concentrations for a normal 8-hour work day or 40-hour work week.

**TABLE 5.**  
**Exposure to Fumigants**

Substance	Threshold limit values (TLV’s) for workers exposed to fumigants during a normal 8-hour work day or 40-hour work week*		Fumigant odors and detection levels	
	ppm <sup>a</sup>	mg/m <sup>3</sup> <sup>b</sup>	Odor detection ppm	Odor
Phosphine	0.3	0.4	1	Garlic
Methyl bromide	5.0	60	—	No odor
Chloropicrin	0.1	0.7	1–3	Strong, Biting

\*Source—American Conference of Governmental Industrial Hygienists, Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH for 1979; P.O. Box 1937, Cincinnati, Ohio 45201. The TLV’s in the table should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations. They are subject to variation and the latest documentation should be consulted for the most current values. V.K. Rowe, DowElanco Chemical Company, Research Department.

<sup>a</sup>Parts of vapor or gas per million parts of contaminated air by volume at 25°C and 760 mm H.G. pressure.

<sup>b</sup>Approximate milligrams of substance per cubic meter of air.

# Types of Fumigants

## Safe Use of Fumigants

Grain fumigants are commonly used around storage facilities in elevators, feed manufacturing, and food processing plants. Because of this, there is a tendency for employees who work with fumigants and fumigated materials to become lax in their safety precautions.

ALL FUMIGANTS CAN BE LETHAL if they are used carelessly or without adequate safety precautions.

Phosphine and chloropicrin are highly toxic; methyl bromide also is hazardous to humans. There are also physical hazards associated with fumigants.

Humans can be poisoned by inhaling the gases of fumigants and by absorption through the skin (depending on the fumigant). Most commercial products have an unpleasant odor but the pure chemicals can either be odorless or have a sweet smell. Also, humans may become insensitive to the odor of a fumigant.

Continued intake of methyl bromide, whether it be by inhalation, skin contact or other means, results in damage to body organs and tissues. This damage is not readily apparent to the individual, especially in the early stages, but it is irreversible and can proceed to a point where the person affected becomes unable to continue working. Instances are known where the effect has accumulated over a 20-year period leaving the victims in unemployable condition and too old to switch to non-hazardous, lighter duty work.

All workers in areas where fumigants are being used or where fumigated commodities are being handled should be aware of the symptoms of light exposure to the fumigants. Such symptoms are warnings that the concentration of fumigants in the air is too high for continued personnel safety.

## Symptoms of Fumigant Poisoning

The following are symptoms of light exposure of chronic fumigant poisoning:

1. Headache.
2. Dizziness and equilibrium disturbances.
3. Visual disturbances.
4. Irritation of respiratory tract (leads to more "lung colds," asthma attacks, and other lung and throat problems).
5. Narcosis (desire to sleep, drowsiness).
6. Muscle cramps—especially in arms and legs.

NOTE: The ingestion of alcoholic beverages (from 24 hours before to 24 hours after exposure) will intensify the symptoms and effects of fumigant poisoning.

## Safety Precautions

### Warning Signs (Placards)

Warning signs must be posted on doors and other means of access before fumigants are used in any structure. The applicator must place or post all entrances to the structure under fumigation with signs (Figure 15) bearing in English and Spanish:

- The signal word DANGER/ PELIGRO and the SKULL and CROSSBONES symbol in red.
- The statement "Area and/or commodity under fumigation, DO NOT ENTER/NO ENTER."

Table 6.

Fumigant	Fumigant Toxicity and Flammability		
	Toxicity to		Flammability (Explosive concentrations in air)
	Grain insects	Humans	
Phosphine	High	Very high	Very (1.79%)*
Methyl bromide	Moderate	Medium	Nonflammable
Chloropicrin	Very high	Very high	Nonflammable

\*Phosphine reacts with copper and copper alloys giving severe corrosion. Such metals should be protected from the gas.

# Types of Fumigants

- The statement, "This sign may only be removed after the commodity is completely aerated (contains 0.3 ppm or less of hydrogen phosphide gas; 5.0 ppm or less of methyl bromide; 0.1 ppm or less of chloropicrin). If incompletely aerated commodity is transferred to a new site, the new site must also be placarded if it contains more than \_\_\_\_\_ (the amount indicated for a specific fumigant label). Workers must not be exposed to more than \_\_\_\_\_ (amount indicated for a specific fumigant label)."
- The date and time fumigation begins and is completed.
- Name of fumigant used.
- Name, address and telephone number of the applicator.

Warning signs must not be removed until the treated commodity or structure is aerated to the designated safe level for entry. To deter-

mine whether aeration is complete, each fumigated commodity, structure or vehicle must be monitored and shown to contain the designated safe level of gas or lower.

## Security Guards

Security guards may be necessary if the structure is at an exposed location where the public (especially children) may attempt unauthorized entry. Security guards also may be needed if plant operations do not permit the security of the fumigated area.

Guards must have the authority to refuse entry to anyone not wearing protective equipment. They should have suitable protective equipment available if an emergency requires entry into the fumigated area. They also should be trained in first aid procedures for fumigant poisoning and have the appropriate materials readily available.

## Precautions

Precautions include an accounting for all personnel known to be working in the area, a room-by-room and floor-by-floor check to ascertain that no person has been overlooked and the use of a portable public address system (bull horn) in each space to warn anyone present of the imminent fumigation. If bells, whistles or other devices are used to give warning signals, all personnel must have been instructed as to the meaning of these signals.

Doors, windows and other points of access must be locked or otherwise secured against accidental or unauthorized entry into fumigated areas. Preferably there should be one person ultimately responsible for evacuating all people, securing the affected area and restricting access until the area has been cleared of the fumigant.

Notices of fumigated areas must be provided to night watchmen, janitors, maintenance crews and others who have master keys and ready access into the fumigated area. None of these should enter a fumigated area except in an emergency, and then only with adequate protection.

Figure 15

# DANGER

## PELIGRO

**AREA AND/OR COMMODITY UNDER FUMIGATION, DO NOT ENTER/NO ENTRE**

**This sign may only be removed after commodity is completely aerated (contains 0.3 ppm or less phosphine gas). If incompletely aerated commodity is transformed to a new site, the new site must also be placarded and workers must not be exposed to more than 0.3 ppm phosphine.**

### FUMIGATION WITH

**Brand Name:** \_\_\_\_\_

Fumigation Being Performed By	Date of Fumigation	Emergency Telephones
NAME: _____	Date Applied _____, 19____ Day: _____	_____
ADDRESS: _____	_____ AM _____ PM	Night: _____
_____	Do not open _____, 19____	
	Before _____ AM _____ PM	

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# Types of Fumigants

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The following EPA statement is required:

Fumigated areas must be placarded on all entrances with signs containing at least the signal word "DANGER" and the skull & crossbones and the words "Area under fumigation, do not enter until completely aerated," the date of fumigation, name of the fumigant used, emergency telephone number to contact and the name and address of the fumigator. Do not remove warning signs until the fumigated area is completely aerated and safe for entry, as indicated by a suitable detector.

Other prefumigation precautions are:

1. All possible sources of fire must be eliminated. Turn off all pilot lights, gas burners, oil burners and electrical equipment.
2. If possible, provide for the start of post-fumigation ventilation by controls outside of the fumigated area.
3. If several floors or rooms are involved, rehearse the fumigation sequence so everyone knows where the others are and where to exit the area.

4. Discuss emergency plans for handling all possible problems.
5. Locate a nearby telephone for use in case of an emergency.
6. Have fumigant testing equipment available and check it for proper operation.
7. Have first aid materials ready and available.

All areas, both those fumigated and nearby connected buildings, must be thoroughly ventilated before any person is allowed to enter.

Special attention must be given to basements and pits. Some gases are heavier than air and tend to accumulate and remain in low places where they can be hazardous to any human or animal entering such places.

## Fumigation References

There are a number of good references on fumigation and pests controlled by fumigation. For the most current information on fumigants and fumigation, refer to current labels and technical labelling for information on using specific fumigants effectively and safely.

Bond, E. J. 1984. Manual of Fumigation for Insect Control. FAO Plant Production and Protection Paper 54. Rome: Food and Agriculture Organization of the United Nations, 432 p.

This publication has a very thorough coverage of fumigants and fumigation. It is available from UNIPUB, Inc., 4611-F Assembly Drive, Lanham, MD 20706-4391

Krischik, V., G. Cuperus and D. Galliard 1995. Stored Product Management. (Revised from Management of Grain, Bulk Commodities, and Bagged Products, 1991) Circular Number E-912, Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. 242 p.

There are several chapters devoted to stored-product insects and integrated pest management techniques (including Chemical Management, Practical Fumigation Techniques and Closed Loop Fumigation) in this publication.

Mallis, A. 1982. Handbook of Pest Control. New York: Mac Nair-Dorland Company, 1101 p.

This general publication has sections on stored-product pests and a good section on fumigation.

Mills, R. and J. Pedersen 1990. A Flour Mill Sanitation Manual. St. Paul: Eagan Press. 164 p.

Stored-product pests are discussed in relation to an integrated approach to pest management in a cereal food processing situation.

Sauer, D. ed. 1992. Storage of Cereal Grains and Their Products. St. Paul: American Association of Cereal Chemists, Inc.

This publication has chapters describing stored-product pests and various aspects of their control, including fumigation.

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# Types of Fumigants

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## Questions

1. (45) Aluminum and magnesium phosphides involve \_\_\_ gas which is toxic to many forms of animal life.
  - a. phosphine
  - b. methyl bromide
  - c. carbon tetrachloride
  - d. ethylene bromide
2. (45) The maximum safe exposure limit to methyl bromide gas is \_\_\_ ppm.
  - a. 2
  - b. 3
  - c. 4
  - d. 5
3. (46) Methyl bromide liquid in contact with \_\_\_ may result in spontaneous ignition.
  - a. iodized salt
  - b. photo chemicals
  - c. aluminum
  - d. sponge rubber
4. (46) Threshold limit values (TLV's):
  - a. Represent the maximum toxic levels for the pests
  - b. Represent the minimum toxic level for most pests
  - c. Represent the conditions believed safe for nearly all workers
  - d. Represent the level of methyl bromide that can be smelled by humans
5. (47) Continual intake of \_\_\_ by inhalation, skin contact or other means results in damaged body organs and tissues.
  - a. carbon dioxide
  - b. nitrogen
  - c. chloropicrin
  - d. methyl bromide
6. (47) Symptoms of light exposure to fumigants include:
  - a. Headache
  - b. Dizziness
  - c. Irritation of a respiratory tract
  - d. All the above
7. (48) Fumigant warning signs (placards) must not be removed until:
  - a. 1 hour after fumigant application
  - b. 2 hours after fumigant application
  - c. 3 hours after fumigant application
  - d. aeration is completed
8. (48) Security guards at fumigation jobs:
  - a. Must have authority to refuse entry to anyone
  - b. Should have suitable protective equipment available for emergencies
  - c. Should be trained in first aid
  - d. All the above
9. (48) Precautions for fumigation include:
  - a. An accounting for all personnel known to be working in the area
  - b. A room-by-room check to be sure nobody has been overlooked
  - c. A public address system to warn anyone present
  - d. All the above

# Vertebrate

## Pests

The term ADC refers to animal damage control. Animal damage control is practiced as a field of specialization within the wildlife management profession. In Kansas, Kansas State University provides a headquarters for governmental assistance and advice in animal damage problems either from the United States Department of Agriculture, Animal, Plant Health Inspection Service, Animal Damage Control (USDA-APHIS-ADC), Kansas Department of Wildlife and Parks and/or the Cooperative Extension Animal Science Animal Damage Control program. Because of the wide variety of possible wild animal problems, changing land, and changing product registration, we encourage people confronted with a problem of this nature to contact your local extension office for specific information.

Wild animals generally are thought of as having value, whether measured by economic, recreational or aesthetic standards. However, the activities of some wild animals can conflict with the endeavors of people.

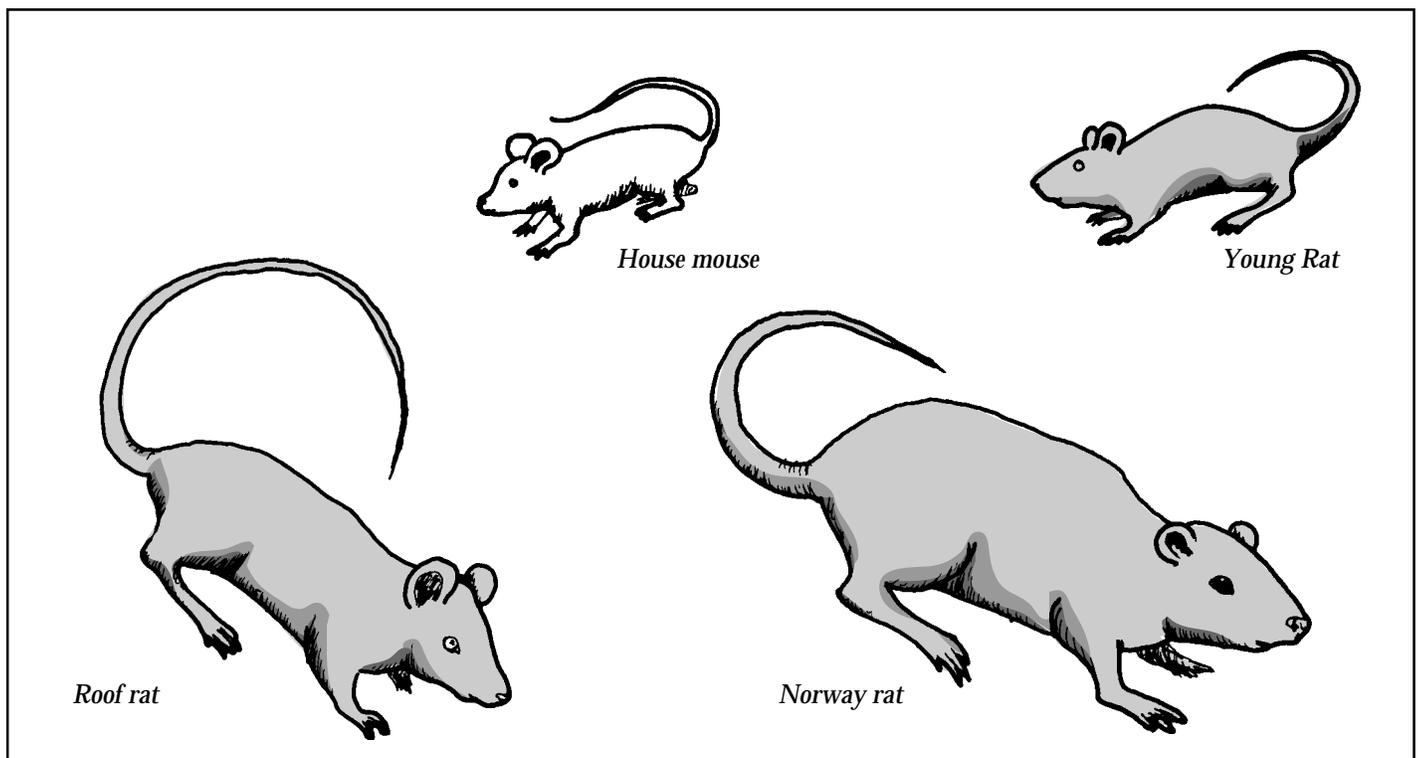
In fact, each year rodents and birds destroy or contaminate enormous amounts of stored grain. One rat eats about 50 pounds of grain per year, wastes twice that much, and contaminates much more. Even a slight contamination of grain placed in interstate shipment for food processing purposes causes contamination of the entire car load. Rodents, called commensal rodents, are the worst problem. These are the non-native Norway rat and house mouse. Rarely, the roof rat can be found in Kansas. There are 23 other field rodents that seldom, if ever, live indoors. One of these field rodents, the deer mouse, will sometimes be found indoors, but generally in Kansas field rodents are not a problem in stored grains.

Birds eat and contaminate large quantities of grain. Bird damage control, like commensal rodent control, is important from a health as well as economic standpoint.

### Rodents

For the purposes of this discussion, commensal rodents are the Norway rat (*Rattus norvegicus*), roof

Figure 16



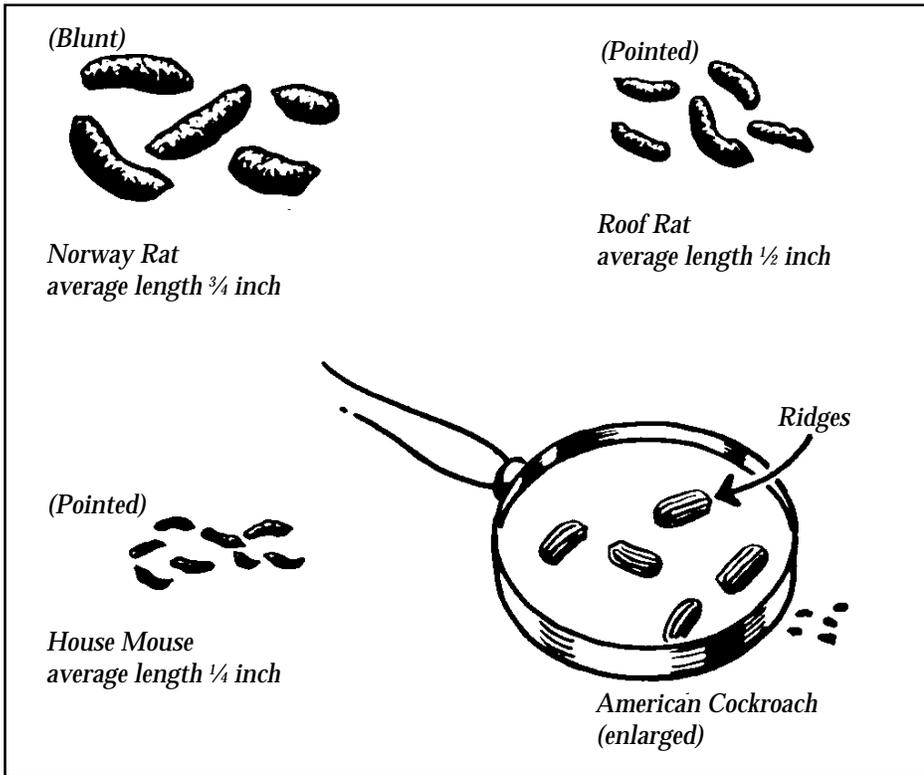
# Vertebrate

## Pests

rat (*Rattus rattus*), and house mouse (*Mus musculus*). Their major discernable characteristics are shown in Figure 16.

Inspection for nuisance rats and mice are an essential part of protecting stored products from loss and contamination. Evidence of their presence includes:

Figure 17



The first step is designed to put the rodents under maximum stress. A thorough cleaning of food, water (in the case of rats) and harborage is very important and the degree in which this first step is done will determine the success or failure of the other four steps that follow. Good housekeeping should always be practiced to keep food to the minimum and to limit places where rodents can hide and nest. But, before any control program is started, an effort should be made to clean all rooms within a building. Reduce harborage outside the building by eliminating weeds, refuse piles, overgrown vegetation, and rubbish piles. Place garbage and trash in garbage cans and industrial dumpsters with tight-fitting covers. Eliminate as much of the rodent's water source as possible because rats need water daily and mice will drink free-standing water if available. However, mice can survive without free-standing water by obtaining moisture from their food. Most people place an overdependence upon rodenticides when more relevance should be placed on good housekeeping.

The second step immediately follows the first and is the use of a toxic bait to get a rapid reduction in the rodent population. The use of a rodenticide should be secondary to step one.

Serious consideration must be given to the use of rodenticides in food facilities. Another consideration is the possible contamination of stored grains and cereal products by rodenticides that could be moved from place to place by the rodents. In spite of these concerns, in a large population of rodents, rodenticides should be considered.

Tracking powders are dusts containing a rodenticide. This form of bait is effective, particularly for mice because rodents often groom themselves after running through the dust and lick their feet, thereby absorbing the toxicant. This method is not advisable in a food facility, because

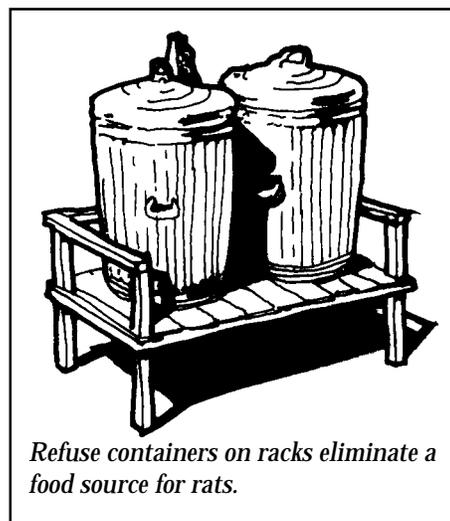


Figure 18

- seeing the animals,
- rodent noises,
- rodent droppings,
- runways,
- tracks,
- chewed or gnawed materials, and
- odors.

Rat and mouse feces are one of the best indications of their presences. Rat, mouse and larger cockroach droppings are shown in Figure 17.

### Control Techniques

There is no simple, fool-proof way to control rodents in stored grain facilities. A five-step approach to rodent control seems to work best. Step one should always be followed by two, three, four and five in that order.

# Vertebrate

## Pests

of possible contamination. Rodents can carry powders throughout the building.

It is the applicator's responsibility to choose the right bait to fit the situation. The bait will need to be used safely and will need to be accepted and consumed by the rodents. Pre-baiting becomes important. Generally, in stored product areas, it is difficult to get rodents to eat the baited rodenticides, because of the high quality food they have become accustomed to. Therefore, the bait to be used should be placed without the toxicant added to test to see if the rodents will accept the bait. If they do, then the rodenticide-laced

bait can be used. Place bait in safe, secluded areas where rodents are frequenting. Proper placement of bait is important. Put out bait at close intervals. Underbaiting is one of the most common mistakes in rodent control. Use bait forms that are best suited for the particular conditions such as wax bait blocks for damp areas, cereal bait where bait security is important, and tracking powders where competitive foods are abundant.

Follow label directions and use tamper-proof bait stations. Store all rodenticides in dry, locked compartments and where chemical contamination will not occur.

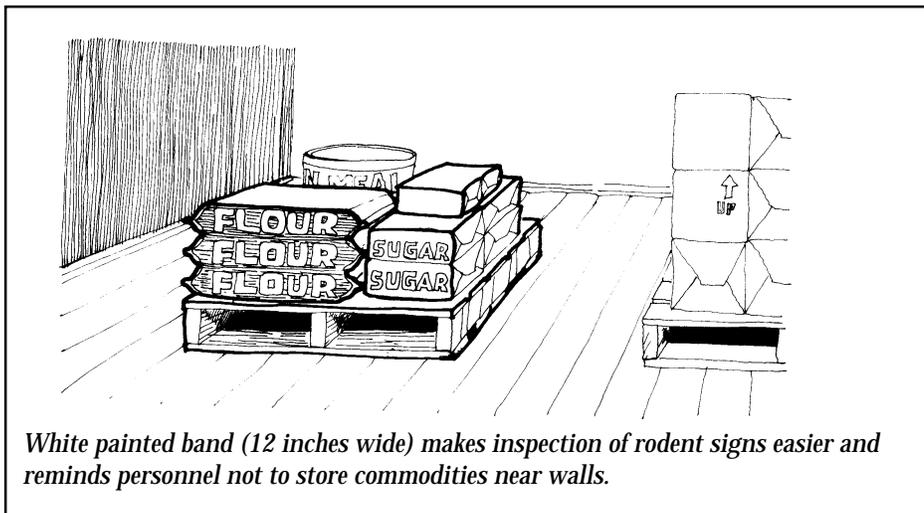


Figure 19

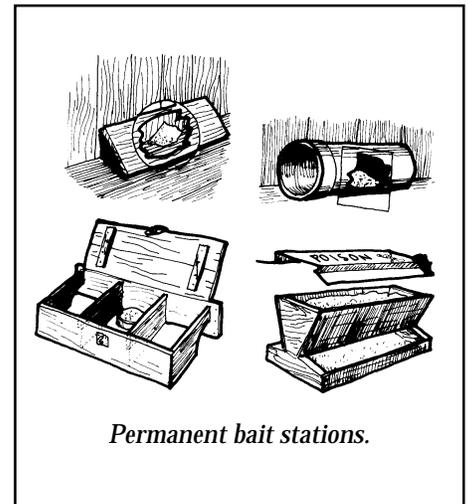


Figure 21

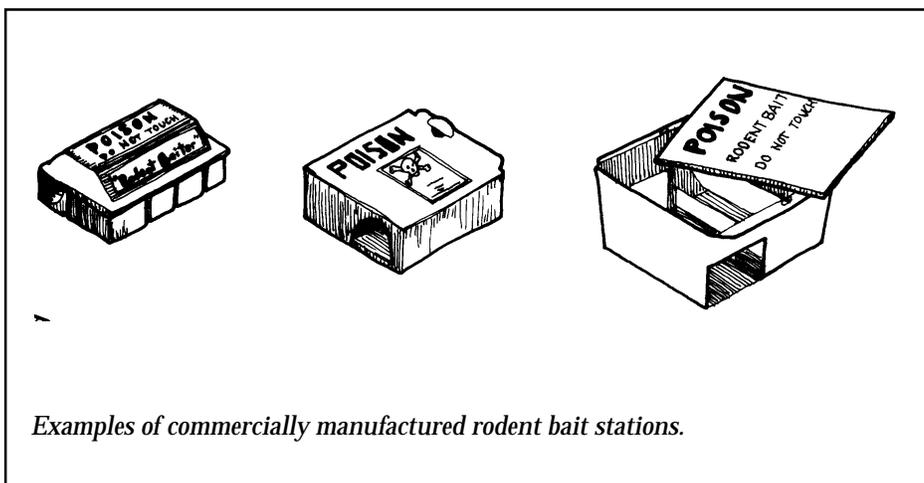


Figure 20

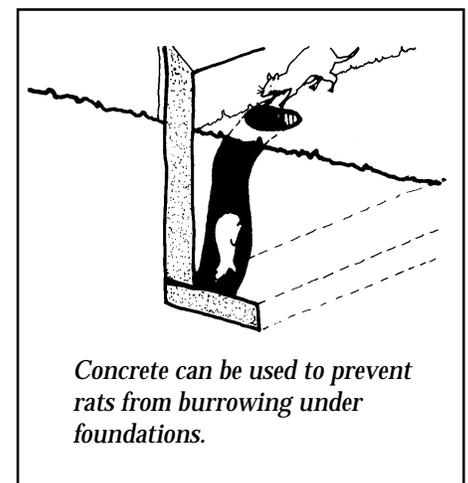
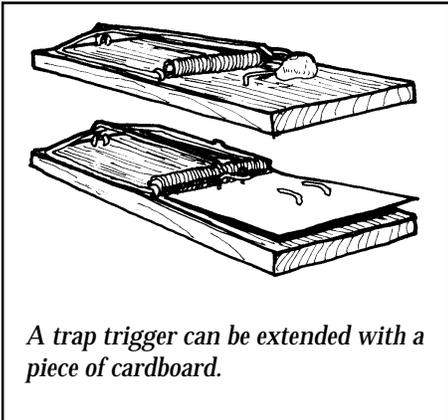


Figure 22

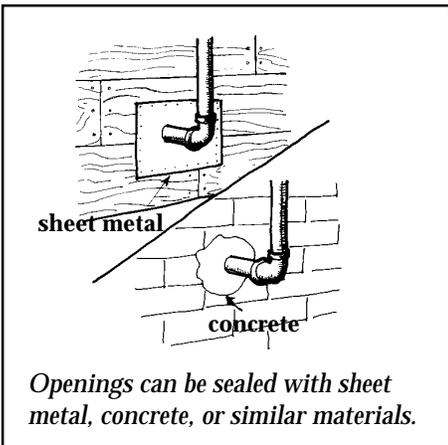
# Vertebrate

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*A trap trigger can be extended with a piece of cardboard.*

Figure 24



*Openings can be sealed with sheet metal, concrete, or similar materials.*

Figure 25

The third step is the establishment of a continuous baiting program. Incoming rodents will soon re-establish the former rodent numbers. This is especially true unless improved housekeeping practices are imposed. When bait is used, it should be used in bait boxes that are well marked and locked. Fresh bait should be kept in constant supply in the stations. The stations should be placed outdoors, next to the building and near entry sites and indoors along the walls. Some good rules to remember are:

- Use locked bait stations to protect against unsuspecting people and other animals.
- Note location of all bait stations.
- Note the rate of bait consumption.
- Pick up all dead rodents with gloved hands and destroy the carcasses by burning.
- Replace moldy, wet or caked bait with fresh bait.

Norway rats burrow into the soil and these burrows can be fumigated to kill the rats. Read and follow label instructions for using fumigants in burrows, along foundations, and/or near the building infested with rats.

The fourth step is the use of traps. Traps have a definite place in rodent control activities. In food handling buildings, traps often are recommended. Trapping often is necessary in removing bait-shy rodents. The most common trap is a snap-trap with a wooden base. Multiple-catch traps are popular in food handling

buildings. Good baits for catching mice with snap traps are:

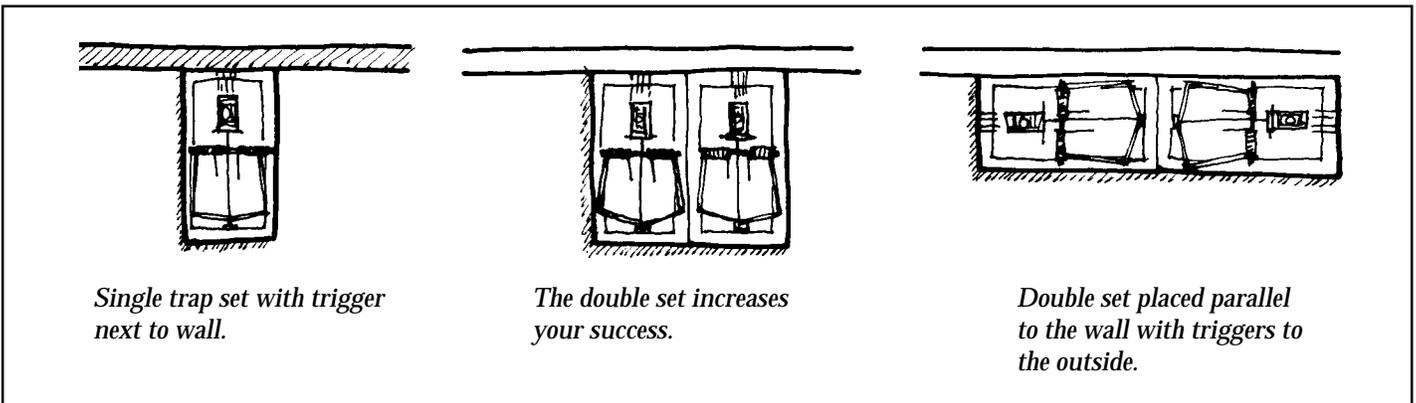
- bacon,
- peanut butter,
- gum drops,
- chocolate candy,
- fresh bread, or
- apples.

Traps near a wall should be set at right angles to the wall, with the trigger end toward the wall. It is an advantage to change baits frequently.

Snap traps for rats can be unbaited if the triggers are modified. This can be accomplished by gluing a 1½-inch square of cardboard securely to the trap trigger. The expanded trigger trap must then be placed in the rat's normal path. Camouflaging with straw or other material may help. Cage or live traps are used for catching rats. It is important to set out a sufficient number of traps. Usually no more than 20 percent of the traps set in a single night may be expected to catch rats. Because rats become "trap wise" in a short time, trap locations need to be changed frequently.

Multiple catch traps, generally used to catch mice, need to be checked on a regular basis. These traps should be cleaned and tuned as they are subject to damage to the spring mechanism. Human odor is not a factor in trapping rodents.

Glue boards have become popular in rodent control over the recent years. Very sticky material is placed in plastic traps or on cardboard and these are placed in the rodent's



*Single trap set with trigger next to wall.*

*The double set increases your success.*

*Double set placed parallel to the wall with triggers to the outside.*

Figure 23

# Vertebrate

## Pests

normal or forced pathways. Once entrapped, the rodent and glue boards are both discarded.

The fifth step is rodent proofing. Rodent proofing becomes nearly as important as the first step. Each place presents a different situation for consideration. Remember that the exterior of the structure needs to be checked for all accessible entries for rodents. Those places must be permanently closed or protected with screens or grating. The interior of the building must have no dead spaces, such as double walls, ceilings, sub-floors, little used rooms, staircases, or boxed-in piping where rats might find safe places to hide and/or nest. Rodent-proofing generally requires well-designed plans with solid construction using steel and concrete. Curtain walls may be used to protect otherwise vulnerable foundations. Openings for pipes, wires, etc., require permanent seals—usually metal or concrete. Ventilator screens should have holes no larger than ¼ of an inch in diameter.

In spite of all precautions, some rats and mice may get into buildings. If these rodents meet good house-keeping restrictions, the rodents will find themselves unwelcome.

### Bird Damage Control

The three kinds of birds that are involved in most damage near stored product facilities are:

- starlings,
- European sparrows, and
- Feral pigeons.

None of these species are native to North America and they compete with native species of birds.

Starlings are black, light-speckled, robin-size birds with a chunky, meadowlark shape. The bill of both sexes is yellow during the reproductive cycle (January to June) and dark at other times. Juveniles are pale brown to grey. The tail is short, and the wings have a triangular shape when outstretched in flight. Starling flight is direct and swift, not rising and falling like many blackbirds.

Sparrow roosts in rural and urban sites cause:

- health,
- filth,
- noise, and
- odor problems.

Their droppings damage and deface equipment and vehicles. In addition, sparrows compete for nest sites with native hole-nesting birds such as bluebirds, flickers, woodpeckers, and purple martins.

Pigeons may carry:

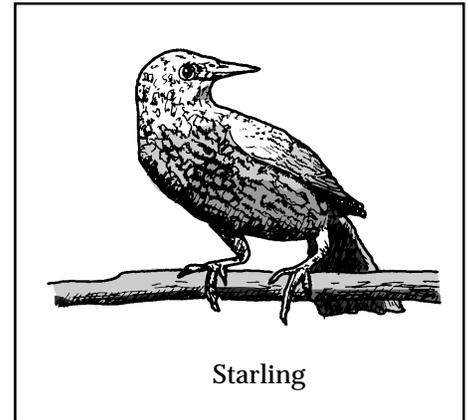
- pigeon ornithosis (psittacosis),
- Newcastle disease,
- aspergillosis,
- pseudotuberculosis,
- pigeon coccidiosis,
- toxoplasmosis,
- encephalitis, and
- Salmonella typhimurium.

Except for the last three, these diseases rarely infect humans, but may be serious if not diagnosed promptly. Salmonella is found in about 2 percent of pigeon feces and is statistically the most frequent cause of salmonella food poisoning in humans.

Histoplasmosis and cryptococosis are systematic fungus diseases that may be contracted by cleaning up dusty bird manure. Bird ectoparasites—bugs, fleas, tick and mites—frequently invade homes from bird nests in or on buildings and transmit diseases by biting. Some bites cause welts and skin infection.

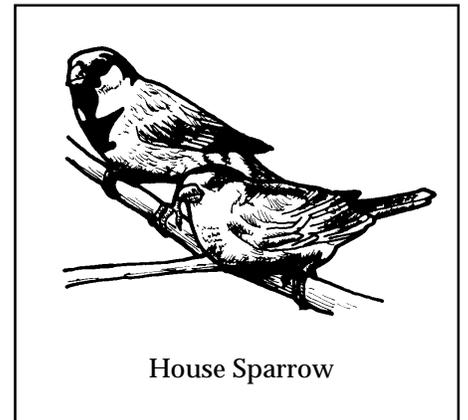
Bird droppings deface and accelerate deterioration of buildings and automobiles and land on unwary pedestrians. Bird feces can contaminate grain destined for human consumption. Nests may clog drain pipes, interfere with awnings and make fire escapes hazardous.

European birds need shelter for cover, roosting and nesting. The kind of shelter depends on the season, the species and the reason for seeking shelter. When birds roost or nest in inappropriate places, denying access to roost sites also will discourage feeding.



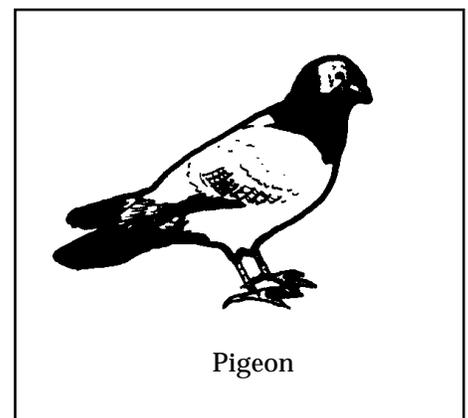
Starling

Figure 26



House Sparrow

Figure 27

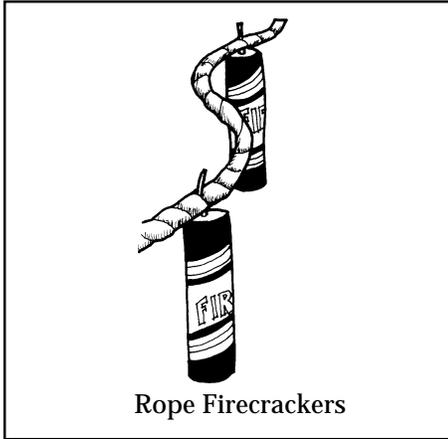


Pigeon

Figure 28

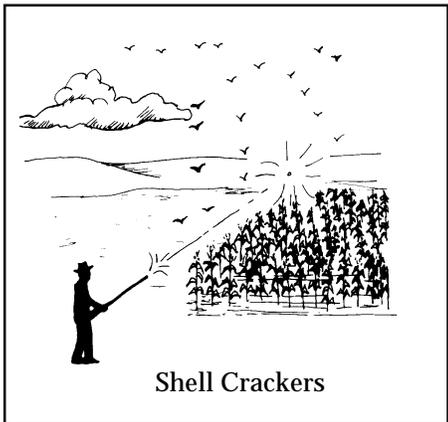
# Vertebrate

## Pests



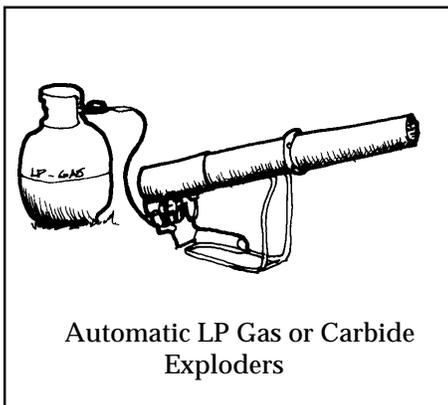
Rope Firecrackers

Figure 29



Shell Crackers

Figure 30



Automatic LP Gas or Carbide Exploders

Figure 31

When birds nest in inappropriate places, be persistent about removing nests; birds will keep trying to reestablish them in the same place. A longer term solution is to exclude birds from an area or make it less comfortable.

The limitations of known animal damage control measures to control large-scale bird problems, make it necessary to understand population control as a management technique. In good habitats abundant animal species recover quickly from the loss of individuals. Animal populations respond with increased birth and survival rates and decreased emigration. These are known as compensatory responses. Increased immigration may follow removals, and some animals learn to avoid control efforts.

The most effective way to control problem birds is to understand their daily requirements, and remove or exclude these. This kind of manipulation for purposes of increasing or decreasing numbers is an important part of wildlife management. Some basic principles provide a background for understanding how to control problem birds effectively and appropriately.

To survive, all wild animals need habitat, which is comprised of four essential elements: space, food, shelter and water. Wildlife managers manipulate these elements to attract and maintain wildlife species and control problem species.

Space is the area needed by a wild animal. Just as some people are happy in a city apartment while others need a sprawling ranch, some birds need more space than others. In reference to wild animals, there are two kinds of space:

- Home range—the entire area that an animal uses to eat, sleep, and go about its daily activities;
- Territory—that portion of the home range an animal defends against intruders, usually where it raises young.

In most cases, the male bird establishes and defends the territory.

In the spring, the brightly colored male sings to attract a mate and to announce to other male birds of the same species the location of his territorial space. After the pair builds a nest, the male continues to defend the territory while the female hatches eggs. This factor cannot be controlled because space is determined by the area of a yard or farmstead.

Food, water and shelter are elements that can be manipulated to manage birds in the yard or other urban settings. Providing these elements attracts birds; removing them keeps them away. All are essential, yet not all bird problems can be eliminated by just taking away one element.

Variety is a key word in wildlife management. It often is necessary to use a variety of excluding and repelling methods simultaneously to control nuisance birds.

### Controlling Damage

#### Exclusion

**Structures.** Where starlings are a problem inside buildings or other structures, close all openings larger than 1 inch so they cannot enter. This is a permanent solution to problems inside the structure. Heavy plastic (PVC, polyvinyl chloride) or rubber strips hung in open doorways of farm buildings have been successful in keeping birds out, while allowing people, machinery, or livestock to enter. One installation approach is to hang 10-inch wide strips with about 2-inch gaps between them. Such strips also must protect feed bunkers. Where birds are roosting on a ledge, place a board or metal covering over the ledge at a 45° angle. Porcupine wires (metal protectors) also are available for preventing roosting on ledges or roof beams. Netting also is useful around buildings for covering windows or other openings.

Farm management practices are important in long-term starling control. These practices limit food and water available to starlings, thus making the environment less attractive. The following practices used

singly, or preferably in combination, will reduce feed losses and the chances of disease transmission as well as the cost and labor of conventional control measures:

1. Clean up spilled grain.
2. When storing grain, use bird-proof facilities.
3. Use bird-proof livestock feeders. These include flip-top pig feeders, lick wheels for liquid cattle supplement, and automatic-release feeders (magnetic or electronic) for costly high-protein rations. Avoid feeding on the ground because this is an open invitation to starlings.
4. Where possible, feed livestock in covered areas such as open sheds because these areas are less attractive to starlings.
5. Use feed forms that starlings cannot swallow such as cubes or blocks greater than ½ inch in diameter. Minimize use of ⅜-inch pellets—starlings eat these six times faster than granular meal.
6. When feeding protein supplements with other rations, such as silage, mix them well to limit starling access to the supplements.
7. Where possible, adjust feeding schedules so that feed exposure to birds is minimized. For example, when feeding once per day, such as in a limited energy feeding program for gestating sows, delay the feeding until late in the afternoon when foraging by starlings is decreased. Feeding cattle at night, where appropriate, is another possibility. Starlings prefer to feed early to midday and in areas where feed is constantly available. Feeding schedules that take these factors into account reduce problems.
8. Starlings are especially attracted to water. Drain or fill in unnecessary water pools around livestock operations. Where feasible, livestock waterers can be made unavailable or less attractive to starlings by controlling the water level. Lower the water level so starlings cannot reach it when

perching on the edge of the waterer. At the same time, keep the water level deep enough so they cannot stand in it.

9. Modify starling roost sites by closing openings in buildings or other structures so starlings cannot enter.

### ***Frightening***

Frightening devices include recorded distress or alarm calls, gas-operated exploders, battery-operated alarms, pyrotechnics (e.g. shell-crackers, bird bombs), chemical frightening agents (see Avitrol below), lights (for roosting sites at night), bright objects, and other noisemakers. Beating on tin sheets or barrels with clubs also scares birds. Some novel visual frightening devices with potential effectiveness are eye-spot balloons, hawk kites, and mylar reflective tape. Ultrasonic (high frequency, above khz) sounds do not frighten starlings and most other birds because, like humans, they do not hear these sounds.

Harassing birds, throughout the evening as they land, can be effective in dispersing bird roosts if done for three to four consecutive evenings or until birds no longer return. Spraying birds with water from a hose or from sprinklers mounted in the roost trees has helped in some situations. A combination of several scare techniques used together works better than a single technique used alone. Varying the location, intensity, and types of scare devices improves their effectiveness.

Two additional tips for successful frightening efforts: (1) begin early before birds form a strong attachment to the site and (2) be persistent until the problem is solved.

### ***Repellents***

Soft, sticky repellents are non-toxic materials used to discourage starlings from roosting on ledges or roof beams. Examples include Roost-No-More, Bird Tanglefoot and 4-The-Birds. It often helps to first put masking tape on the surface needing protection, then apply the repellent

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# Vertebrate

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## Pests

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onto the tape. This increases effectiveness on porous surfaces makes removal, if desired, easier. Over time, these materials lose their effectiveness and must be replaced.

### **Trapping**

The wide-ranging movements of starlings, the time necessary to maintain and manage traps, and the number of starlings that can be captured compared to the total number in an area, often make trapping an impractical control method. However, trapping and removing starlings can be successful at locations where a static population is causing damage or where other techniques can't be used. An example is using decoy traps to remove starlings from an orchard where they are damaging fruit crops. Decoy traps for starlings should be at least 5 to 6 feet high to allow servicing and can be quite large (e.g. 10 feet wide  $\times$  30 feet long). A convenient size is 6  $\times$  8  $\times$  6 feet. If desired, the sides and top can be constructed in panels to facilitate transportation and storage. In addition, decoy traps can be set up on a farm wagon and moved to the best places to catch starlings. To be successful, the trap should be placed

where starlings are likely to congregate. Leave a few starlings in the trap as decoys; their feeding behavior and calls attract other nearby starlings. Decoy birds in the trap must be well watered (which may include a bird bath) and fed. A well-maintained decoy trap can capture 100 or more starlings per day depending on size and location, time of year, and how well the trap is maintained. Should any non-target birds be captured, release them immediately. To kill captured starlings humanely, use appropriate procedures such as carbon dioxide exposure or cervical dislocation (quickly breaking the neck).

### **Shooting**

The number of starlings that can be killed by shooting is small in relation to the numbers of starlings usually involved in pest situations. Therefore, shooting is not normally recommended.

If any toxic baits are to be used, contact a qualified person trained in bird control work for technical assistance (e.g. contact USDA/APHIS/ADC) or the Cooperative Extension Service Animal Damage Control office at Kansas State University.

### Questions

1. (51) Commensal rodents are non-native and include the roof rat, house mouse, and \_\_\_\_.
  - a. Norway rat
  - b. pack rat
  - c. deer mouse
  - d. field mouse
2. (52) When inspecting for nuisance rodents, evidence includes
  - a. seeing and hearing rodents
  - b. rodent droppings and odor
  - c. rodent runways and tracks
  - d. all the above
3. (52) The second step in rodent control is:
  - a. a thorough cleaning of the area
  - b. the use of rodenticides
  - c. trapping
  - d. screening
4. (54) The fourth step in a rodent control program is the
  - a. establishment of a good cleaning program
  - b. establishment of a pre-baiting program
  - c. establishment of a continuous baiting program
  - d. establishment of a trapping program
5. (55) In rodent proofing, vent screens should have holes no larger than \_\_\_\_ inch in diameter.
  - a.  $\frac{1}{8}$
  - b.  $\frac{1}{4}$
  - c.  $\frac{1}{2}$
  - d. 1
6. (55) There are three kinds of birds that do the most damage near stored product facilities. Which of the following is NOT one of them?
  - a. Starlings
  - b. European sparrows
  - c. Crows
  - d. Feral pigeons
7. (56) To survive, all wildlife needs which of the following?
  - a. space
  - b. food and water
  - c. shelter
  - d. all the above
8. (56) Which of the survival needs of birds can NOT be controlled?
  - a. space
  - b. food
  - c. water
  - d. shelter
9. (57) Bird damage control can include which of the following techniques?
  - a. Exclusion
  - b. Frightening
  - c. Repellents
  - d. All the above
10. (58) Trapping birds to control damage can capture as many starlings per day as \_\_\_\_:
  - a. 50
  - b. 100
  - c. 150
  - d. 200

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## **Answers to Study Questions**

### **Pages 3-13**

1. c 2. a 3. d 4. b 5. b  
6. d 7. a 8. d 9. b 10. b

### **Pages 15-17**

1. a 2. d 3. c 4. d

### **Pages 19-22**

1. b 2. c 3. b 4. c 5. c 6. c 7. a

### **Pages 24-26**

1. d 2. d 3. d 4. b 5. c  
6. b 7. a 8. d

### **Pages 28-29**

1. c 2. a 3. a 4. d 5. a 6. c

### **Pages 32-37**

1. d 2. b 3. b 4. d 5. c 6. a  
7. b 8. c 9. b 10. c 11. b

### **Pages 39-43**

1. d 2. d 3. d 4. a 5. a  
6. b 7. c 8. d 9. b 10. c

### **Pages 45-48**

1. a 2. d 3. c 4. c 5. d  
6. d 7. d 8. d 9. d

### **Pages 51-58**

1. a 2. d 3. b 4. d 5. b  
6. c 7. d 8. a 9. d 10. b

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**ACKNOWLEDGEMENT:**

Appreciation is expressed to the following for cooperation in the Pesticide Applicator Training Program:

Jeanne Fox, Ecological Specialist, Pesticide Use Section, Plant Health Division, Kansas Department of Agriculture

Gary Boutz, Administrator, Pesticide Use Section, Plant Health Division, Kansas Department of Agriculture

H.P. Boles (retired), U.S. Grain Marketing Research Laboratory, Manhattan, Kansas, is acknowledged for the insect life cycle drawings in this manual.



Cooperative Extension Service, Kansas State University, Manhattan

S-16

October 1996

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File Code:Entomology 4, 11

AB 10-96—5M