

# Food Related Fumigation

Classification 8

## Training Manual



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# Preface

This manual provides information for the Arkansas commercial pesticide applicator wishing to become certified in Food Related Fumigation - Classification 8. To become a certified applicator in this category, a candidate must pass both a general standards exam and pass an examination based primarily on the material presented in this manual and (Circular 6) Arkansas Pest Control Law (Act 488 of 1975, as amended). Information covered in the general standards examination is contained in "A Guide for Private and Commercial Applicators: Applying Pesticides Correctly." Refer to (Circular 6) Arkansas Pest Control Law (Act 488 of 1975, as amended) for specific requirements. The Arkansas State Plant Board administers the examinations. Up-to-date study materials can be obtained from the Arkansas State Plant Board, #1 Natural Resources Drive (P.O. Box 1069), Little Rock, AR 72203-1069, phone (501) 225-1598. Additional study information may be obtained from the University of Arkansas Cooperative Extension Service, the pesticide label, and current publications on the subject, pesticide distributors, and manufacturers.

## Acknowledgments

Information accumulates from direct observations, scientific literature, and anecdotes from others. Information from these sources blurs together quickly, and consequently, unique ideas are rare in society. Credit for sources of information on urban pest control and management must go to:

Land Grant University Extension and research workers, most entomologists, who pioneered this work, those who kept training and research alive during the period when the success of synthetic organic pesticides preempted nearly all but control evaluations from the 1940s to the 1960s, and those who persist today; Pest Control Industry workers who held training sessions nationally, regionally, and locally where information was disseminated among the experienced and provided to the inexperienced; Environmental Protection Agency personnel who molded modern training and influenced the need for national uniformity in training requirements; State regulatory personnel who cooperated with Universities and Industry and who strongly emphasized the importance of training; and the few textbook authors in the United States and England who compiled the reference data in the understandable and usable form that allows urban pest management practitioners to be professionals.

This manual have been adapted from commercial applicator certification training manuals for "Fumigation" and "Fumigation of Soil and Agricultural Products" primarily developed by the **Virginia Cooperative Extension, Virginia Polytechnic Institute and State University** with information also from Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University and University of Nebraska Cooperative Extension, University of Nebraska-Lincoln.

**The pesticide information presented in this publication was current with federal and state regulations at the time of printing. The user is responsible for determining that the intended use is consistent with the label of the product being used. Use pesticides safely. Read and follow label directions. The information given herein is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Cooperative Extension Service is implied.**

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# Unit 1: Introduction

## Learning Objectives

After reading this unit, the reader will be able to:

- Explain what fumigants are and how they work.
- Understand the scope of the manual.
- Define Integrated Pest Management (IPM).
- Select fumigants as one aspect of an IPM program.
- Describe the advantages and disadvantages of fumigants.

The introduction describes the importance of fumigation. While highly toxic, fumigants are often the best and only way to control pests in hard-to-reach areas. They are also important for quarantine – between states and between countries.

By reading this unit, you will learn what fumigants are and how they work. This unit will explain the principles of Integrated Pest Management (IPM). You will discover how you can use fumigation as one aspect of a well-planned IPM program. This unit also outlines the scope and purpose of the manual. Finally, this unit will describe the advantages and disadvantages of fumigants.

## Terms to Know

**Aeration** – When fresh air is introduced to dilute and remove fumigant-filled air. Aeration must follow all fumigation operations.

**Commodities** – Items produced for trade or commerce.

**Fumigant** – A fumigant is a pesticide that is a gas, or forms a gas, when applied. In a high enough concentration, this gas (vapor) has pesticidal action.

**Infestation** – A pest population that grows so large it becomes harmful or unpleasant.

**Integrated Pest Management (IPM)** – A pest management system that uses all appropriate strategies to reduce pest populations.

**Molecule** – The smallest particle of a substance that retains all of the properties of that substance.

**Pest** – Any living thing that is undesirable or causes harm to people, property, or the environment. An organism may be a pest in one place but not in another; for example, termites in a house vs. those that recycle dead trees in a forest.

**Quarantine** – A period of time during which a vehicle, commodity, or other item is detained and isolated to prevent pests from entering an area, state, or country. Commodities are often quarantined at shipping ports before entering the United States.

The earliest use of fumigants as pesticides dates back to 2500 B.C. At this time, people burned sulfur to control insects and mites. Today, we use fumigants to control insects, rodents, and other pests. We rely on these chemicals to treat processing plants, boxcars, and ships. Fumigation is one of the quickest and most effective ways to eliminate pests from processed food, wood, large buildings, and sometimes homes. We also use fumigation in quarantine. It helps to prevent pests from traveling from one location to another.

However, fumigants are some of the most toxic pesticides in the world. Even small amounts can kill nontarget insects, animals, and people. Fumigators require a great deal of specialized training, skill, and technical knowledge.

## What is Fumigation?

A fumigant is a gas with pesticide activity. Fumigants are gases or form gases after application. In a high enough concentration, a fumigant can kill insects and other pests. Fumigants may be odorless and usually cannot be seen.

People often mistake smokes, fogs, mists, and other aerosols for fumigants. However, these pesticides produce relatively large particles or

droplets that are very different from fumigants. They are not true fumigants because they are not gases.

As a gas, a fumigant consists of separate molecules that are much smaller than the droplets of a fog or mist. Fumigants can move into tiny gaps such as those in flour or through small openings in equipment. Fumigants can even penetrate seemingly solid items like brick, concrete, and wood. However, these items are not as solid as they appear. In a magnified view, it is possible to see the molecules of wood and the spaces between them. Fumigant molecules actually move between the wood molecules to reach the pests. Because fumigants penetrate so well, they must be confined in an enclosed space. As soon as a fumigant escapes from an enclosure, its effectiveness is lost.

*NOTE: Fumigants provide no residual protection. Once a commodity has been treated and aerated, new pests can attack at any time.*

## Scope of This Manual

Fumigation is used to treat a wide range of pests in many locations. It is most often reserved for pests that live in hard-to-reach areas in food storage and commodities. Other times, you may need to fumigate as a last resort for a difficult infestation.

This manual covers fumigation of food and processed commodities. Structures include commodity storage areas such as warehouses, boxcars, and grain bins. Processed commodities and food include all types of processed goods such as flour, meal, candy, cereals, grain, and other products.

## The Food Related Fumigation Manual

The purpose of this manual is to help you fumigate food and processed commodities in a safe and effective way.

It starts by describing the major pests of food and stored commodities. While the list is long, it is by no means complete. Professional organizations, universities, industry, and government agencies produce detailed field

guides and other pest identification references. These sources will help you learn more about the pests described here. They will also describe pests not included in this manual.

Many things can be pests. Insects, fungi, birds, and rodents can all harm food and stored commodities. Fumigation is most often used to control insects. For this reason, insect pests are the focus of this manual. Rodent pests will be discussed briefly. You will learn how to identify these pests by sight and by their habits. You will learn about their life cycles and what to look for when scouting. This manual also describes the most vulnerable stage(s) of common pests and the best time(s) for efficient and effective control.

You will also learn about fumigants. Fumigants have many characteristics that can affect how well they work. These include boiling point, molecular weight, solubility, and flammability. External factors such as temperature and humidity can also affect performance. This manual will describe these factors and help you select the best fumigant for your situation.

This manual will introduce you to a range of fumigation materials and methods. You will learn the basic types of fumigation (vault, tarpaulin, and spot) used to treat food and commodities. Each method has its pros and cons. You will learn how to select a fumigation method based on the pest, the product or site infested, and the severity of the infestation. During fumigation, difficulties often arise. You will learn how to prevent these problems and how to handle them if they do develop.

Aeration must follow all types of fumigation. Aeration introduces fresh air to dilute and remove fumigant-filled air. Proper aeration is key to safe fumigation. Procedures for aeration vary with the fumigant, the area, and the items fumigated. This manual will describe aeration techniques for a variety of situations.

Pest control decision making will be addressed throughout this manual. Before fumigating, answer the following questions:

- Is the problem actually caused by a pest?
- If so, what pest?
- What effective and affordable control options are available?

- Is the problem severe enough to warrant fumigation?
- Is the pest in a vulnerable stage in its life cycle?

A good planner makes careful records of pest problems: when and where the problem occurred, solutions, and results. He or she also learns how to prevent future problems.

Fumigants are the most hazardous of all pesticides. Even small amounts of many fumigants can cause serious illness or death. This manual describes ways to protect the public, your co-workers, and yourself from exposure. It provides safety checklists for all stages of fumigation. You will learn about special tools, first-aid techniques, and protective clothing and equipment for fumigators.

Respirators and gas detectors are two of the most important safety tools used in fumigation. Respirators provide clean air to workers during fumigation and aeration. Gas detectors monitor and record gas levels before, during, and after treatment. This manual will describe several models of each device. You will learn how to select the best model for your situation. You will also learn how to inspect, maintain, and use this equipment properly.

Finally, this manual will discuss four common fumigants used to treat food and commodities.

Read and study this manual carefully. This information and training in the field will help you become an effective and safe fumigator.

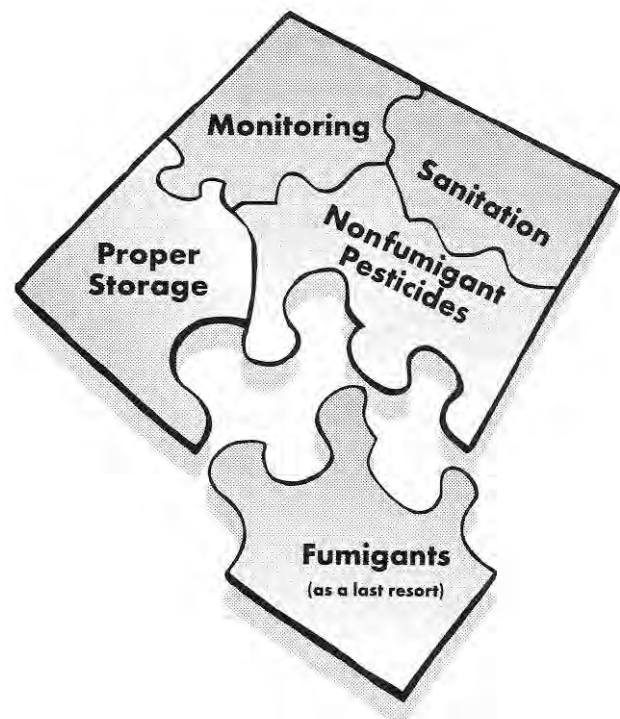
## IPM and Decision Making

There are many ways to control pests that infest food and stored products. Your job is to select the best method for the situation at hand. Pesticides and other control methods often provide good to excellent control temporarily. However, if you want consistent, reliable, long-term control, you need Integrated Pest Management (IPM).

IPM is an ecological approach to pest control. It is based on the habitat and life cycle of the pest. It combines all of the most appropriate pest control strategies into a unified, site-specific plan. IPM plans may

include both nonchemical and chemical management methods. IPM is dedicated to removing causes rather than simply treating symptoms. The goals of an IPM program are to reduce pest numbers to an acceptable level in a way that is practical, cost-effective, and safe for people and the environment.

The first strategy of an IPM program is prevention. Prevention relies on sanitation, proper storage, and the condition of the commodity before and after it is placed into storage. You may be able to exclude pests or provide them with unsuitable living conditions. Preventing a pest problem before it occurs saves time and money.



IPM also relies on scouting and sampling. Scouting and sampling will help you determine if treatment is needed and/or if previous control measures were effective. Check structures and commodity storage areas regularly. Look for signs of new infestations. Sample commodities to check their physical condition. Determine what pests are present, how many of each kind are in the area, and how much damage they are causing.

When an infestation does occur, identify the pest. Learn how it causes damage and when it is

most vulnerable. Then, develop a control plan. Consider all appropriate control options. Your strategy should be economical and safe for the environment. Follow-up site inspections are critical. Did the control tactic work? Is re-treatment needed? Continue to monitor areas for long-term control.

Fumigation is only one option of an IPM program. Because it is specialized, very toxic, and often expensive, fumigation should be the last resort to a pest problem. When deciding whether to fumigate, weigh these advantages and disadvantages.

## Advantages of Fumigants

- They are effective against insects, rats, birds, mammals, and fungi.
- Most are fast acting. They are the quickest way of controlling many pests.
- They are capable of providing total eradication.
- Human exposure is limited. Areas are evacuated during treatment and must be aerated before reentry.
- Most fumigants, when used properly, do not leave residues on surfaces.
- There are several ways to apply fumigants.
- They penetrate and treat cracks, crevices, burrows, partitions, commodities, and equipment that cannot otherwise be reached.
- You can apply them without disturbing the commodity.
- They are usually readily available.
- You can use some fumigants in or near food without leaving harmful residues, tastes, or odors.

## Disadvantages of Fumigants

- They are highly toxic to most living things, including humans. Breathing even small amounts of some fumigants can be fatal.
- They require special protective equipment, such as a Self-Contained Breathing Apparatus (SCBA) and gas detectors.
- They require highly trained applicators.
- They offer no residual control. Once an area or item is aerated, traces of fumigant do not remain to help control future pests.
- They must be confined in a tightly sealed area to be effective.
- Some may injure seeds and reduce germination. Others may leave toxic residues, tastes, or odors.
- Because they are fast acting, response to problems and emergencies must be quick. Spills, leaks, and equipment failures usually call for immediate action.
- They often require warm temperatures to be effective. Temperature requirements may be hard to meet, especially in the winter.
- Some are expensive.
- Some are corrosive.
- They usually require a special license(s) or permit(s). This is because most are classified as restricted-use. Only properly certified applicators can purchase and use restricted-use pesticides.
- Some fumigants are hard to remove from fumigated material (ex., methyl bromide).



# Test Your Knowledge

**Q. In what situations are fumigants commonly used?**

- A. We rely on fumigants to treat processing plants, boxcars, and ships. Fumigation is one of the quickest and most effective ways to eliminate pests from processed food and commodities. We also use fumigation in quarantine. It helps to prevent pests from traveling from one location to another.

**Q. What is a fumigant?**

- A. A fumigant is a pesticide that is a gas, or forms a gas, when applied. In a high enough concentration, this gas (vapor) has pesticidal action.

**Q. How does being a gas contribute to a fumigant's effectiveness?**

- A. As a gas, a fumigant consists of separate molecules that are much smaller than the droplets of a fog or mist. Fumigants can penetrate very small spaces where pests live, such as those in flour. Fumigants can even penetrate seemingly solid items like brick, concrete, and wood.

**Q. What is the first thing you should do when you detect a pest problem?**

- A. Identify the pest.

**Q. Name two of the most important safety tools for fumigators.**

- A. Respirators and gas detectors.

**Q. What is Integrated Pest Management (IPM)?**

- A. IPM is an ecological approach to pest control. It is based on the habitat and life cycle of the pest. It combines all appropriate pest control strategies including nonchemical and chemical management methods. IPM is dedicated to removing causes rather than simply treating symptoms. Prevention is key.

The goal of an IPM program is to reduce pest numbers to an acceptable level in a way that is practical, cost effective, and safe for the environment.

**Q. How does fumigation fit into an IPM program?**

- A. Fumigation is only one part of an IPM program. Because it is specialized, very toxic, and often expensive, fumigation is usually the last resort to a pest problem.

**Q. Describe scouting. Explain its importance in effective pest management.**

- A. Scouting is checking or monitoring for pests in an area to determine what pests are present, how many of each kind are in the area, and how much damage they are causing. Scouting will help you determine if treatment is needed and/or if previous control measures were effective.

**Q. List some of the advantages of fumigants.**

- A.
- They are effective against insects, rats, birds, mammals, and fungi.
  - Most are fast acting.
  - They are capable of providing total eradication.
  - Human exposure is limited.
  - Most fumigants, when used properly, do not leave residues on surfaces.
  - There are several ways to apply fumigants.
  - They penetrate and treat hard-to-reach areas.
  - You can apply them without disturbing the commodity.

- They are usually readily available.
- You can use some fumigants in or near food without leaving harmful residues, tastes, or odors.

**Q. List some problems with fumigants.**

- A.
- They are highly toxic to most living things, including humans.
  - They require special protective equipment.
  - They require highly trained applicators.
  - They offer no residual control.
  - They must be confined in a tightly sealed area to be effective.

- Some may injure seeds and reduce germination. Others may leave toxic residues, tastes, or odors.
- Response to problems and emergencies must be quick.
- Temperature requirements may be hard to meet.
- Some are expensive.
- Some are corrosive.
- They usually require a special license(s) or permit(s).
- Some fumigants are hard to remove from fumigated material.

# Unit 2: Pest Identification, Biology, and Management

## Learning Objectives

For each pest described in this unit, the reader will be able to:

- Identify it by appearance, habits, and types of damage.
- Describe its preferred habitat.
- Understand its behavior and life cycle.
- Recognize conditions favorable to pest problems.
- Discuss prevention and control methods.

This unit describes the most common pests of food and processed commodities controlled with fumigants. By reading it, you will learn why these organisms are considered pests. You will also learn what these pests look like and where they live. Proper identification of pests is essential to choosing the most effective control method. This unit will also describe techniques used to prevent or control infestations.

Universities, government agencies, industry, and other organizations produce detailed field guides and other useful references. These sources will help you to learn more about the common pests described here. In addition, they may describe pests not included in this unit.

*NOTE: Every living thing has a scientific name and a common name. Since it does not change, Latin is the language that scientists use to name living things; scientific (Latin) names are the same throughout the world. On the other hand, common names may vary across the country, and sometimes even within a state or county. Sometimes people may refer to two different things by the same common name. When you discuss a pest problem with another person, make sure you are both referring to the same pest. Use scientific names whenever possible. This unit gives the common and the scientific (Latin) name for the insects described. Scientific names are in italics and placed in parenthesis. The first name is the “genus.” The second name is the “species.” The term “spp” indicates that there are several species within a single genus.*

## Terms to Know

**Abdomen** – The hindmost or rear body section of an insect.

**Antennae** – A pair of jointed appendages on the head of an arthropod. Antennae are usually long and slender. They are used to sense things in the arthropod’s environment.

**Arachnid** – A wingless arthropod with the body divided into two parts. Arachnids have four pairs of legs on the rear body section. They do not have antennae. Mites, spiders, and ticks are arachnids.

**Arthropod** – An animal with jointed legs and a segmented jointed exoskeleton. Beetles, wasps, crayfish, and spiders are arthropods.

**Caterpillar** – The larval stage of a butterfly or moth.

**Cocoon** – An envelope formed by an insect larva, in which it spends the pupal state.

**Colony** – A family group of social insects. Social insects, like ants and termites, live together in large groups called colonies. Usually, individuals in a colony “specialize.” Different jobs include finding food, taking care of the young, building and repairing the nest, and laying eggs.

**Contact Pesticide** – A chemical that causes a localized injury where it touches a pest. Contact pesticides do not need to be ingested by the pest to cause toxic effects.

**Egg Case** – A capsule containing eggs.

**Forewings** – The pair of wings closest to the head of an insect.

**Frass** – The waste product of insects. Frass can be muddy, powdery, or pelletized. The type of frass found on or in infested items can be useful in pest identification.

**Galleries** – Areas excavated in wood by termites, ants, and the larvae of various beetles.

**Germinal** – At an early stage of growth. The germ, embryo, or nucleus of a grain kernel.

**Grain Elevator** – A facility for holding stored grain before shipment.

**Grub** – The larval stage of some beetles.

**Habitat** – A specific area or environment in which an animal normally lives.

**Hind Wings** – The pair of wings closest to the rear of an insect.

**Host** – An organism with a parasite living in or on it. The parasite obtains part or all of its nourishment from the host.

**Infest** – To inhabit or overrun in large numbers.

**Infestation** – A pest population so large that it is harmful or unpleasant.

**Insect** – An arthropod with a body divided into three regions: head (front), thorax (middle), and abdomen (rear). Insects have three pairs of legs on the thorax. Usually, adult insects have one pair of antenna and two pairs of wings. Ants, cockroaches, beetles, and flies are insects.

**Instar** – In insect development, a stage between successive molts. For example, the first instar is between hatching and the first molt.

**Larva (Larvae = plural)** – An immature stage in the life cycle of an insect with complete metamorphosis. Most larvae look like segmented worms with legs. As a rule, the larval stage is an active, feeding stage. Maggots (flies) and caterpillars (butterflies and moths) are insect larvae. In complete metamorphosis, the larval stage is between the egg and the pupa stage.

**Life Cycle** – The stages of development. The continuous sequence of changes that an organism undergoes during its life.

**Mandibles** – The jaws used by some insects to bite and/or chew.

**Metamorphosis** – The change in body form during the life cycle. Some organisms are born looking like small adults. Others change considerably in appearance (in stages) as they develop. Most insects go through some sort of metamorphosis in their life cycle.

**Complete Metamorphosis** – Insect development involving four different body forms and life stages. A good example of complete metamorphosis is the life cycle of a butterfly or moth. A butterfly's life cycle starts with an egg. An active feeding stage called a larva hatches from the egg. A butterfly larva is called a caterpillar. When caterpillars get to a certain

size and age, they make a protective case. The next stage, which is called a pupa, does not feed. Inside the case, the pupa changes into an adult.

**Gradual Metamorphosis** – Insect development in three stages. In gradual metamorphosis, the egg hatches into a nymph. A nymph is a small, immature stage resembling the adult in body form. As the nymph grows, it develops wings and functional reproductive organs. Grasshoppers and cockroaches go through gradual metamorphosis.

**Molt** – To shed. Arthropods shed their exoskeleton when they molt.

**Nematicide** – A chemical or physical agent that kills or inhibits nematodes.

**Nymph** – The developmental stage of an insect with gradual metamorphosis. Nymphs hatch from eggs and gradually develop into mature adults.

**Pheromone** – A chemical released by an organism that influences the behavior of other organisms of the same species. Pheromones are often used in traps to attract insects to a specific location.

**Pronotum** – A shield-like top plate on the front of the thorax. In some insects, like the cockroach, the pronotum covers the head.

**Pupa (Plural = Pupae)** – In complete metamorphosis, the stage of development between the larva and adult. Pupae do not feed. Usually, they are not mobile.

**Residual Pesticide** – A pesticide that persists and remains toxic after it is applied. Residual pesticides can kill pests over a period of time.

**Sign** – The visible parts or products of a disease-causing organism. Examples include fungal spores or mycelia or ooze from bacterial cankers.

**Soil-Borne Pathogen** – A disease-causing organism that lives in soil. Soil-borne pathogens generally infect the roots and lower stems of plants but not the leaves or upper stems.

**Symptom** – A visible reaction by a host plant to the presence of a pathogen or other health problems.

**Thorax** – The middle segment of an insect's body. The thorax lies between the head and the abdomen.

# Who “Dunnit”?

## Pests of Stored Food Products

Every living thing has a scientific name and a common name. Since it does not change, Latin is the language that scientists use to name living things; scientific (Latin) names are the same throughout the world. On the other hand, common names may vary across the country, and sometimes even within a state or county. Sometimes people may refer to two different things by the same common name. When you discuss a pest problem with another person, make sure you are both referring to the same pest. Use scientific names whenever possible. This unit gives the common and the scientific (Latin) name for the insects described. Scientific names are in italics and placed in parenthesis. The first name is the “genus.” The second name is the “species.” The term “spp” indicates that there are several species within a single genus.

Each type of insect pest has a set of characteristics that can be used to identify it. This “profile” includes appearance, preferred habitat or food, signs of damage, seasonal life cycle, and periods of activity. Insects also look different and/or have different body forms during their life. It is important to recognize the profile for an insect pest during each stage of its life.

Often, successful pest management depends on early diagnosis. Since many insect pests are small and hard to see, it is important to look for signs of damage. Effective diagnosis of an infestation depends on several factors:

- Recognition of damage
- Accurate identification of what is causing the problem
- Knowledge of the pest’s life cycle and habits, and
- An assessment of the distribution, density, and dynamics of the pest population

Regular and careful monitoring will detect early warning signs of pest activity. A well-trained pest manager can match symptoms with a probable cause. Close examination will usually

find the pest. Knowing the pest’s biology will help you decide when and how to manage it effectively and economically. Finally, you will need to study the pest population to decide if fumigation is necessary. You will need to know at least three things:

1. How large is the pest population?
2. How are the pests in the population distributed (ex., randomly or in clusters)?
3. Is the population increasing or decreasing in size?

This unit describes some of the most common pests of stored food products. Each section includes a description of the pest, its life cycle, habitat preferences, and the damage it causes. While the list of pests is long, it is by no means complete. For information about pests not included in this manual, consult the county Extension agent at your local Cooperative Extension Service office.

Insects cause vast losses of stored products worldwide. Stored products include:

- Milled or ground food such as flour, meal, cereals, cake mixes, and pet food
- Nuts and dried fruits
- Meats and other animal products such as wool, fur, and angora, and
- Spices, coffee, and tea

The type of damage caused varies with the insect and the stored food product. Some insects can stain and severely damage food goods. Others consume large amounts of stored food, reducing the amount for sale. Still other pests make fresh and stored food products inedible and unmarketable. In all cases, stored-product pests can cause significant financial losses.

Common pests of stored products include moths, beetles, and cockroaches. These pests can be controlled with fumigant pesticides in some situations.

The most common moths found that are a pest for stored products include:

- Indianmeal moth
- Webbing moth

The most common beetles found that are a pest for stored products include:

- Rice weevil
- Granary weevil
- Cigarette beetle
- Drugstore beetle
- Confused flour beetle
- Red flour beetle
- Sawtoothed grain beetle
- Merchant grain beetle
- Larder beetle

Other pests:

- Cockroaches
- Rodents

A wide range of pests infest stored food products. Insects, mites, and rodents can all harm stored commodities. This manual will focus on pests that are commonly controlled by fumigation.

Determining the type of pest causing damage is often difficult. Many are small and hard to see. Others hide in cracks, crevices, or within grain kernels themselves. In the field, pests hide in the soil and in the roots and stems of plants. With no suspect present, your only clue may be the damage itself. Often the damage from one pest can be distinguished from that of another pest. To manage a pest effectively, you must be able to identify it. You must also understand its life cycle and environmental requirements. Treatment of an unidentified pest can lead to poor results. You may also be in violation of state and federal pesticide laws. This unit will help you recognize the most common pests of soil and agricultural products.

This unit describes some of the most common pests of soil and agricultural products. Each section includes a description of the pest, its life cycle, its habitat preferences, and the damage it causes. Although the list of pests is long, it is by no means complete. For information about pests not included in this manual, consult the Extension agent at your local Cooperative Extension Service office.

This unit also describes prevention and control options (chemical and nonchemical) for each pest. When chemical control is necessary,

baits and nonfumigant pesticides should be your first line of attack.

## Locations to Find Pests of Stored Food Products

Insects are the most common pests of raw agricultural products. Raw products include whole grains (corn, rice, wheat, etc.), cured tobacco, baled cotton, seeds, and other unprocessed agricultural goods. They attack these commodities in:

- Grain elevators
- Silos
- Storage bins
- Barns
- Warehouses
- Food processing plants
- Storage facilities
- Railroad cars, and
- Tractor trailers

Although most insects can be nuisances, only a few cause serious damage. Fumigation is reserved for the most damaging insect pests and pest situations.

## Primary Feeders vs. Secondary Feeders of Stored Grain

Insect pests of stored agricultural products can be divided into two groups: primary and secondary feeders. The distinction is based on the feeding habits of the pest.

Primary feeders are capable of destroying whole, sound grain. The most damaging primary feeders are those that develop within grain kernels. These insects feed on the “germinal” region (early growth) of the seed, reducing its nutritional value and its ability to sprout. Damage caused by internal feeders also makes grain more susceptible to secondary feeders (insects that feed on grain debris). Adult females of internal feeders deposit eggs on or in whole kernels. Larvae develop within the kernels.

**Primary arthropod feeders include the:**

- Angoumois grain moth
- Rice, granary, and maize weevils, and
- Lesser grain borer

Secondary feeders feed only on damaged grains and seeds. The outer layer of the grain or seed must be damage-cracked, holed, abraded, or broken. This may be caused by physical damage during harvesting, rapid drying, or by the feeding of a primary feeder. Some secondary feeders live in grain storage areas with primary feeders. The grain trade generally refers to secondary-feeding beetles as “bran bugs” or “bran beetles.” Concentrations of bran beetles may raise the temperature and/or moisture level within stored grain. These conditions favor rapid population growth.

**The most common secondary feeders of stored food products include the:**

- Indianmeal moth
- Mediterranean flour moth
- Tobacco moth
- Cadelle beetle
- Cigarette beetle
- Confused and red flour beetles
- Flat grain beetle
- Sawtoothed and merchant grain beetles
- Yellow mealworm beetle, and
- Grain mite

Both primary and secondary feeders can cause significant financial losses to stored grain and food products. Common pests of raw agricultural products include moths, beetles, mites, and rodents. You can control these pests with fumigant pesticides in many situations.

**Other pests of raw agricultural products include:**

- Rodents
- Rats and
- Mice

## Common Pest Descriptions

### Moth Pests

Moths are second only to beetles in the amount of damage they cause to stored products. Thankfully, only the larval stage causes damage.

### Damage

Moth larvae damage grain by eating and contaminating it so that it is not fit for human consumption. Some moths like whole grains.

Others prefer milled or ground foods such as flour, cereals, and pet food. Damage usually occurs when these items are stored for an extended period. If control is poor, moths may follow a product throughout the manufacturing and distribution process. You can find moth pests in fields, storage bins, mills, delivery trucks, retail stores, and consumers' homes.

### Life Cycle

To control moths, you must understand their life cycle. Moths are close relatives of butterflies. They develop by complete metamorphosis. Female moths lay eggs singly or in small groups. An adult female can produce several hundred eggs during her brief life. The caterpillars hatch from the eggs and feed on nearby food. Each caterpillar grows and sheds its skin several times. After feeding for several weeks, the caterpillar spins a cocoon. In the cocoon, it transforms into a pupa. The adult moth emerges several weeks later. Adults live for a short time and do not feed on grains. Females die soon after they lay their eggs. Moths may produce several generations per year, depending on the temperature and food source. In good conditions (warm temperatures and abundant food), they may complete their life cycle in one to three months.

### Identification

Adult moths have two pairs of wings that fold over the body when the moth is resting. Like butterflies, some moths have color patterns on their wings. Others have solid-colored wings. The antennae of female moths are long and slender. The male's antennae are long and brushlike or featherlike.

Moth larvae called caterpillars resemble small worms with legs. Some species have distinct color patterns that can help with identification. It is easy to confuse moth larvae with beetle larvae. An easy way to distinguish between the two is to look at the middle of their bodies. Moth larvae usually have fleshy, leg-like appendages called “prolegs” on several of the middle segments of their bodies. Prolegs are not present on the middle sections of beetle larvae.

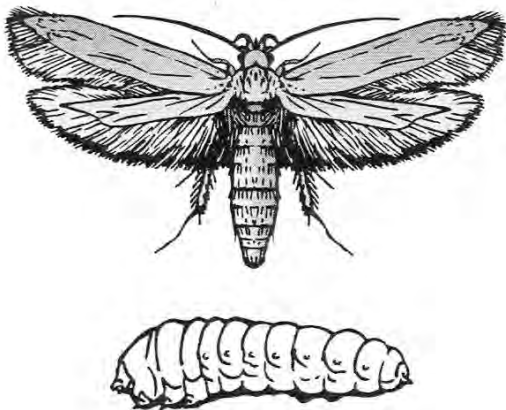
There are many types of pest moths. The following are some of the most common and troublesome to raw commodities in Arkansas.

## Angoumois Grain Moth (*Sitotroga cerealella*)

Adults have four wings and about a 2/3-inch wingspan. The forewings are buff to pale yellowish brown. Hind wings are gray and pointed, resembling a pointed finger. Both sets of wings are fringed with long hairs. Adults are nonfeeding, short-lived, and attracted to light. In the spring, they often fly out to fields and lay eggs on the grain kernels while they are still on the plant.

Each female lays 40 to 400 eggs directly on grain kernels. The eggs are white when first deposited but soon turn red. Emerging larvae are white with yellowish heads and reddish brown mouthparts. Each larva bores into a whole grain kernel, spinning a silken web over the hole through which it enters. Once inside the kernel, larvae pupate inside the kernel. When they emerge, Angoumois grain moths leave a distinctive round flap over the hole in the grain.

Angoumois grain moths are primary feeders that attack only whole kernels or caked material. Barley, rye, corn, oats, rice, wheat, and various seeds are common targets. Larvae attack grain in the field as well as in storage. They cause a reduction in grain weight and quality. Heavily infested grain smells bad and is less attractive for consumption. Corn cribs infested with this insect will contain ears with small holes in individual kernels. Ears throughout the crib will be infested. In bins, however, only the top few inches of grain will be infested. The Angoumois grain moth prefers damp grain to dry grain. Adult moths cause no damage.



**Angoumois grain moth adult and larva**

## Indianmeal Moth (*Plodia interpunctella*)

Adult Indianmeal moths have four wings spanning about 3/4 inch. You can distinguish them from other moths by the color pattern of their front wings. The outer two-thirds of the front wings are reddish brown and the bases are grayish white. The hind wings are pale gray. The head and thorax are reddish. Adult Indianmeal moths are weak fliers. They are usually active for only a few hours in the evening. Most of the time, they remain close to the infested material.



**Indianmeal moth adult and larva**

Female adult Indianmeal moths lay from 100 to 400 eggs singly or in groups directly on food material. The small, pale yellow eggs hatch in about three days. Larvae emerge and feed on nearby grain products. They are usually dirty white but may have a greenish or pinkish tint. Full-grown caterpillars are about 1/2 inch long with a brown head. Caterpillars spin silk thread as they crawl. Heavily infested materials are often covered with a fine, web-like mesh of silk. Caterpillars usually move away from their food to spin a cocoon and pupate. Sometimes you will find Indianmeal moth caterpillars crawling across ceilings or walls far from the source of infestation.

In agriculture, the Indianmeal moth is one of the most common pests of grain storage and processing facilities, as well as stored products in homes and warehouses. It is a secondary pest that feeds on cracked corn and grain that is damaged by other insects. It attacks grain and grain products, seeds, nuts, a variety of dried



fruits, and other commodities. Because of its preference for corn, the Indianmeal moth is common in the corn-growing and corn-storage areas of the United States. Adult Indianmeal moths cause no damage.

In stored products and around the home, Indianmeal moth larvae are one of the most common pests of stored flour products, ground meal, birdseed, and dry pet food. They also feed on other dry foods including dried fruit, seeds, powdered milk, chocolate, and candy. Adult Indianmeal moths cause no damage.

### **Mediterranean Flour Moth** (*Ephestia kuehniella*)

Adult moths have a wingspan of about 1 inch. The forewings are pale gray with wavy black lines running across them. The hind wings are dirty white. When the adult is at rest, the head and abdomen are slightly raised, making the wings look as if they slope downward. Adults fly at night in a very characteristic zigzag pattern. Adults are also nonfeeding and short lived.



**Mediterranean flour moth adult and larva**

Adult females lay up to 675 white eggs on or near food. In three to five days, pinkish white larvae emerge. Larvae have reddish brown heads, a few small hairs, and a few black spots on their bodies. They spin silken tubes within which they feed and mature. When fully developed, larvae are about 1/2 inch long. Larvae are active crawlers. As they move, they spin silken threads that mat food particles together. These mats can clog processing equipment. Pupation occurs near clean food, away from large amounts of infested material.

The Mediterranean flour moth is a secondary feeder that prefers flour and meal. However, it also infests grain, nuts, seeds, and

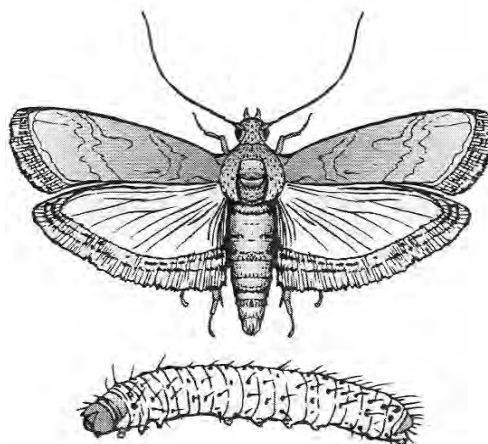
other stored foods. Adult Mediterranean flour moths do not cause damage.

### **Tobacco Moth** (*Ephestia elutella*)

The tobacco moth is smaller than, but similar to, the Mediterranean flour moth. Adults are light grayish brown with two light-colored bands extending across each forewing. Its wingspan is about 5/8 inch. Black scales border the forewings. The hind wings are uniformly gray in color. Adults moths are nonfeeding and short-lived. They are attracted to lights at night and fly toward the top or roof of buildings at dawn and dusk.

Adult females lay up to 270 eggs singly or in small clusters on or near food. When they emerge, larvae move onto and over produce, feeding and spinning threads that can form webs. Larvae are pinkish to yellowish to off-white with a brown head and pronotum. Larvae molt five time, and when full grown, they migrate to sheltered areas to pupate.

Found worldwide, the tobacco moth is a severe pest of stored tobacco. It is a secondary feeder that attacks the highest-priced amount of sugar. Larvae deposit silken webbing containing fecal pellets on the cured tobacco leaf as they feed. When infestations are high, tobacco moths may consume entire leaves except for the midvein. Tobacco moth larvae also feed on a range of cereal, vegetable, and seed products. Adult tobacco moths do not cause damage.



**Tobacco moth adult and larva**

## Control

To control moths attacking food and fabrics, prevention is key.

**Food Products** – Routine cleaning of all food-handling equipment with preventative spot fumigation may reduce or eliminate the need for large-scale fumigation. Good sanitation involves removing spilled flour, meal, dust, and other stored product in and around the holding area. Be sure to clean corners, floors, and walls. Bits of product remaining can harbor insects that can move into the new products stored in the same area.

If an infestation does develop, first find and destroy infested materials. Then treat the location where they were stored. Thoroughly clean the area to remove spilled food products. Practice good housekeeping to prevent reinfestation.

**Fabrics** – Control small infestations by cleaning fabrics and storing them in tight containers with moth crystals. Large infestations such as in a warehouse may require fumigation. However, the problem must be severe enough and/or the products must be valuable enough to justify the expense of fumigation. Practice good housekeeping to prevent reinfestation.

Use fumigation as a last resort.

## Control of Moth Pests

To control moths, prevention is key. Routine cleaning of all storage facilities, with preventive spot treatments and space sprays, may reduce or eliminate the need for large-scale fumigation. Good sanitation involves removing spilled grain, grain dust, and other stored products inside and outside the storage area. Be sure to clean corners, floors, and walls. Bits of product remaining can harbor insects that can move into the new products stored in the same area. Also, make sure that grain and feed in adjacent buildings are not infested. Moths can fly from one building to the next.

Prevention also involves following good grain storage practices. Monitor for insect infestations and heating in stored grain. Aerate to maintain low moisture levels in the grain. Mix and level the grain so fines and other grain debris are

evenly distributed throughout the grain. For more information on proper grain storage, see Unit 4.

If an infestation does develop, find and destroy infested materials. Then treat the location where they were stored. Thoroughly clean the area to remove spilled product. Practice good housekeeping to prevent reinfestation. Use insecticides to help prevent damage when environmental conditions are favorable for moth infestations. Use fumigation as a last resort.

## Beetle Pests

There are hundreds of thousands of beetle species in the world. Fortunately, only a few attack raw agricultural and stored products. Those that do, however, can cause serious damage and large financial losses if left uncontrolled.

## Damage

Beetles attack a wide range of agricultural and stored products. Most species infest a specific commodity or type of commodity. For example, cigarette beetles prefer dried plant materials such as cured tobacco, herbs, and spices. Rice, granary, and maize beetles attack stored grains. By knowing which pest(s) attack(s) which product(s), you can more quickly pinpoint the source of damage.

## Life Cycle

Like moths, beetles develop by complete metamorphosis: egg, larvae, pupae, and adult. Female beetles lay eggs singly or in small groups on a variety of foods. The larva, or “grub,” that hatches from the egg will feed on the available food. The grub stage may last 14 to 16 months. Full-grown grubs build cocoons out of scraps of food. They pupate inside these cocoons. After several weeks, adult beetles emerge. Adults live for several months or as long as one year. Both adult beetles and grubs are active feeders, damaging a range of stored products. In warm climates or heated buildings, beetles can produce six or more generations a year.

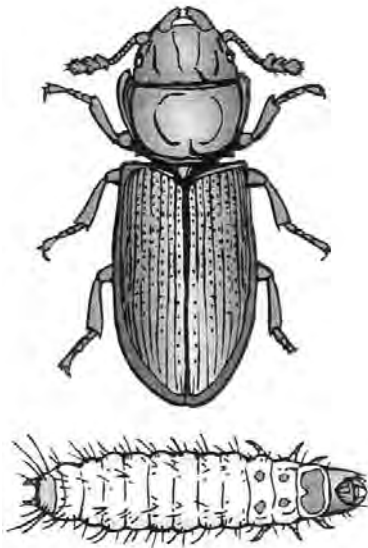
## Identification

Beetles are very diverse in appearance. However, there is one feature common to most beetle species. Adults have a pair of thin inner wings covered by a pair of shell-like outer wings. These outer wings are called “elytra” or “wing covers.”

The following are a few of the most common beetle pests of raw agricultural products.

### Cadelle

(*Tenebroides mauritanicus*)



Cadelle adult and larva

Cadelle beetles are one of the largest stored-products pests. Adults measure 1/3 to 1/2 inch in length. They are long, flattened, and shiny black. They have brown antennae and legs. Adult cadelles are long-lived, often surviving for more than a year.

The adult female cadelle lays about 1,000 eggs over several moths. Emerging larvae are grayish white with a black head and thoracic shield. When larvae are mature, they measure about 5/8 inch long. Larvae have a black plate with two hornlike projections on the upper side of their last abdominal segment.

Cadelle beetles are secondary pests. They attack grain in rice mills, flour mills, and storage bins on farms. The larvae and adults feed by moving from grain to grain and devouring the germinal region. Cadelle larvae also cause

damage by boring into the floor and walls of wooden storage bins. They sometimes burrow into empty bins as larvae and remain dormant until fresh grain is stored. A seemingly clean bin may hold thousands of insects. Cadelle larvae and adults are large and can go without food for 52 (adults) to 120 (larvae) days. Since they live for nearly one year, they are more common in old grain bins and flour mills.

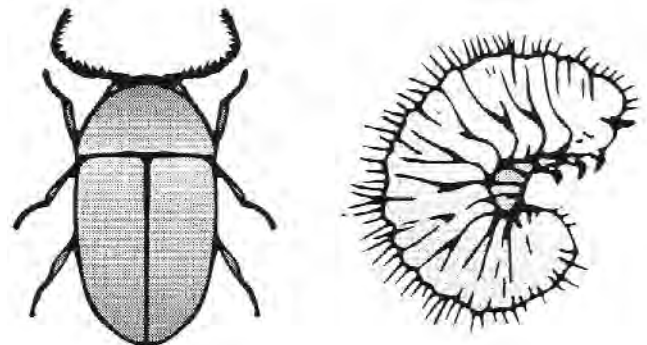
### Cigarette Beetle

(*Lasioderma serricorne*)

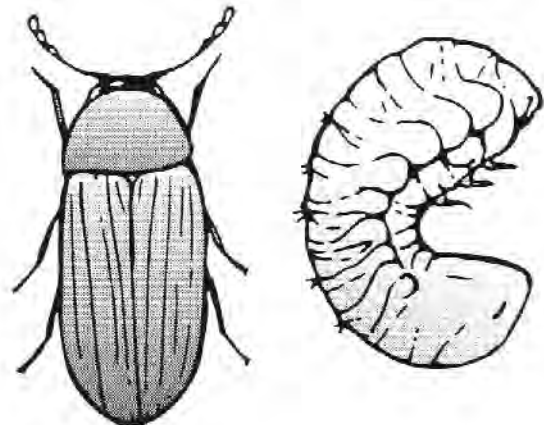
### Drugstore Beetle

(*Stegobium paniceum*)

Adult cigarette and drugstore beetles are small, oval insects. They usually measure 1/16 to 1/8 inch long. They look hump-backed because their heads are bent at an angle under their thorax. Their bodies are covered with small hairs that give them a silky, yellowish brown to reddish color. You can distinguish the two



Cigarette beetle adult and larva



Drugstore beetle adult and larva

beetles by their antennae, wing covers, and flight habits. Adult drugstore beetles have enlarged terminal segments of their antennae. They seldom fly, and their wing covers have faint, longitudinal rows of punctures or pits. On the other hand, cigarette beetle antennae are saw-like. They often fly, and they have scattered punctures over their wing covers.

Adults of both species are nonfeeding. The cigarette beetle female lays her eggs in groups of 30 to 40 eggs. Female drugstore beetles lay eggs singly. Both deposit their eggs on or near food sources. When the eggs hatch, tiny, C-shaped larvae emerge. The larvae are creamy white with yellow heads and brown mouth parts. Mature larvae are about 1/6 inch long. Larvae are often covered with the material they infest.

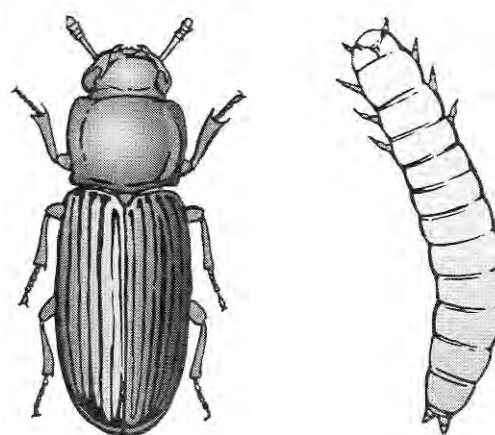
As its name implies, the cigarette beetle is primarily a pest of dried tobacco. It can infest stored, bundled leaves as well as finished products like cigars and cigarettes. However, this beetle can also feed on a variety of stored food products including cereals, ginger, raisins, dates, pepper, and dried fish.

The drugstore beetle feeds on a variety of foods and spices including red pepper, cayenne pepper, ginger, and paprika. They also attack some medicines. Drugstore and cigarette beetles can penetrate most paper packaging materials.

### **Confused Flour Beetle** (*Tribolium confusum*)

### **Red Flour Beetle** (*Tribolium castaneum*)

Adult confused flour beetles and red flour beetles are long, flat, shiny, reddish brown insects. They measure about 1/7 inch long. The head and upper parts of the thorax are densely covered with minute punctures or "pits." The wing covers are ridged lengthwise. You can distinguish between the two beetles by their antennae and ability to fly. The antennae of the confused flour beetle gradually enlarge toward the tip, producing a four-segment club. The red flour beetle's antennae enlarge abruptly at the last few segments, giving the antennae a knobbed appearance. The red flour beetle is a strong flier. The adults are very active, especially in the evening hours. The confused flour beetle cannot fly.



**Confused flour beetle adult and larva**

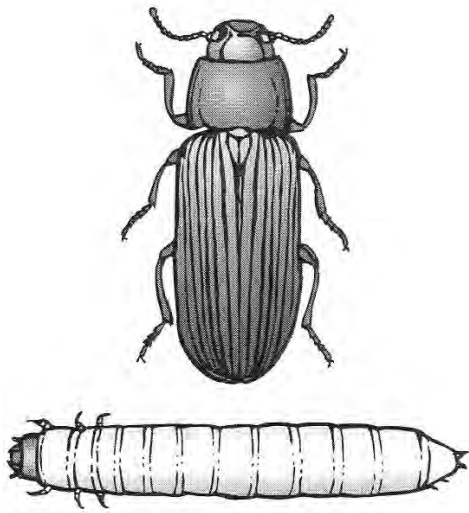
Female flour beetles lay an average of 450 eggs directly on the food source. Eggs are small and clear white. The female covers the eggs with a sticky secretion to which bits of the food adhere. Small, brownish white larvae hatch in five to twelve days. They are full grown in one to four months. A full-grown larva is about 3/16 inch long and tinged with yellow. Larvae feed on broken kernels, flour, meal, and other starchy materials. They are often hard to detect because they cover themselves with bits of the food they infest. They may appear as tiny lumps in the flour. The larvae pupate and transform into adults.

Confused and red flour beetles are serious pests in flour mills. They do not penetrate whole grain kernels or undamaged grain. Instead, these secondary feeders cause damage by scraping the surface of foods or eating finely ground material. Their preferred foods include grains and grain products, peas, beans, flour, dried fruits, shelled nuts, spices, and other commodities. These beetles may leave a bad odor that affects the taste of infested products.

### **Flat Grain Beetle** (*Cryptolestes pusillus*)

The adult flat grain beetle is tiny, flat, and reddish brown. It measures 1/16 inch long. You can distinguish it from other stored-product pests by its long antennae, which often grow two-thirds the length of the insect's body

Female flat grain beetles lay small white eggs in the crevices of grain. When they emerge,

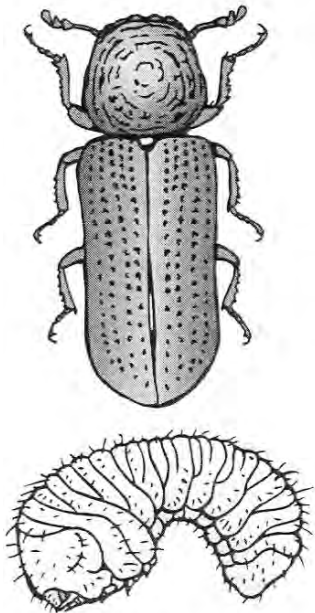


**Flat grain beetle adult and larva**

larvae are slender and pale, with dark-colored legs and a dark head. Each larva has a pair of black, spine-like “tail horns” at the end of its body. Mature larvae form cocoons to which food particles stick.

The flat grain beetle is a widely distributed secondary pest. It primarily feeds on the germinal region of stored grains, especially wheat. It prefers damaged grain with a high moisture content.

### **Lesser Grain Borer** (*Rhizopertha dominica*)



**Lesser grain borer and larva**

The adult lesser grain borer is 1/8 inch long and shiny dark brown or black. It has a slender cylindrical form. Its body surface is somewhat roughened, and its head turns down under its thorax. Lines of small pits occur on the wing covers. Powerful jaws allow the lesser grain borer to bore into wood as well as grain. The last three segments of the antennae are enlarged on one side. Adult lesser grain borers are strong fliers and long-lived.

Adult female lesser grain borers lay up to 500 eggs singly or in clusters in loose grain. When the larvae emerge, they are C-shaped and white with dark heads and claws. Larvae burrow into and feed on the interior of nearly all types of stored grain. When mature, the larvae measure about 1/8 inch. They complete development by pupating inside grain kernels. It is often difficult to detect infestations of lesser grain borers because the adults and larvae are usually together inside the infested grains.

Lesser grain borers occur worldwide. They are primary feeders that attack cereal and coarse grains, especially whole corn and wheat kernels. Both adults and larvae are voracious feeders and can penetrate packaging. Grain infested with the lesser grain borer has a characteristic sweet and slightly pungent odor. This odor contains a male-produced pheromone that has proven to be an effective lure for traps.

### **Rice Weevil** (*Sitophilus oryzae*)

### **Granary Weevil** (*Sitophilus granaries*)

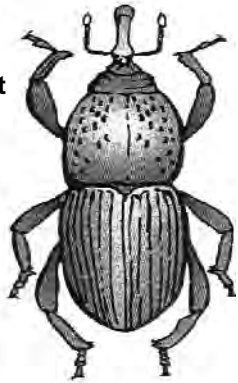
### **Maize Weevil** (*Sitophilus zeamais*)

Weevils are among the most destructive pests of grains, seeds, and grain products. Most are primary feeders that attack the inside of grain kernels. Of these, the rice weevil, the granary weevil, and the maize weevil are the most common in Arkansas.

Adult rice and granary weevils vary in size but average about 1/8 inch long. The bodies of rice and granary weevils are reddish brown to black with ridged wing covers. Their thoraxes are densely pitted. Their mouthparts form elongated snouts, characteristic of all weevils.



**Rice weevil adult**



**Granary weevil adult**



**Rice/granary weevil larva**

You can distinguish between the granary and rice weevils by the shape of their pits, the color of their bodies, and their ability to fly. Adult rice weevils are dull in color and readily fly. They tend to have round pits covering the thorax. They also have four pale reddish to yellow marks on the corners of the wing covers. Adult granary weevils have oval pits, a polished coloration, and they cannot fly.

Their wing covers are solid in color. The maize weevil and the rice weevil are so close in appearance that identification should be left to the experts. Maize weevils are slightly smaller than rice weevils.

Adult rice and maize weevils live for four to five months. Each female lays 300 to 400 eggs. Adult granary weevils can live for seven to eight weeks. Each female lays 50 to 200 eggs. Females of all three species use their strong mandibles to chew a small hole in a grain kernel. There they deposit a single egg and seal the hole with a gelatinous fluid. The small, white, legless larvae hatch, feed, and develop inside kernels of grain. Since rice and maize weevils can fly, infestations

may develop in the field before harvest. On the other hand, granary weevils cannot fly. You most often find these insects only where grain is stored.

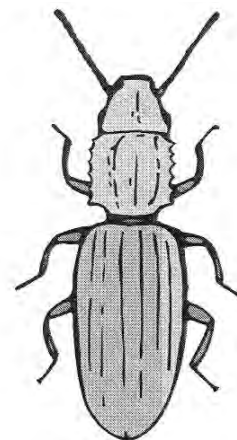
Granary weevils are tolerant of low temperatures and cold climates. Within grains, larvae can survive at least ten weeks at 41°F. Adults easily overwinter in unheated buildings and bulk grain. Adult rice and maize weevils do not normally overwinter in cold climates unless the grain heats up due to a high moisture content.

Rice, granary, and maize weevils are primary feeders that attack grain before harvest and in storage. They feed on both unbroken and broken grain kernels. Wheat, corn, oats, rice, sorghum, and buckwheat are just some of their preferred foods. These pests also infest grain products such as spaghetti and macaroni. Both the adults and larvae damage agricultural products.

### **Sawtoothed Grain Beetle (*Oryzaephilus surinamensis*)**

### **Merchant Grain Beetle (*Oryzaephilus mercator*)**

Adults of these two beetles are 1/8 inch long, slender, dark brown, and flat. They have sawtoothed-like projections on each side of the thorax. The larvae are yellowish white and less than 1/8 inch long. They become covered with



**Sawtoothed grain beetle adult and larva**

the food they ingest and appear as small lumps in flour. Merchant grain beetles are known to fly, whereas sawtoothed grain beetles do not fly.

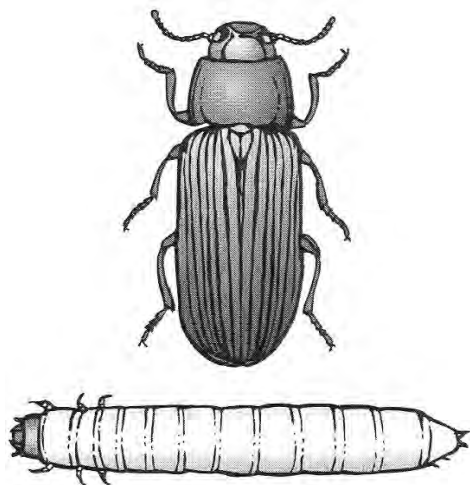
Adults of these two beetles usually live six to ten months, but some may live as long as three years. The female lays 50 to 300 eggs in flour, meal, or other stored products. The eggs hatch in flour, meal, or other stored products. The eggs hatch in about four days, and the larvae begin feeding immediately. When the larvae are full grown, they construct cocoons out of fragments of foods. Within these cells, the larvae change to pupae and then to adults.

Sawtoothed and merchant grain beetles are secondary feeders that attack nearly all foods of plant origin. Although they are not able to attack intact kernels, they do cause a considerable amount of damage to grains by infesting slightly damaged pieces. Sawtoothed and merchant grain beetles also feed on grain products such as flour, meal, cereal, and macaroni, as well as nutmeats, candy, and dried fruits. Since these beetles are very flat, they easily hide in cracks and crevices and often penetrate improperly sealed packaged foods. The sawtoothed grain beetle prefers areas of high temperature and humidity.

### **Yellow Mealworm or “Mealworm Beetle”**

**(*Tenebrio molitor*)**

Adult mealworm beetles are about 1/2 inch long. Their bodies are shiny dark brown or black. Tiny punctures occur in rows along the wing



**Yellow mealworm beetle and larva**

covers. The antennae are slightly clubbed at the tip. Yellow mealworm beetles have well-developed wings and are strong fliers.

Adult mealworm beetles lay their eggs in grain or food products. Each female produces up to 500 bean-shaped eggs. The eggs are white and sticky, quickly becoming covered with food particles. Larvae are pale brown to yellow, smooth, and hard bodied. When fully developed, they measure 1 1/4 inches long. Larvae develop slowly, living at least one year. They pupate near the surface of the food.

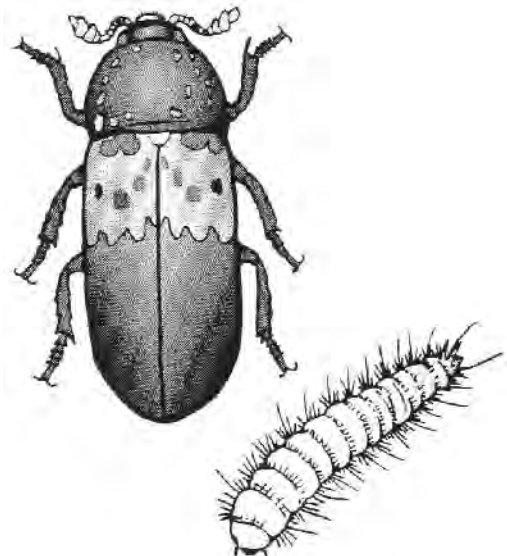
The mealworm beetle is a common pest of grain, grain dust, and debris. Yellow mealworm infestations typically indicate poor sanitation. You may find them in grain spillage, neglected corners where grain dust has accumulated, or under bags of grain. They also occur in poultry houses, where chicken droppings mix with grain.

### **Larder Beetle**

**(*Dermestes lardarius*)**

Adult larder beetles are 1/4 to 3/8 inch long, oval, and elongated. They are dark brown to black with a broad pale yellow band across the front third of their wing covers. The band is speckled with darker spots. Also noticeable are the short, clubbed antennae.

Adult females lay 100-800 eggs on food or in cracks where food is stored. Brown, hairy larvae emerge in 12 days. They range in length from



**Larder beetle adult and larva**

3/8 to 5/8 inch. To pupate, larder beetle larvae bore into solid materials such as ham and wood. After three to five days, adults emerge.

Adults and larvae feed on a variety of animal products including dried fish, ham, bacon, meats, cheese, and dried pet food. They will also attack dried museum specimens such as insects, hides, feathers, horns, and hair. Larvae cause most of the damage, but adult feeding can also cause problems. Larder beetles are often found with masses of dead insects gathered at windows or ventilators.

## Control

Controlling beetles in stored products is much the same as controlling moths. Prevention is key.

**Food Products** – Clean in and around storage areas regularly. Good sanitation involves removing spilled flour, meal, dust, or other stored product in and around the holding area. Be sure to clean corners, floors, and walls. Bits of product remaining can harbor insects that can move into new products stored in the same area. Apply nonfumigant pesticides to areas that are hard to reach. Routine cleaning, with preventive spot fumigation, may reduce or eliminate the need for large-scale fumigation.

If an infestation does develop, first find and destroy infested materials. Then treat the location where they were stored. If the infestation is severe, you may need to fumigate. Practice good housekeeping to prevent reinfestation.

**Animal Products** – Practice good sanitation to prevent larder beetle infestations. This involves keeping areas free of hair, dead insects, spilled animal food, and other items in which larder beetles commonly nest. When small infestations develop, find and remove infested items. If you cannot identify the source of infestation and the problem is severe, fumigation may be necessary. Fumigation may also be needed when an individual item, such as an animal hide, is attacked. This is true if:

- Other control options such as chemical sprays would damage the item, or
- Other types of pesticides are not able to penetrate the item and kill the beetles

## Control of Beetle Pests

Controlling beetles in stored products is much the same as controlling moths. Prevention is key. Start by cleaning in and around product storage areas regularly. Practice good sanitation by removing spilled grain, grain dust, and other stored product inside and outside the storage area. Be sure to clean corners, floors, and walls. Bits of product remaining can harbor insects that can move into new products stored in the same area. Apply nonfumigant pesticides to areas that are hard to reach. Routine cleaning, with preventive spot fumigation, may reduce or eliminate the need for large-scale fumigation.

Prevention also involves following good storage practices. Monitor for insect infestations and heating in stored products and grain. Aerate storage facility to maintain low moisture levels in the grain. Mix and level the grain so fines and other grain debris are evenly distributed throughout the grain.

If an infestation does develop, first find and destroy all infested products. Then treat the location where they were stored. If the infestation is severe, you may need to fumigate. Practice good housekeeping to prevent reinfestation.

## Other Pests

### Grain Mites

(*Acarus siro*)

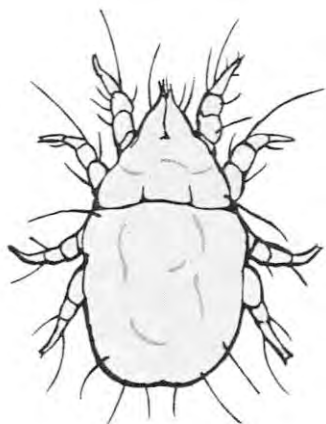
Mites are not insects. They belong to a group of arthropods called “arachnids.” This same group includes spiders. Mites look and behave much like insects with a few differences. Adult mites have eight legs and two body segments. Insects have six legs and three body segments.

Mites go through three stages of development: egg, nymph, and adult. Some references refer to the first nymphal instar as a larva, but it is technically a nymph. Adult and nymphal mites have eight legs and are similar in appearance.

Adult grain mites are pearly white with pale yellow to reddish legs. Their bodies are oval, measuring about 1/128 to 1/64 inch long. Two pairs of long hairs trail from the rear of the body. Grain mites are not hard shelled.



Mites develop by gradual metamorphosis. An adult female can lay up to 800 eggs in her lifetime. She deposits white, oval eggs one at a time directly in food material. When the larvae hatch, they feed and grow quickly for about three days. Fungi attract the mites to the food source. Fungi on unbroken grain weaken the hull, allowing mites access to the germ where they feed and reproduce. Mites cannot survive when the humidity drops below 60 percent. Their life cycle takes 17 to 28 days.



**Grain mite**

Also called the “flour mite,” the grain mite occurs worldwide. It infests grain and flour with a high moisture content. It is responsible for “mite dust” on the surface of cheese or on the

floor near bags of flour or wheat. Grain mites also attack cereals, animal feeds, dried fruits, and other vegetable materials. The grain mite occurs in fields, barns, bird nests, grain elevators, and other areas. By attaching itself to insects, birds, and other animals, the grain mite can disperse widely. Large populations leave a characteristic minty odor. Grain mites can cause a type of dermatitis in humans known as “grocer’s itch.”

## **Control of Grain Mites**

The best way to control grain mites is to monitor the humidity and moisture level in and around stored products. Ventilate storage areas well. Keep the relative humidity below 60 percent. It is also important to move susceptible products and clean storage areas periodically.

When small infestations develop, remove and destroy the infested product. Clean the area thoroughly. Apply a nonfumigant pesticide to kill remaining mites and their eggs. Large infestations usually require fumigation.

Accurate identification of pests is vital for control methods of any type to be effective. Once you decide fumigation is the best way to control the pest, your knowledge of methods and application procedures comes into play.

## Test Your Knowledge

**Q. Give several examples of raw agricultural products.**

- A. Whole grains (corn, wheat, rye, etc.), cured tobacco, baled cotton, and seeds

**Q. Describe the difference between primary and secondary feeding insects.**

- A. Primary feeding insects are capable of destroying whole, sound grain. The most damaging primary feeders are those that develop within grain kernels. These insects feed on the “germinal” region (early growth) of the seed, reducing its nutritional value and its ability to sprout. Adult females of internal feeders deposit eggs on or in whole kernels. Larvae develop within the kernels.

Secondary feeding insects feed only on damaged grains and seeds. The outer layer of the grain or seed must be damaged—cracked, holed, abraded, or broken. Secondary feeders live in grain storage areas or in flours, meals, and other processed cereal products.

**Q. Is damp grain or dry grain more susceptible to insect infestation?**

- A. Damp grain

**Q. What stage in a moth’s life cycle causes damage to stored products?**

- A. The larval (caterpillar) stage

**Q. How can you distinguish between moth larvae and beetle larvae?**

Look at the middle of their bodies. Moth larvae usually have fleshy, leg-like appendages called prolegs on several of the middle segments of their bodies. Prolegs are absent on the middle segments of beetle larvae.

**Q. Describe the life cycle of a moth.**

- A. Moths develop by complete metamorphosis. Females lay eggs singly or in small groups. The caterpillars that hatch from the eggs feed on nearby food. Each caterpillar grows and sheds its skin several times. After feeding for several weeks, the caterpillar spins a cocoon. In the cocoon, it transforms into a pupa. The adult moth emerges in about 30 days. Adults live for a short time

and do not feed. Females die soon after they lay their eggs.

**Q. A pest has spread silk webbing over some stored grain. Which of the following insects is most likely the cause?**

- Indianmeal moth
- Rice weevil
- Grain mite
- Sawtoothed grain beetle

- A. The Indianmeal moth

**Q. If the kernels in the top few inches of grain in a bin each have a small hole in one end, what pest is most likely the cause?**

- A. The Angoumois grain moth

**Q. What is the best way to prevent moths from attacking stored grain and other raw agricultural products?**

- A. Good sanitation. This involves removing spilled grain, grain dust, and other stored product inside and outside the storage area. Be sure to clean corners, floors, and walls. Bits of product remaining can harbor insects that can move into the new products stored in the same area. Also, make sure that grain and feed in adjacent buildings are not infested. Moths can fly from one building to the next. Prevention also involves following good grain storage practices. Monitor for insect infestations and heating in stored grain. Aerate to maintain low moisture levels in the grain. Mix and level the grain so fines and other grain debris are evenly distributed throughout the grain.

**Q. On what grade of tobacco does the tobacco moth normally feed? Why?**

- A. The tobacco moth attacks the highest-priced tobacco grades since these contain the greatest amount of sugar.

**Q. On what products does the Mediterranean flour moth normally feed?**

- A. The Mediterranean flour moth is a secondary feeder that prefers flour and meal. However, it also infests grain, nuts, seeds, and other stored foods.

**Q. True or False: Like moths, beetles develop by complete metamorphosis.**

A. True

**Q. What stages in a beetle's life cycle damage stored products?**

A. Adult beetles and beetle larvae (grubs) damage stored products. Both stages have chewing mouthparts, enabling them to feed on a variety of products.

**Q. The larvae of what beetle bore into the floors and walls of wooden storage bins?**

A. The cadelle

**Q. How can you distinguish between adult rice weevils and adult granary weevils?**

A. You can distinguish the two beetles by the shape of their pits, the color of their bodies, and their ability to fly. Adult rice weevils are dull in color and readily fly. They tend to have round pits covering their thoraxes. Adult granary weevils have oval pits, a polished coloration, and they cannot fly.

**Q. Which species of beetles prefer to feed on the germinal region of grains?**

A. The cadelle, the flat grain beetle, and the lesser grain borer.

**Q. Why are lesser grain borer infestations often hard to detect?**

A. The adults and larvae are usually together inside the infested grains.

**Q. What is the preferred food of the cigarette beetle?**

A. The cigarette beetle feeds on dried tobacco products, including whole leaves, cigars, and cigarettes. It also feeds on stored food products, including cereals and spices.

**Q. Why are flour beetle larvae hard to detect?**

A. They are small, and they cover themselves with bits of the food they infest. They may

appear as tiny lumps in flour. However, unless a stored product is sifted, the larvae are usually hard to find.

**Q. Which of the following pests penetrate intact grain kernels?**

- Rice and granary weevils
- Confused and red flour beetles
- Sawtoothed and merchant beetles

A. The rice and granary weevils

**Q. What do sawtoothed grain beetles and merchant grain beetles feed on?**

A. Nearly all foods of plant origin. Although they are not able to attack intact kernels, they do cause a considerable amount of damage to grains by infesting slightly damaged pieces. Sawtoothed and merchant grain beetles also feed on grain products such as flour, meal, cereal, and macaroni, as well as nutmeats, candy, and dried fruits.

**Q. Describe the preferred habitat of mealworm beetles.**

A. Mealworm beetles prefer dark, damp areas to feed on grain, grain dust, and debris. Yellow mealworm infestations typically indicate poor sanitation. You may find them in grain spillage, neglected corners where grain dust has accumulated, or under bags of grain. They also occur in poultry houses, where chicken droppings mix with grain.

**Q. What is the best way to prevent mites from damaging stored products?**

A. Control grain mites by monitoring the humidity and moisture level in and around stored products. Ventilate storage areas well. Keep the relative humidity below 60 percent. It is also important to move susceptible products and clean storage areas periodically.

# Miscellaneous Pests

## Cockroaches

There are more than 4,000 species of cockroaches in the world. However, only about ten are normally found living with people. These ten species have adapted to human habits. Our homes and other structures (ex., warehouses) provide them shelter, food, and water. In Arkansas, the most common invaders are the American cockroach, German cockroach, Oriental cockroach, and brownbanded cockroach.

## Damage

Cockroach infestations are not only a nuisance, they threaten human health and product quality as well. Cockroaches contaminate food with their feces, their body parts, and the disease-causing organisms they carry. Cockroaches carry four strains of poliomyelitis, more than 40 different disease-causing bacteria, and the eggs of several pathogenic worms. In addition, they have an unpleasant odor. Cockroaches contaminate nearly all stored products including food, packing materials, glues and pastes, grease, soaps, fabrics, and other items. They also transfer stains and odors to surfaces they touch.

## Life Cycle

Cockroaches undergo gradual metamorphosis. Females do not lay eggs one at a time. Instead, they produce small egg cases that contain from 6 to 40 eggs. The number of eggs per case varies by species. Females deposit their egg cases in protected places with adequate food and water.

“Nymphs” begin feeding soon after they hatch from the egg case. They have the same diet as the adults. Nymphs look like small wingless adults. After shedding their exoskeletons several times to grow larger, they become mature, reproductive adults.

Most mature cockroaches have wings. Adults live for a few months to over a year, depending on the species. They mate several times, and the females generally produce one egg case per month.

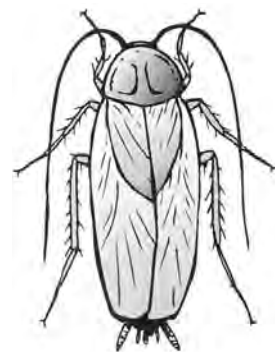
## Identification

Cockroaches vary somewhat in their appearance and habits. All species have chewing mouth parts and flattened oval bodies. Their antennae are long and slender. When viewed from above, the head is covered by a shieldlike structure called a “pronotum.” Some species have well-developed wings. Others have no wings. Cockroaches are fast-moving insects that seek cover in the daytime or when disturbed at night. However, when infestations are heavy, you can see cockroaches foraging during the day.

The following describes the features, behavior, and preferred food of the four most common cockroach pests in Arkansas.

### American Cockroach (*Periplaneta Americana*)

The American cockroach is the biggest species in Arkansas. Adults range from 1 1/3 to 1 1/2 inches in length but may grow as long as 2 inches. Adults are reddish brown. The pronotum has a light-colored margin. In this species, the male has wings longer than the abdomen. The female's wings are shorter, just covering the abdomen.



American cockroach

The female American cockroach usually deposits her egg case as soon as she produces it. She may live for 12 to 18 months and usually lays 10 to 15 egg cases.

Nymphs feed on the same material as the adults. They take a year or more to complete their development. Adults and nymphs actively forage during the warm months of the year. American cockroaches are inactive during the winter even in warm climates.

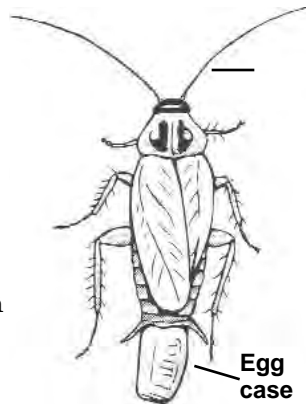
American cockroaches prefer warm, moist, and dark habitats. They often infest basement areas near water heaters, floor drains, or water sumps. They also like boiler rooms, sewer systems, and warehouses. In Arkansas, this species is primarily an indoor pest. However,

some individuals will move outdoors during the warm months. This can occasionally cause indoor control efforts such as fumigation to be ineffective if pests are able to escape to the outdoors. American cockroaches move by running from place to place. They have wings, but rarely fly.

American cockroaches damage all types of stored products including food, packing materials, glue, fabric, and other items. Like Oriental cockroaches, American cockroaches produce frass that can stain and damage many items.

### **German Cockroach** **(*Blattella germanica*)**

The German cockroach is the most common and widespread structural cockroach. Adults are 1/2 to 3/4 inch long. Their bodies are yellowish-brown with two dark stripes running lengthwise on the pronotum. Both males and females have well-developed wings, but they do not fly. Wings cover the entire abdomen.



**Female German cockroach with egg case**

German cockroaches lay small, brown egg cases. Each egg case contains from 30 to 40 eggs. The female carries the egg case until about 24 hours before the eggs are ready to hatch. Then, she places the egg case near food, water, and shelter. Once she becomes an adult, a female lives about six months. On average, she will produce one egg case a month, yielding about 240 nymphs. The average life cycle is about 100 days under favorable conditions.

While females are producing and carrying an egg case, they are inactive. They do not feed or seek water and often remain hidden. This can protect them and their young from certain pest control efforts such as baits and sprays. However, it does not protect them from fumigation.

German cockroaches live indoors only. They will eat almost any food consumed by humans. They are most commonly found where food is

handled or stored. German cockroaches also damage other stored products including packing materials, glues, grease, fabrics, and other items.

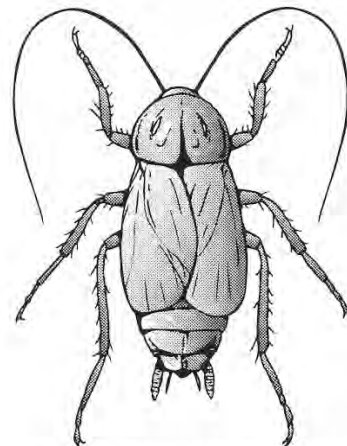
### **Oriental Cockroach** **(*Blatta orientalis*)**

Adult Oriental cockroaches are shiny black or very dark brown. Males are about 1 inch long, and females slightly longer. Females do not have wings, but they do have "wing pads." Males have short, wide wings that cover about 1/2 to 3/4 of the abdomen. Neither sex can fly.

The female glues her egg case to a surface in a protected area soon after it forms. She usually produces 8 egg cases during her life span. Nymphs develop slowly during the spring and summer. By fall, they are nearly full grown. Large nymphs overwinter with little feeding and molt to the adult stage in the spring. Adults live only a few months.

Oriental cockroaches are widespread in the United States. They can tolerate cool conditions and are often active in the early spring. This species lives both indoors and outdoors. It is strongly associated with excess moisture. Oriental cockroaches often live in sewers and enter buildings through drains and small cracks. Once inside, Oriental cockroaches infest crawl spaces and basement areas. Drains and cracks may provide an escape for these pests when threatened by indoor control efforts such as fumigation.

Like other cockroaches, the Oriental cockroach feeds on a wide range of stored products including foods, fabrics, glues, grease,



**Male Oriental cockroach**

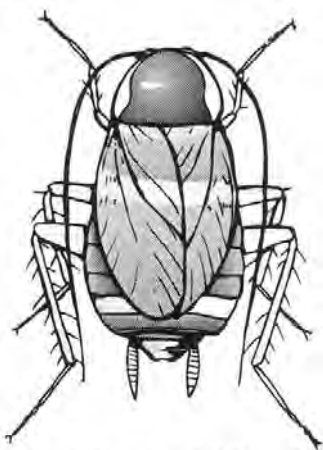
soap, and other items. They also produce frass that can stain many items.

## **Brownbanded Cockroach** **(*Supella longipalpa*)**

The brownbanded cockroach is similar in size and color to the German cockroach. However, the brownbanded cockroach has two light colored bands running from side to side just below the pronotum, at the base of the wings. The pronotum is dark brown with light sides. It does not have stripes. The female's wings are slightly shorter than her body, and the tip of her abdomen is rounded. By comparison, the male's wings are longer than his tapered abdomen. Females measure 1/2 inch long. Males tend to be slightly smaller. Male brownbanded cockroaches can fly, but usually move by running on walls and floors. Females cannot fly.

Females carry their small egg case for about 36 hours. Then, they glue it to a surface in a protected place. The number of eggs per case ranges from 18 to 20. Each female will produce about 14 egg cases during her life. The average time for development from egg to adult is 150 to 160 days.

Unlike other cockroaches, brownbanded cockroaches can withstand somewhat dry environments. This allows them to move into all areas of a building or home. You will often find them close to the ceiling or above ceiling tiles. Brownbanded cockroaches also prefer buildings that maintain high temperatures. They favor areas near stoves or around electric motors of machinery and appliances. This species does not normally infest food establishments.



**Female brownbanded cockroach**

Brownbanded cockroaches are often difficult to control. Because this species is not attracted to moisture, moist or gel baits provide little relief. In addition, their high habitats (on ceilings or above ceiling tiles) are difficult to reach with pesticide sprays. For these reasons, fumigation is often the only choice for large infestations.

## **Control**

The first step in controlling cockroach infestations is to eliminate food, water, and harborage sites (such as cracks and crevices). Poor sanitation, scraps left over from lunches, empty soda bottles, and dirty appliances will support cockroach populations in office buildings and factories. In particular, keep shipping and receiving areas free of food and water sources. These areas are where cockroaches gain access to buildings.

Favorite cockroach “hideouts” include:

- Under sinks
- Behind baseboards
- In and under stoves and refrigerators
- In, behind, and under built-in shelves and cabinets
- Under trash
- In washing machines
- Around machinery in warehouses
- In and under pallets, cardboard boxes, and stored paper goods, and
- In cracks and crevices in concrete, brick, or block walls

When chemical control is necessary, baits and nonfumigant pesticides should be the first line of attack.

While fumigation is rarely used to control cockroaches, it may be necessary in the following situations:

- When infestations are too severe for other pesticides (ex., mobile homes that have cockroaches living in walls, ceilings, under floors, and in other hard-to-reach areas)
- When a high-value product is at stake, and
- In a storage facility where product turnover is too fast for baits to kill cockroaches before the next shipment

## Rodents

Rodents are major pests of stored products. Four large, gnawing teeth (two on top and two on bottom) characterize these small- to medium-sized mammals. Rodents include mice, squirrels, rats, groundhogs, gophers, and similar mammals.



Mouse

The most serious rodent pests causing damage to stored products in Arkansas are the Norway rat (*Rattus norvegicus*) and the house mouse (*Mus musculus*). The roof rat (*Rattus rattus*) is an occasional problem as well. Rodent pests consume and contaminate large amounts of stored products. One rat can consume about

50 pounds of grain a year and can contaminate much more. Rodents also gnaw holes in wood, rubber, wiring, and insulation. Their burrows can undermine structures. Another common rodent pest, the groundhog (*Marmota monax*), causes damage by burrowing. Mounds of earth excavated from the burrows present a hazard to farm equipment, horses, and riders. Groundhogs also damage fruit trees and ornamental shrubs when they gnaw or claw woody vegetation.

## Control

Control rodents with a combination of sanitation, exclusion, and trapping. Nonfumigant rodenticides such as baits can also maintain populations at low levels. However, over a large area such as in a warehouse, fumigants may be the most cost-effective way to reduce rodent numbers.

Accurate identification of pests is vital for control methods of any type to be effective. Once you decide fumigation is the best way to control the pest, your knowledge of methods and application procedures comes into play.

## Test Your Knowledge

**Q. Why are cockroaches considered pests?**

- A. Cockroaches carry bacteria that cause disease. Many people are allergic to them, and they can cause some types of asthma. They have an unpleasant odor. They can stain and contaminate a number of stored products.

**Q. Describe the general body form of a cockroach.**

- A. Cockroaches have flattened bodies and long, slender antennae. When seen from above, the head is covered by a shieldlike pronotum. Most adult cockroaches have wings.

**Q. Describe the life cycle of a cockroach.**

- A. Cockroaches develop by gradual metamorphosis. Females produce eggs in cases. In some species, the female carries the case on her abdomen until the young are ready to hatch. These females retreat to a protected spot while carrying a case. In other species, the egg cases are deposited in an out-of-the-way place soon after they form. Nymphs hatch from the eggs and gradually develop into mature adults.

**Q. What environmental conditions do most cockroach species prefer?**

- A. Warm, moist conditions

**Q. Which species of cockroach can withstand dry conditions?**

- A. The brownbanded cockroach

**Q. Which species of cockroach does not normally infest food establishments?**

- A. The brownbanded cockroach

**Q. If a product is stained by cockroach frass, what two species would you suspect?**

- A. The American cockroach and the Oriental cockroach

**Q. Which of the four species of cockroaches discussed in this manual is the largest in size?**

- A. The American cockroach

**Q. Which of the four species of cockroaches discussed in this manual is the most common and widespread structural cockroach pest?**

- A. The German cockroach

**Q. Describe three situations in which fumigation may be necessary to control cockroach infestations.**

- A. 1. When infestations are too severe for other pesticides (ex., mobile homes that have cockroaches living in walls, ceilings, under floors, and in other hard-to-reach areas).  
2. When a high-value product is at stake.  
3. In a storage facility where product turnover is too fast for baits to kill cockroaches before the next shipment.

**Q. In what ways do rodents damage stored products?**

- A. By consuming and contaminating them. One rat can consume about 50 pounds of grain a year and can contaminate much more. Through their saliva, feces, and urine, rodents can introduce pathogens that are harmful to humans and livestock.

**Q. Name two types of rodents that commonly damage stored products.**

- A. 1. The house mouse  
2. The Norway rat



# Monitoring and Sampling in Raw Agricultural Products

Inspect for pests before they become a problem, and you will save time and money. Sampling will tell you the physical condition of your commodity or soil, and which and how many pests are present. It will also help you evaluate the effectiveness of previous control programs and allow you to take corrective measures before fumigation is required. Be thorough and use appropriate sampling equipment. Know where, how, and at what intervals you should sample.

## Detecting Pest Problems – Raw Products

To manage stored-grain insects effectively, always examine the grain before it is unloaded and moved into storage. Check grain for insects, moisture content, and sour or musty odors. Use manual or hydraulic probes to withdraw grain samples from incoming loads. Sift and check these samples for insects.

**Table 2-1. Number of live insects required for Federal Grain Inspection Service designation as “infested.”**

Grain	Insect Density Per Kilogram of Grain
Wheat, rye, triticale	<ul style="list-style-type: none"> <li>• More than one live weevil, or</li> <li>• One live weevil plus any other live insect pest, or</li> <li>• No live weevils, but two or more other live insect pests</li> </ul>
Corn, barley, oats, sorghum	<ul style="list-style-type: none"> <li>• More than one live weevil, or</li> <li>• One live weevil plus five or more other live insect pests, or</li> <li>• No live weevils, but ten or more other live insect pests</li> </ul>

Once grain has been stored, it is important to inspect bins regularly. Sample stored grain at 30-day intervals until it cools to less than 20°C. By taking samples, you can measure the grain temperature and moisture and detect any new insect problems. If there are “hot spots” (temperatures greater than 10°F higher than the rest of the grain), collect samples from these

areas. Hot spots indicate a high moisture content that favors insect and fungus activity. Determine the moisture content of your commodity and the presence of any insects. It is especially important to check for insects in samples from the grain surface and from areas where fines have collected. Infestations often begin in these locations.

Table 2-2 lists the minimum number of samples you should take when monitoring round bins. If temperatures are unusually high in certain spots, collect samples from those areas. Determine the moisture content and presence of any insects.

**Table 2-2. Minimum number of samples for determining temperature, moisture, and insect levels in round bins.**

Bin Height	Temperature Probes		Moisture and Insect Determinations	
	Shallow*	Deep*	Shallow*	Deep*
Less than 24 feet	2	3	3	5
Greater than 24 feet	2	5	3	10

\* Take shallow samples at or just below the surface of the grain. Take deep samples from various depths determined by the sampling equipment and your ability to probe the grain mass. Be sure to take one shallow sample and one deep sample from the center of the grain mass. This is especially important if fines are concentrated in the central core.

## Sampling Tools

Several types of probes are available for sampling grain. Industry suppliers can give you instructions for using these devices.

- **Partitioned grain trier (“probe”) –** This tool captures insects in stacked compartments. Suppliers sell 3-, 5-, 10-, and 12-foot models. Always sample the center surface of the storage bin and at least two other locations near the surface. To operate the grain trier, insert it into the grain at a 10° angle with the compartments closed and facing upward. Once the trier is in the grain, open the compartments to take a grain sample. Then, shut the compartments and remove the trier from the grain. Place the samples from each section in a plastic bag or other container. Sieve each sample and check for insects.

- **Deep-bin or deep-cup probes** – Use these probes to collect samples from greater depths within a grain mass. They extend up to 15 feet below the surface. The sample cup is attached to the end of a metal probe and inserted closed into the grain mass.
- **Vacuum samplers or power probes** – These tools allow you to collect samples from depths greater than 10 to 15 feet. A modified shop vacuum can collect samples from depths as great as 20 to 30 feet. Hydraulic or mechanically powered probes can collect samples from depths as great as 100 feet.

## Traps

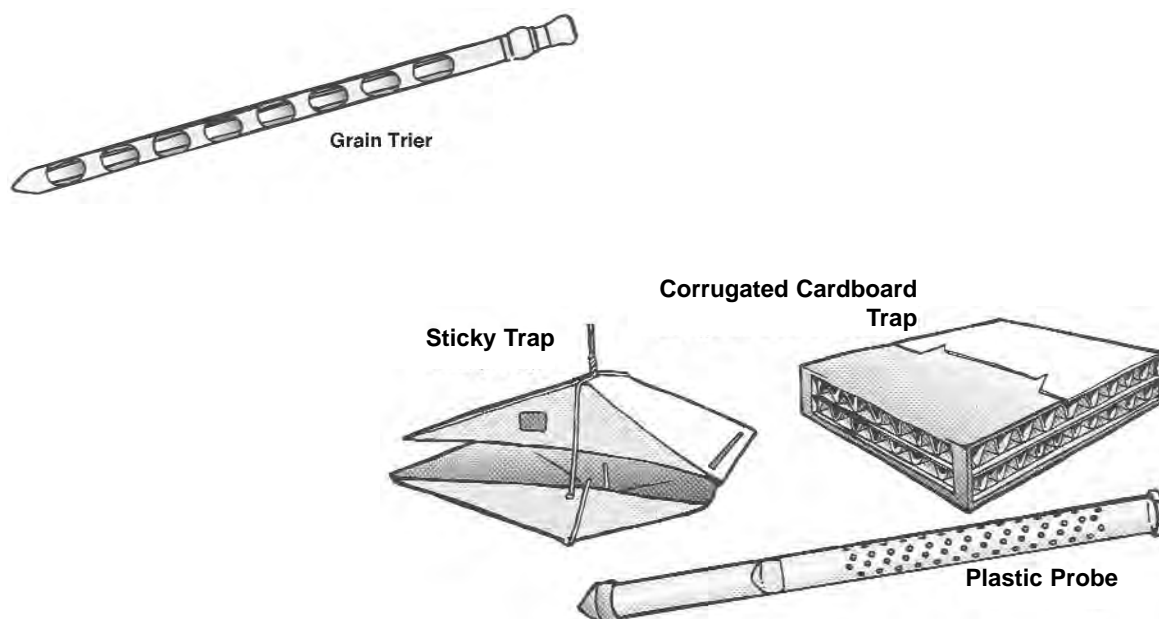
Traps are another way to monitor insect activity in stored grain. Because traps depend on insect movement, they are not effective when grain or air temperatures are below 50°F. At these temperatures, insects are not active.

- **Plastic probe or pitfall traps** – These traps consist of a long, clear plastic cylinder

with perforations drilled through the upper part. Insects crawl through the perforations and drop through a funnel into a lower catch-tube. See product literature for more complete instructions. Pheromones and food baits often enhance collections in these traps.

- **Corrugated cardboard trap** – This trap holds an oil lure that attracts and kills insects that are active where the trap is placed. You can use these traps on the surface of a grain mass to detect insect presence. They are also effective around bagged seeds or feeds in warehouses.
- **Paper sticky traps** – Baited with attractants, paper sticky traps allow you to monitor the flight of the lesser grain borer, cigarette beetle, and several other pests in warehouses and processing plants.

If you need help with insect identification contact your University of Arkansas Division of Agriculture County Extension agent.



## Test Your Knowledge

**Q. What are “hot spots”? Why are they of particular concern in stored grain?**

- A. Hot spots are areas in stored grain where temperatures are greater than 10°F higher than the rest of the grain. Hot spots indicate a high moisture content that favors insect and fungus activity.

**Q. Name several things you should look for or measure when sampling grain.**

- A. 1. The presence of insects  
2. Sour or musty odors  
3. High grain temperatures  
4. High moisture levels

**Q. Why is it important to collect samples from the grain surface and areas where fines have collected?**

- A. Insect infestations often begin in these locations

**Q. If you needed to collect a sample 50 feet deep within a grain mass, what type of probe would you use?**

- A. A hydraulic or mechanically powered probe

**Q. What type of trap allows you to monitor the flight activity of insect pests?**

- A. Paper sticky traps

**Q. At what temperatures are insect traps often NOT effective? Why?**

- A. Because many insect traps depend on insect movement, they are not effective when grain or air temperatures are below 50°F. Insect activity decreases below 50°F.

**Q. Describe the difference between how “biotic” and “abiotic” factors cause plant health problems.**

- A. Abiotic (nonliving) conditions such as too much or too little moisture or fertilizer tend to cause uniform problems over large areas. Pesticide carryover from previous growing seasons or pesticide drift can also affect plants uniformly over large areas. Biotic (living) factors include diseases, insects, or nematodes. Problems caused by these organisms rarely affect every plant in a field. Instead, they tend to concentrate in spots or areas within a field or planting. However, biotic problems can spread from small areas to attack large numbers of nearby plants, sometimes very quickly.

Often, both living and nonliving stress factors work together to cause plants to decline.

**Q. What is the difference between a “sign” and a “symptom” of a plant disease?**

- A. A sign of disease is a visible pathogen or part of a pathogen (ex., fungal spores, bacterial ooze). A symptom of a disease is a reaction of a plant that provides a visual clue that the plant is suffering. Symptoms may include slow or irregular growth, wilting, or even death.

**Q. Describe two different tests used to diagnose and predict damage caused by nematodes.**

- A. Diagnostic assays are used to identify whether a nematode is the cause of a particular problem. Predictive nematode assays are used to predict nematode populations before the planting season begins or before problems become more severe. This can help you predict when pesticide use (including soil fumigation) is necessary.

**Q. Why is it important to take multiple soil samples when sampling for nematode assays?**

- A. Diagnostic assays are used to identify whether a nematode is the cause of a particular problem. Predictive nematode assays are used to predict nematode populations before the planting season begins or before problems become severe. This can help you predict when pesticide use (including soil fumigation) is necessary.

**Q. Why is it important to take multiple soil samples when sampling for nematode assays?**

- A. Nematode numbers usually change dramatically within a single field.

**Q. How would you sample the soil from a field that has several soil types?**

- A. First, divide the field into as many sections as there are soil types. Collect at least 20 samples for every 4 acres within a section.

**Q. What sampling pattern would you use to collect soil samples around a single tree?**

- A. Collect 10 samples – 5 near the trunk and 5 from the dripline.

# Unit 3: Characteristics and Effects of Fumigants

## Learning Objectives

After reading this unit, the reader will be able to:

- Describe several characteristics of fumigants.
- Explain how these characteristics can affect how, when, and where you use a particular fumigant.
- Identify several factors that can affect fumigant performance during stored product and soil fumigation.

Like all pesticides, several factors can affect how well a fumigant will work. These range from characteristics of the fumigant itself (boiling point, molecular weight, etc.) to external factors such as air movement, temperature, and applicator knowledge and skill. This unit will describe each of these factors. You will discover how small differences can have a big effect on fumigant performance and safety.

## Terms to Know

**Absorption** – When fumigant molecules penetrate into a material (commodity, soil, or other item being fumigated).

**Adsorption** – When fumigant molecules stick to the surface of a material (commodity, soil, or other item being fumigated).

**Aeration** – *Fumigant application*: The process of replacing fumigant-containing air or water with fresh air and/or water that contains little or no fumigant. Aeration must follow all fumigation operations.

**Boiling Point** – The temperature at which a liquid becomes a gas.

**Desorption** – The liberation or removal of a fumigant from treated surfaces and/or substances.

**Diffuse** – To spread or distribute, to move in all directions.

**Dosage** – The concentration of a fumigant (ounces, pm, etc.) times the exposure time (hours, minutes, etc.). The dosage requirements depend on the pest, the fumigant, the

temperature, the rate of leakage (some leakage is inevitable), and many other factors.

**Equilibrium** – Even distribution. For example, a fumigant has reached equilibrium when there is an equal concentration of gas throughout a given structure.

**Field Capacity** – The moisture level of soil at which air has largely replaced water in soil macropores but not micropores. For example, at 50 percent field capacity, the total space between soil particles is shared equally by air and water, with most of the water being found in soil micropores.

**Inert** – Not reactive.

**Macropores** – The large spaces between soil particles in which air and water can move readily.

**Metabolism** – All chemical reactions that take place in a living thing. For example, insects metabolize food to produce energy.

**Micropores** – The small spaces between soil particles where little air movement occurs and water moves slowly. Plants absorb most of the water they need from soil micropores.

**Molecular Weight** – The sum of the atomic weights of all the atoms in a molecule. All fumigants have a unique molecular weight.

**Molecule** – The smallest particle of a substance that retains all of the properties of the substance.

**Pesticide Resistance** – The ability of an organism to tolerate a pesticide. There are different levels of resistance. For example, some insects may be sensitive, weakly resistant, or strongly resistant to a specific insecticide. Total resistance is immunity.

**Seal** – To enclose an area so that fumigant gas cannot escape too quickly. A good seal will contain a lethal amount of gas long enough to kill the target pests.

**Soil Texture** – The relative proportion of the different sizes of mineral particles – sand, silt, and clay – that make up a soil.

**Solubility** – How readily a substance will dissolve in a liquid.

**Sorption** – Adsorption and/or absorption.

**Stratification** – When fumigants rise or fall, making layers of gas within a confined area. Diffusion is incomplete, leaving some areas untouched by the fumigant. Stratification results in an incomplete treatment.

**Tilth** – The physical condition of soil that determines the ease at which it can be tilled or cultivated and its suitability for seed germination and plant growth.

**Vapor Pressure** – The pressure exerted by a liquid or a solid as it volatilizes (becomes a gas).

**Vaporize** – When a solid or liquid turns into a vapor (gas).

**Volatility** – How readily a substance transforms from a solid or liquid into a gas.

Unit 1 defined a fumigant as a pesticide in gas form. At a high enough concentration, this gas can kill bacteria, fungi, insects, nematodes, and weeds. Unit 1 also explained that as a gas, fumigant molecules can move into tiny gaps such as between kernels of grain or through small openings in the soil. This is why fumigants are so effective in certain situations.

This unit will focus on factors that affect fumigant performance: both characteristics of the fumigant and external factors.

## Characteristics of Fumigants

There are many fumigants on the market. Your job is to select the best product for the pest and situation at hand.

Boiling point, molecular weight, specific gravity, solubility, and flammability are different for all fumigants. Each characteristic makes a fumigant act a certain way under certain conditions. Understanding how these factors affect application will help you select the best product for the job.

Always consult the label information for each product that you consider. It will contain information on the following characteristics.

## Molecular Weight and Specific Gravity

All substances, including air and fumigants, have a “molecular weight.” The molecular weight of air is about 29. Fumigants with a molecular weight lower than 29 are lighter than air and may rise. Those with a molecular weight higher than 29 are heavier than air and may sink.

All substances also have a “specific gravity.” The specific gravity of air is 1. Fumigants with a specific gravity greater than 1 are heavier than air and may sink. Fumigants with a specific gravity less than 1 are lighter than air and may rise.

Gases are unique in that their specific gravities are related to their molecular weights. For example:

$$\text{Specific Gravity of a Fumigant} = \frac{\text{Molecular Weight of a Fumigant}}{\text{Molecular Weight of Air}}$$

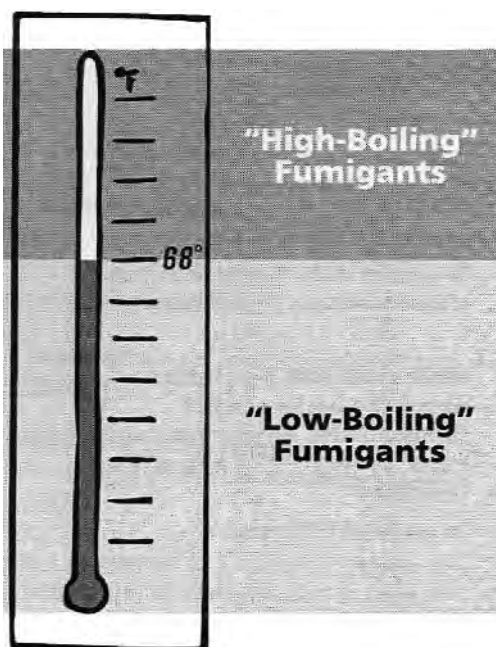
*NOTE: This relationship is valid only when the temperature and pressure of the fumigant and air are the same.*

The molecular weight and specific gravity of a fumigant can help you determine how well it will distribute throughout an area. Even distribution is referred to as an “equilibrium.” Most fumigant gases are heavier than air. For example, the molecular weight of methyl bromide is 94.95, making its specific gravity 3.28. This means methyl bromide is 3.28 times heavier than air. When the molecular weight of a fumigant is greater than or less than air, you may need to use fans and/or other tactics to achieve equilibrium during fumigation.

## Boiling Point

Boiling point is the temperature at which a fumigant becomes a gas. Most fumigants reach their boiling point between -125.9°F and 233.6°F. “Low-boiling” fumigants become gases below room or moderate outdoor temperatures (68° to 77°). To stabilize these chemicals, manufacturers keep them as liquefied gases under pressure in cylinders or cans. Fumigants with boiling points higher than 68°F, “high-boiling” fumigants, are initially liquids at normal fumigation temperatures. While these

chemicals have slow evaporation rates, they will eventually vaporize during treatment. To use these products, you may need to wait for a warm day or increase the temperature within the area you plan to treat.



Boiling point also indicates the vapor pressure of a fumigant. In general, the higher the boiling point, the lower the vapor pressure, and the slower a fumigant will change to a gas.

## Solubility

Solubility tells you how readily a fumigant gas will dissolve in certain materials, depending on their moisture content.

Some fumigants are soluble in water, oil, or other liquids. These pesticides may dissolve in commodities that have high moisture or oil contents. For example, methyl bromide is soluble in oil. If you use this fumigant to treat commodities with a high oil content, such as peanuts or soybeans, it may dissolve in the oil. Once dissolved, the methyl bromide may be difficult to aerate. This is particularly a problem when multiple treatments of these commodities are necessary.

## Flammability

Some fumigants, such as phosphine, are extremely flammable. Formulations of flammable fumigants may contain fire retardants. For example, some products that produce phosphine also produce ammonia and carbon dioxide. However, the best way to prevent fire hazards is to apply and dispose of fumigants properly. Always read the label information to learn which conditions favor fire or explosions. The label information will describe how to avoid these problems.

**Table 3-1. Physical and chemical properties of fumigants commonly in use at the time this manual was printed.**

Fumigant	Molecular Weight	Boiling Point (°F)	Specific Gravity*	Flammability (in air)
Methyl Bromide	94.95	38.4	3.28	nonflammable
Phosphine	34	-125.9	1.17	flammable
Sulfuryl Fluoride	102.07	67	3.52	nonflammable

\*Specific gravity = the molecular weight of a fumigant divided by the molecular weight of air (29).

# Test Your Knowledge

**Q. How can the molecular weight of a fumigant affect its ability to diffuse throughout a room?**

A. Fumigants with molecular weights lower than 29 are lighter than air and may rise. Those with molecular weights higher than 29 are heavier than air and may sink. Both extremes may require you to use fans and other means to prevent stratification.

**Q. Define stratification.**

A. When air and fumigant form layers and do not mix.

**Q. What does the solubility of a fumigant tell you?**

A. Solubility tells you how readily a fumigant will dissolve in water, oil, or other substances. For example, if you apply a fumigant that is soluble in oil to grain that has a high oil content, the fumigant will dissolve into the oil of the grain. The fumigant will remain in the oil and contaminate the grain.

**Q. Why do you need to know the boiling point of a fumigant?**

A. To predict if the fumigant will be effective at a particular temperature.

**Q. Where can you find information about the boiling point, flammability, sorptive capacity, and other properties of a specific fumigant?**

A. In the label information.

# Factors That Affect Fumigation of Stored Food Products

A variety of factors affect the use and success of fumigants. Some of the most important factors in stored product fumigation are:

- Pest characteristics
- Temperature of the commodity or area you plan to treat
- Moisture in the commodity or area to be fumigated and in the air surrounding/within it
- Air movement and diffusion within the area you fumigate
- Construction of the structure within which you treat an item or the quality of the seal enclosing the area to be fumigated, and
- Applicator knowledge and skill

## Pest Characteristics – Raw Product Fumigation

Several aspects of the pest's biology can influence the effectiveness and timing of a fumigant treatment. These include:

- The insect's stage of growth. Pupa and eggs are the hardest to kill because they are not active. Adults and young larvae are most susceptible.
- The activity level of the insect. Active adults and larvae are easier to kill than are inactive or hibernating adults and larvae. This is because active insects have a higher metabolism, allowing them to process the pesticide faster. Therefore, whenever possible, wait until the insects are mature and active before fumigating.
- The feeding habits of the insect. Insects that develop outside grain kernels are usually more susceptible to fumigants than species that develop inside grain kernels.

- The size of the infestation. Heavy infestations are more difficult to control. Masses of insects generate large amounts of dust, damaged grain, webbing, and cast skins. These materials interfere with fumigant penetration and increase sorption.
- Some insects have "resistance" to fumigants. Resistance is the ability of an organism to tolerate a pesticide. There are various levels of resistance. For example, some insects may be sensitive, weakly resistant, or strongly resistant to a specific insecticide. Total resistance is immunity. Frequent fumigation at dosages too low to kill all insects promotes problems with resistance.

Although this information is true for most insects, application recommendations vary with the pest. Use the information from Unit 2 to help you identify the most susceptible stage(s) of development and activity level(s) of the pest that you wish to control.

## Temperature

"Temperature" refers to the temperature:

- Of the commodity that you plan to treat, or
- Under the tarp or within the structure where treatment will occur

Temperature affects both the dosage and exposure period needed for pest control. As a rule, the higher the temperature, the less fumigant you will need. This is because as temperature increases, insect metabolism increases. As metabolism increases, insects breathe faster absorbing more fumigant. Less fumigant is needed to kill the pest. As the temperature drops, the reverse is true. Insect breathing slows. You may need to add fumigant to get the same level of control. Below 40°F, fumigants may not be effective at all.

Higher temperatures also increases the volatility of fumigants. Volatility refers to how readily a substance turns into a gas (vaporizes). The higher the volatility, the faster a fumigant disperses and penetrates. Sorption by the material being treated decreases and less fumigant is needed. (See "Sorption" later in this unit to learn how temperature affects this process.)



Finally, temperature can cause a fumigant to “stratify.” Stratification occurs when air and fumigant form layers and do not mix. In general, if the temperature of a fumigant is significantly lower than air, stratification becomes more severe.

For best results, fumigate when temperatures are above 60°F.

## Moisture

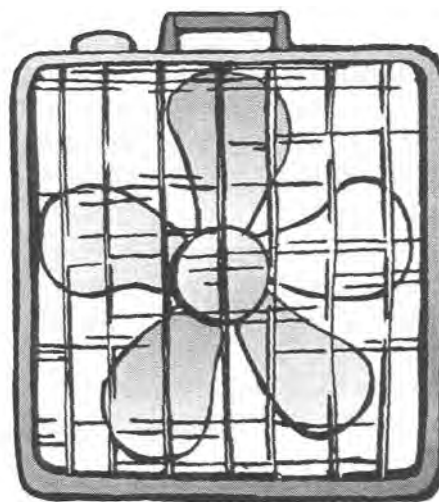
As the moisture content of a commodity increases, sorption increases. This makes it more difficult for a fumigant to penetrate a commodity. Therefore, products with high moisture contents require higher doses of fumigant. High moisture contents also increase the potential that residues will exceed legal limits due to the increased sorption and slow desorption.

On the other hand, some dry fumigant formulations (such as phosphine tablets and pellets) need humidity to generate gas. These are called “moisture-activated” fumigants. If the air is too dry or the moisture content of the commodity is too low, these fumigants will stay in solid form.

## Air Movement

To be effective, a fumigant gas must diffuse (spread) evenly and quickly throughout the commodity or space that you are treating. The gas must enter small crevices, cracks, or spaces so that a lethal concentration contacts every pest. Even distribution is called an “equilibrium.” The ability of a fumigant to reach equilibrium depends on several things. In general, gases diffuse more quickly at higher temperatures and lower air pressures. Fumigants also spread faster when their initial concentration is high and the penetration distance is short.

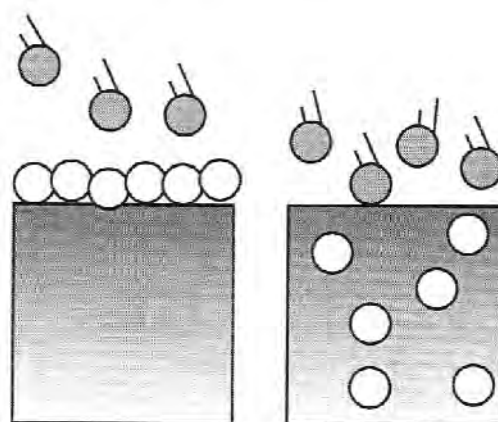
Some fumigants require air circulation to diffuse quickly. Without air circulation, the air and fumigant may form layers and fail to mix – a condition called “stratification.” Fans, ducts, and blowers are often necessary. Select equipment that fits the job. Fans are usually sufficient to stir the air in open areas. Confined areas with tightly packed commodities may require blowers or ducts to move the fumigant from one place to another. However, once the fumigant reaches equilibrium, the problem of stratification decreases.



Sometimes you will need help to distribute a fumigant throughout a treatment area.

## Sorption

When a fumigant gas contacts materials, gas molecules undergo the process of “sorption.” There are two types of sorption: adsorption and absorption. Adsorption occurs when fumigant molecules stick to the surface of a treated material. Absorption occurs when the molecules penetrate into the material. Both types of sorption reduce the effectiveness of fumigants by removing molecules from the air. These bits of fumigant are no longer able to move freely and kill the target pest(s). Sorption also slows “aeration” – the process by which fumigant is released after treatment.



Adsorption vs. absorption

Some fumigants are more subject to sorption than others are. Read the label information for sorption information about each product you consider.

Commodities and the structures that house them also vary in their “sorptive” capacity. Loads of grain with many small pieces have a lot of surface area and are more sorptive. Inert surfaces such as metal are less sorptive.

Knowing how sorptive certain chemicals and commodities are is critical. This information will help you determine how much fumigant to use, how long to contain the fumigant, and how long to aerate the treatment area or product. When sorption levels are high, you will need to use more fumigant. You will also need to increase the treatment time because diffusion is slower. When treatment is complete, aeration periods must be long enough to allow the fumigant to slowly “desorb” from the commodity. If aeration is too short, traces of fumigant may remain sorbed to the product. This can cause toxic residues, off-flavors, or odors in the treated material.

As a rule, sorption is greater at cold temperatures. For example, if the temperature inside a warehouse is cool during fumigation, the commodity(ies) will absorb or adsorb the fumigant at a higher rate. You will need to use more fumigant. The same is true for aeration. Aeration normally takes longer when temperatures are low or when products are cold.

Adsorption is usually greater with fumigants of high molecular weights and low vapor pressures.

## Construction of the Structure

Fumigant label information lists a range of dosages from which to choose. Each dosage fits a specific situation. The most important factor in selecting a dosage is the tightness of the structure. The ability of a building to hold a fumigant directly affects the amount of gas needed to sustain a lethal concentration throughout. Higher dosages are needed for structures that are of “loose” construction. For example, warehouses tend to have gaps around windows, doors, and wall joints. Lower doses may be adequate for “tightly” constructed structures such as boxcars and fumigation chambers.

For loosely built structures, it is often better to “seal” the area than to increase the amount of fumigant you use.

## Seal

A tight seal around a structure or commodity ensures effective fumigation and the safety of those nearby. You can seal a structure or commodity in one of three ways:

1. Tape and seal all potential openings within a structure with plastic and fumigation tape.
2. Place a gastight tarp over the item or structure.
3. Use a fumigation chamber.

The quality of a seal is important. It can affect:

- The amount of fumigant needed (the tighter the seal, the less gas that will escape, and the less fumigant that will be needed), and
- The length of time necessary to kill the target pest (the tighter the seal, the more constant the fumigant concentration, and the less time needed to achieve control).

A fumigation chamber is an example of a tight seal. Little gas escapes from a well-constructed chamber. On the other hand, placing a gastight tarp over commodities or structures can provide a poor-to-excellent seal depending on:

- The condition of the tarp
- The tightness of the seams, and
- The type of ground seal

Structures in sandy soils or with dirt crawl spaces may lose gas through the soil. Commodities sitting on concrete floors may lose gas through the concrete. To prevent these problems, always tarp the top and bottom of structures and items on porous bases.

Some structures may be too large to tarp, such as warehouses or large grain bins. In these situations, a tape-and-seal job may be required. Always seal doors, windows, and vents. This will prevent heavy loss through large gaps. In grain bins, you should also seal unloading augers, roof

exhaust vents, and eave gaps (openings where the roof meets the sidewalks). Although tape-and-seal fumigation can prevent many leaks, the fumigant can penetrate untarped walls, even when the walls are made of solid materials like brick and concrete. You will usually need more fumigant to replace what is lost through untarped walls.

Also, consider the condition of the structure and the type of construction. A wooden structure, even when sealed, will not retain fumigants as well as one of brick, concrete, or steel. This is because wood is more porous than the other materials. For example, round steel bins retain fumigant better than flat grain-storage bins, which are usually made of wood. In addition, wooden structures are often not built as “tightly” as structures made with other

materials. For these reasons, it is often necessary to tarp wooden structures during fumigation.

## **Applicator Knowledge and Skill – Raw Product Fumigation**

In the end, you, the applicator, are the most important variable in raw product fumigation. Your education and training will directly affect the success and safety of your operation. Know and understand the properties of every product you plan to use. Consider how different factors will affect treatment. Understand the site – its limitations and its strengths. Choose your dosage and application methods accordingly.

## Test Your Knowledge

**Q. List several factors that influence a fumigant's effectiveness.**

- A.
1. Diffusion: how well a fumigant penetrates a commodity or how well it is circulated throughout an area.
  2. The sorptive capacity of the commodity to be fumigated.
  3. The temperature of the commodity or space to be fumigated.
  4. The moisture content of the commodity or area to be fumigated and the air surrounding/within it.
  5. The construction of the structure to be fumigated or the structure within which you will treat an item.
  6. The quality of the seal enclosing the area to be fumigated.
  7. The characteristics of the target pest.
  8. The level of resistance a pest may or may not have.

**Q. As a rule, at what temperature is fumigation most effective?**

- A. Above 60°F.

**Q. Define volatility. How does the volatility of a fumigant affect dosage?**

- A. Volatility refers to how readily a substance turns into a gas (vaporizes). The higher the volatility, the faster fumigant disperses and penetrates. Sorption by the material being treated decreases and less fumigant is needed.

**Q. What aspects of the pest and pest damage can affect fumigation? How does each aspect affect fumigant performance?**

- A.
1. The insect's stage of growth. Pupa and eggs are the hardest to kill because they are not active. Adults and young larvae are most susceptible.
  2. The activity level of the insect. Active adults and larvae are easier to kill than are inactive or hibernating adults and larvae. This is because active insects have a higher metabolism, allowing them to process the pesticide faster.
  3. The feeding habits of the insect. Insects that develop outside grain kernels are usually more susceptible to fumigants than species that develop inside grain kernels.
  4. The size of the infestation. Heavy infestations are more difficult to control. Masses of insects generate large amounts of dust, damaged grain, webbing, and cast skins. These materials interfere with fumigant penetration and increase sorption.

**Q. What is the difference between adsorption and absorption? How do they affect the performance of a fumigant?**

- A. Adsorption occurs when fumigant molecules stick to the surface of the treated material. Absorption occurs when the molecules penetrate into the material. Both types of sorption reduce the effectiveness of fumigants by removing molecules from the air. These bits of fumigants are no longer able to move freely and kill the target pest(s). Sorption also slows "aeration" – the process by which the fumigant is released after treatment.

# Unit 4: Pest Management Options

## Learning Objectives

After studying this unit, the learner will be able to:

- Define Integrated Pest Management (IPM).
- Describe the advantages and disadvantages of fumigants.
- Evaluate several nonfumigant pest management methods for food and stored commodities.
- Use several methods simultaneously or sequentially to solve a pest problem.

This unit describes the principles of Integrated Pest Management (IPM). It explains how you can use fumigation as one aspect of a well-planned IPM program. You will learn several advantages and disadvantages of fumigants. You will also learn several ways to manage pest problems without fumigation. These “alternatives to fumigation” may be cultural, biological, or chemical. By using a combination of methods, you may often achieve the best control.

## Terms to Know

**Action Threshold** – A pest population level that triggers a management response. Sampling and regular observation are necessary to assess threshold levels.

**Aeration** – *Fumigant application*: The process of replacing fumigant-containing air or water with fresh air and/or water that contains little or no fumigant. Aeration must follow all fumigation operations.

**Aeration** – *Grain storage*: The process of passing air through a stored product such as grain to regulate temperature and moisture content.

**Auger** – A grain transfer tool used to load and unload grain and other stored products.

**Binning** – Placing grain or another raw product into a storage bin.

**Biological Control** – The use of natural enemies (predators, parasites, or pathogens) to control pests and pest populations.

**Cultivar** – An agriculturally derived plant variety with unique characteristics. For example, there are several cultivars of corn. Each one has a unique flavor, color, or pest resistance.

**Cultural Control** – A pest control method that involves changing one or more crop production practices (sanitation, cultivation, crop rotation, use of resistant plant varieties, etc.) to create an uninviting or unfavorable environment for pests.

**Cuticle** – The protective outer covering of an insect.

**Fines** – Broken kernels and pieces of small foreign material within a load of grain.

**Harborage** – Shelter, a home or refuge for an organism.

**Headspace** – The open area between the stored product and the ceiling of the storage facility.

**Hot Spot** – An area in stored grain that is much warmer (10°F or more) than the surrounding grain. A hot spot indicates that the grain has a higher than normal moisture content, possibly caused by insect or fungus activity.

**Insecticide** – A pesticide used to control or repel insects or to reduce the unwanted or harmful effects of insects.

**Integrated Pest Management (IPM)** – A pest management system that uses all appropriate strategies to reduce pest populations.

**Multipurpose Fumigant** – A fumigant that controls more than one type of pest.

**Pathogen** – An organism that causes diseases.

**Pesticide Resistance** – The ability of an organism to tolerate a specific pesticide. There are levels of resistance. For example, some insects may be sensitive, weakly resistant, or strongly resistant to a specific insecticide. Total resistance is immunity.

**Plenum** – An enclosure in which air or other gases are at a pressure greater than the atmospheric pressure outside the enclosure.

**Rodenticide** – Any substance used to control or repel rodents or to reduce the unwanted or harmful effects of rodents.

**Skinning** – Superficial injury, such as to the surface of a grain kernel during harvesting, transport, and storage.

**Topdressing** – A material such as a pesticide applied to or mixed into the upper surface of grain or soil.

## IPM and Decision Making

There are many ways to control pests of food and stored commodities. Your job is to select the best method for the situation at hand. Pesticides and other control methods often provide good to excellent control temporarily. However, for consistent, reliable, long-term control, you will need to use Integrated Pest Management (IPM).

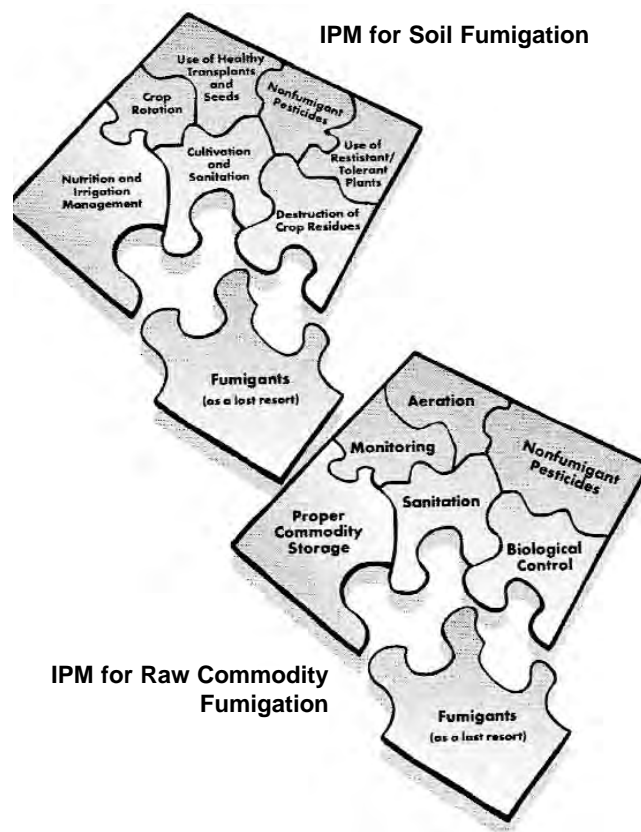
IPM is an ecological approach to pest control. It is based on the habitat and life cycle of the pest. It combines all of the most appropriate pest control strategies into a unified, site-specific plan. IPM plans may include both nonchemical and chemical management methods. IPM is dedicated to managing causes rather than simply treating symptoms. IPM balances the level of control needed with any associated risks. The goal of an IPM program is to reduce pest numbers to an acceptable level in a way that is practical, cost-effective, and safe for people and the environment.

## Prevention

The first strategy of an IPM program is prevention. Prevention of pests in food and stored commodities relies on sanitation, proper storage, and monitoring the condition of the commodity before and during storage. Prevention may help you exclude pests or provide them with unsuitable living conditions. Stopping a pest problem before it occurs saves time and money.

## Sampling and Observation

IPM also relies on sampling and regular observation. Sampling and observation will help you determine if treatment is needed and/or if previous control measures were effective. Check commodity storage areas regularly. When sampling and observing stored products, check their physical condition. Look for signs of new infestations. Determine what pests are present, how many of each kind are in the area, and how much damage they are causing.



## Thresholds

Use information from sampling and observation to make management decisions. Follow the action thresholds that indicate at what point pests need to be controlled.

Thresholds are the basis for IPM. “Damage thresholds” indicate how many pests must be present to cause a problem, such as economic damage or a safety threat. “Action thresholds” indicate the number of pests that must be present for a problem to be severe enough to warrant a control action.

## When an Infestation Occurs

When an infestation does occur, identify the pest. Learn how it causes damage and when it is most vulnerable. Then, develop a control plan. Consider all appropriate control options. Your strategy should be economical and effective, while minimizing harm to people and the environment. Follow-up site inspections are critical. Did the control tactic work? Is re-treatment needed? Continue to monitor areas for long-term control.

Fumigation is only one option of an IPM program. Use it only as a last resort when nothing else works. For stored products, sanitation, proper grain storage, and nonfumigant pesticides can often control pests without the help of fumigants.

When deciding whether to fumigate stored products, weigh these advantages and disadvantages.

## Advantages of Fumigants

- Depending on the specific situation and fumigant, fumigants are effective against insects, mites, and most other living things.
- Most fumigants are fast acting. They are the quickest way of controlling many pests.
- In some cases, they can provide total eradication.
- Human exposure is limited. Areas are evacuated during treatment and must be aerated before reentry.
- Most fumigants, when used properly, do not leave residues on surfaces.
- There are several ways to apply fumigants.
- They penetrate and treat spaces in food and commodities like grain that cannot otherwise be reached.

- When treating raw products, you can apply them without disturbing the commodity.
- They are usually readily available.
- You can use some fumigants in or near food without leaving harmful residues, tastes, or odors.

## Disadvantages of Fumigants

- They are highly toxic to most living things, including humans. Breathing even small amounts of some fumigants can be fatal.
- They may require special protective equipment, such as a self-contained breathing apparatus (SCBA) and gas detectors.
- They require highly trained applicators.
- They offer no residual control. Once an area, item, or field is aerated, traces of fumigant do not remain to help control future pests.
- They must be confined in a tightly sealed area to be effective.
- Some may injure seeds and reduce germination. Others may leave toxic residues, tastes, or odors if used incorrectly.
- Because they are fast acting, response to problems and emergencies must be quick. Spills, leaks, and equipment failures usually call for immediate action.
- They usually require warm temperatures to be effective. Temperature requirements may be hard to meet, especially in the winter.
- Some are expensive.
- Some are corrosive.
- Some are flammable and explosive.
- Some fumigants are hard to remove from treated material.

## Pesticide Resistance

One of the biggest problems with pesticide use is “pesticide resistance.” Pesticide resistance develops when a group of insects are able to tolerate doses of a specific pesticide that would kill a normal population of the same species. Surviving pests reproduce and pass their resistant traits to their offspring. Preventing resistance is of great importance for the pests of stored commodities. New laws and regulations have drastically reduced the number of insecticides approved for use against food and stored product pests. As a pest control operator, you can protect the effectiveness of pesticides by:

- Using IPM
- Using alternative controls and nonchemical controls whenever possible
- Using pesticides only when necessary
- Avoiding repeated use of the same pesticide
- Doing a thorough job when applying a pesticide (do not leave behind pests that can develop resistance and reproduce), and
- Fumigating only when nothing else works

## Alternatives to Fumigation

Many pests of raw commodities can be controlled without fumigants. The key is prevention. Prevention involves sanitation, proper grain storage, and maintaining before and after the raw commodity is placed into storage. In this way, you can keep pests away or reduce the number of pests that are able to develop. Other management strategies such as biological control, aeration, spot treatments, empty bin sprays, grain protectants, topdressing, pest strips, and rodenticides help to reduce existing pest populations.

## Sanitation

The first step in preventing insect infestations is sanitation. By keeping bins and the areas around them clean, you can greatly reduce insect populations. Old grain and grain

products provide food and habitat for insects. These residues can occur inside and around bins, in combines, and in grain transfer equipment. Before storing fresh grain, clean the inside and outside of storage bins and buildings. Clean aeration ducts, augers, and sidewalks. Use both a broom and vacuum. Dispose of all spilled or leftover grains and grain dust. Open the aeration ducts and augers to be sure they are clean. Clean bins immediately after they are emptied and again at least two to three weeks before adding grain. You should also clean bins before applying “empty bin sprays.” (See “Empty Bin Sprays” later in this unit.) Always wear a dust mask when cleaning these and other storage areas. Mow regularly around bins to reduce harborage for rodents and insects.

## Proper Grain Storage

Harvesting grain does not end the danger of pests. You must also store it properly. Good grain storage can prevent infestation and the need for fumigation. In Arkansas, producers may store grain for a few weeks to a few years. The profitability of such storage depends on grain quality and marketing. Grain is usually stored so that it can be sold when market prices are higher than they are during the harvest season.

## Grain Condition

The physical condition of grain when it is placed into storage influences its susceptibility to pests. Only high-quality, undamaged grain with a low moisture content can be stored successfully for long periods. Never mix new grain with old grain in storage.

## Drying Grain Before Storage

Grain is dried to prevent spoilage and to deter insect infestation. Most small grains are dried to 12 to 13 percent moisture. The moisture level may be 1 to 2 percent higher if the producer plans to hold the grain during the cooler part of the year only.

Drying methods may influence grain quality. High-speed, high-temperature drying produces more stress-cracked corn than low-temperature drying. Kernels with stress cracks break readily during handling. Broken kernels are more likely to spoil.

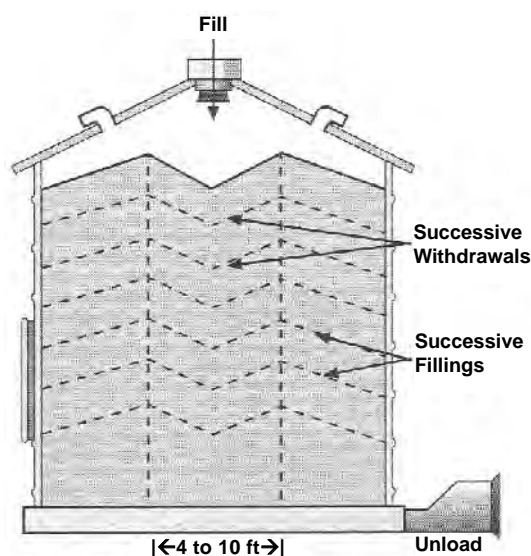


**Table 4-1. Maximum moisture contents for safe aerated grain storage in Arkansas.**

Grain Type and Storage Time	Maximum Moisture Content for Safe Storage (% Wet Basis)
<b>Shelled corn and sorghum</b>	
Sold as #2 grain by spring	14-15
Stored 6 to 12 months	13-14
Stored more than 1 year	12-13
<b>Wheat, oats, and barley</b>	
Stored up to 6 months	12-13
Stored 6 to 12 months	11-12
Stored more than 1 year	10-11

## Broken Kernels and Fines

Many insects that infest stored grain are not able to penetrate the seedcoat of unbroken kernels. These pests depend on the presence of broken kernels and foreign material called “fines.” Broken kernels are also more likely to spoil and mold than are unbroken kernels. Fines decrease the airflow from aeration fans. This can increase aeration time up to 50 percent. Fines also tend to accumulate in the center of the bin. Fines hold moisture, further increasing the chance of insect and mold damage. This is especially true when fines are concentrated in certain parts of the storage.



**Withdrawals during filling remove most fines from the core of fine material.**

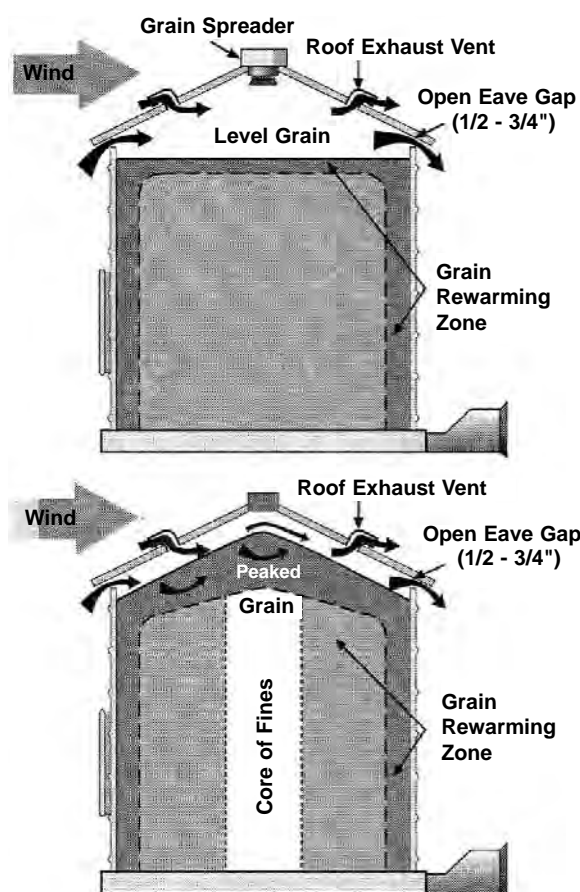
## Grain Cleaning

Cleaning grain before “binning” is the best way to minimize problems with fines. Rotary screen and aspiration cleaners work best. Rotary screen cleaners use a rotating screen to remove foreign material from the grain as it is transferred to a dryer or storage bin. Avoid using perforated or screened sections in the auger. These usually do a poor job of cleaning the grain. They may even reduce grain quality by “skinning” or causing superficial damage to the kernels.

If you cannot clean the grain ahead of time, remove fines during bin loading. When grain is loaded into the center of a round bin, most of the fine material will collect in a center “core” under the spout. Eliminate this problem in one of two ways. First, try using a grain spreader. Grain spreaders distribute fines and grain evenly throughout the bin. This method retains the fines, which may have value as animal food. However, they tend to pack the grain, reducing airflow within the load. You can also remove the core of fine material periodically as the bin is filled. To do this, remove the grain from the bottom of the center core. Mix it with other grain and put it back in the bin.

## Peaked Grain

Peaks occur at the top of a grain pile just below the loading spout. There are several problems with leaving grain peaked in a bin. First, it is impossible to achieve uniform aeration. This is because air moves toward the nearest open areas, the sides, leaving the center core unaerated. (See “Aeration” later in this unit for more information on how it affects stored grain.) Second, when grain is loaded without a spreader, the fines tend to accumulate in the center under the spout. Fines are particularly prone to insect and fungal attack. They are also difficult to aerate. (See “Broken Kernels and Fines” earlier in this unit for more information on how they affect stored grain.) In addition, it is very difficult to enter a bin to sample the grain or to apply a topdressing if the grain is peaked and filled to the top of the bin. It is easier to walk on level grain than on sloped grain. There may also be insufficient headspace. Be sure to level the surface of stored grain so that it is not peaked.



Peaked grain vs. level grain surface in storage bins.

## Storage Facilities and Packaging

Grain should always be stored in a steel bin. Be sure the bin is weather-tight, rodent-proof, and mounted on a moisture-proof concrete base. It should have a grain spreader, a perforated floor-aeration system, an adequate fan, and a weather- and rodent-proof roof vent. Caulk the seams of older bins and inspect them annually for moisture leaks. Buildings used to store other types of commodities should be dry and designed to exclude rodents, birds, and flying insects. There should also be a minimum of harborages for pests. Move or eliminate unnecessary equipment, wood, rocks, and other popular pest hideouts in and around storage facilities.

## Storage Time

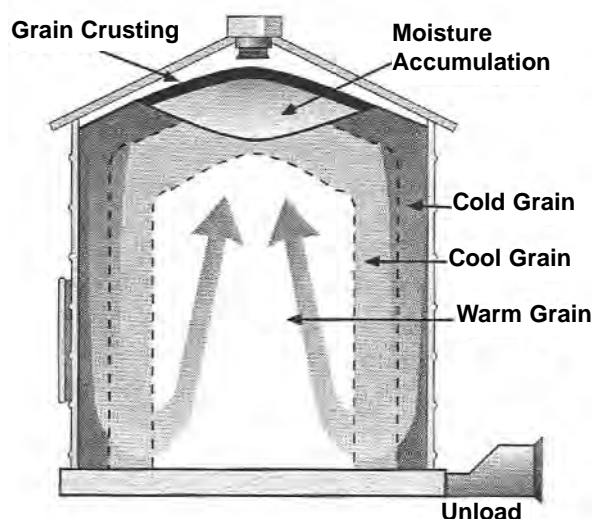
Storage pest problems tend to be seasonal. Grains harvested and stored in the heat of the summer are more susceptible to pests than

grains harvested in the fall when temperatures are cooler. As a rule, the longer a commodity is stored at 60°F to 90°F, the greater the chance of pest problems. If a producer needs to store a commodity for more than one year, or if conditions are more likely to be favorable to pests, he or she should increase monitoring and pest prevention efforts.

## Aeration

Proper aeration can control insects in many ways. Aeration is the movement of air through grain to regulate moisture and temperature. By preventing moisture from building up and moving through a commodity, aeration helps to limit mold growth. This, in turn, reduces the food supply for fungus-feeding insects. Aeration also controls “hot spots.” Hot spots are sites that are much warmer (10°F or more) than the grain in the rest of the storage bin. These areas indicate that the grain has a higher than normal moisture content and may harbor insects or fungi.

Aeration procedures are the same for all types of stored grains. In the fall, aerate to lower the grain temperature below 60°F. At this temperature, most insect and mold activity will decrease. In the fall, winter, and spring, aerate to control moisture migration and to create a uniform temperature throughout the grain mass. If you plan to store grain through the summer, you may need to aerate to control moisture during this season as well. However, most grain is sold before summer to make room for the next crop.



Example of moisture migration in grain stored several months without aeration.

## Biological Control

Biological control is the use of natural enemies (predators, parasites, or pathogens) by humans to control pests and pest populations. These natural enemies, also called biocontrol agents, can sometimes reduce the number of pests in raw commodities. Predatory or parasitic insects are the most common biocontrol agents used to control insect pests of raw commodities.

Unfortunately, it may be difficult to effectively use biological control in an IPM program. This is because beneficial insects require some host insects to become established. It is difficult to keep these pest insects from reaching damaging levels. Stay informed about new developments in biocontrol that may help prevent infestation.

## Nonfumigant Pesticides

### Empty Bin Sprays

Another management strategy is to coat empty bins with insecticidal sprays. These pesticides will kill eggs and insects missed during cleaning. Treat bins as soon as they are clean. Try to delay treatment until the weather is warm and the insects are active. Insecticides are most effective at this time. If treatment occurs more than three months before the bin will be filled, repeat the application at least two weeks before storing the grain. Apply the spray to as many surfaces as possible. Be sure to hit all joints, seams, cracks, ledges, and corners. Spray the ceiling, walls, and floor to runoff. Spray beneath the bin and its supports. Treat the outside surfaces in a similar fashion. Then apply the insecticide in a six-foot border around the outside foundation. For increased protection, treat harvesting equipment, elevators, augers, trucks, and wagons. Be sure these items are thoroughly cleaned. Insecticides will kill most insects emerging from cracks and crevices.

Unfortunately, empty bin sprays do not work for every type of storage bin. More and more producers are using metal bins with perforated floors. These floors aid in grain drying and aeration. They also permit broken grain and grain dust to gather in the subfloor plenum. This is an ideal area for insects to thrive. Additionally, subfloors are often difficult to remove. It may be difficult to inspect, clean, or apply insecticides under them. In these cases, fumigation may be your only practical method of pest control.

## Grain Protectants

You can prevent or reduce insects by applying insecticides directly to the grain. These “grain protectants” are usually applied as grain is moved into storage. Grain protectants are intended to protect the grain, not to eradicate an existing infestation. For eradication, use a fumigant.

If a producer plans to hold grain for more than one month and the grain temperature is likely to be above 60°F, treat the grain with a protectant. To apply liquid protectants, use a gravity drip, compressed air, or wipe-on applicator to apply the insecticide as the grain is augured or elevated into the bin. Mixing of the insecticide and the grain will occur during the bin-filling process. Use the auger diameter, angle, and speed as well as the type of grain to determine the application rate.

Grain protectants are also formulated as dusts. You can apply dusts to grain in trucks before transfer. Spread the dust evenly over the surface of the grain and mix it in with a shovel. Complete mixing will occur as the grain is loaded into the bin.

Unfortunately, insecticides tend to break down faster in areas with high temperatures and moisture. If the moisture level of grain is greater than 13 percent and its temperature exceeds 90°F, a treatment may last for only a couple of weeks. When treating warm grain, be sure to aerate and cool it as soon as possible after it is introduced into the bin. Aeration will not remove the insecticide from the grain.

Most grain protectants are not registered for use on all types of grain. Be sure that you use the correct insecticide for the product you intend to treat. Consider all types of registered protectants including synthetic pesticides, naturally produced toxins, abrasives, and growth regulators.

## Topdressing

Some areas of a grain bin, such as the headspace at the top, are likely to remain hot and humid. These conditions cause some grain protectants to break down quickly at the grain surface. The headspace is also the area where reinfestation tends to recur after fumigation. This is because chemical protectants break down more quickly, and the moisture content of the grain in this area makes it more favorable to

insect pests. Treat the surface of the grain beneath the headspace with an insecticide registered as a topdress treatment. Both sprays and dusts work well. Mix half of the treatment with the upper 3 to 6 inches of grain. Be sure the grain is dry and less than 90°F. The bin should be insect-tight below the treated surface. Once the insecticide is in place, do not disturb the treated surface. It acts as a protective barrier over the entire load of grain. Topdressings can be especially useful against moths, such as the Indianmeal moth, that tend to stay near the grain surface.

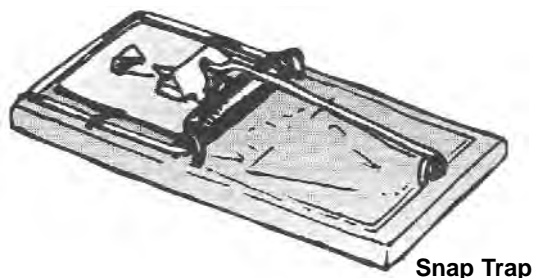
*NOTE: Topdressings will kill insects on the surface and in the upper few inches of grain. They can also prevent new insects from entering the grain load from the top surface. However, they will not control existing infestations deeper in the bin.*

## Pest Strips

You can also hang resin strips in the headspace in the top of the bin to help control adult moths. Use one strip per 1,000 cubic feet of airspace. Replace them once every three months. For resin strips to be effective, you must temporarily seal the top of the bin, including the roof vent. Aeration will prevent this treatment from working.

## Rodenticides

Rodents harm stored grain by eating it and contaminating it with feces and saliva. There are many rodenticides registered for the control of rats, mice, and other rodents. Before using rodenticides, fumigants, or nonfumigants to control vertebrate pests, develop an IPM program. Include prevention through structural exclusion and sanitation, sampling, and nonchemical controls such as snap traps. These methods may reduce or eliminate the need for rodenticides.



Snap Trap

When pesticides are necessary, try nonfumigant rodenticides first. Choose between anticoagulants and nonanticoagulants. Anticoagulants cause death by internal bleeding. These chemicals are normally placed with baits in bait stations. Nonanticoagulants cause death by stopping the heart, damaging the intestines or liver, or by attacking the central nervous system. These chemicals act quickly, and rodents are usually less resistant to them. However, rodents are more likely to reject non-anticoagulants as food. You may need to prebait with untreated food to encourage consumption.

If control with nonfumigant rodenticides is poor, it is usually due to:

- Insufficient or low-quality bait
- Low numbers of bait stations
- Failure to treat the entire infested area
- Invasion from untreated areas such as outside a structure
- Poor placement of the stations
- Other foods being more readily available, or
- Pesticide resistance

When possible, pinpoint the problem and correct it before resorting to fumigation.

## Fumigation

Sanitation, proper grain storage, aeration, and nonfumigant pesticides can go a long way toward preventing or reducing pests in stored grain and other raw products. For some situations, however, fumigation may be the only answer. Fumigants control pests by diffusing through the spaces between grain kernels as well as into the kernels themselves. They often work better than nonfumigant pesticides because they can penetrate into places that are not accessible with insecticide sprays or dusts. They can also kill all stages in an insect's life cycle.

Before using a fumigant to control pests in stored grain and other raw products, make sure you need it. Monitor pest populations throughout the storage period. Do not hold grain or other raw products in storage for longer than necessary. Use all possible cultural and nonfumigant chemical controls to maintain pest populations below damaging levels. Before you decide to fumigate, make sure that pest populations are high enough to warrant fumigation.

## Test Your Knowledge

**Q. What is Integrated Pest Management (IPM)?**

- A. IPM is an ecological approach to pest control. It is based on the habitat and life cycle of the pest. It combines all appropriate pest control strategies, including nonchemical and chemical management methods. IPM is dedicated to removing causes rather than simply treating symptoms. Prevention is key. IPM balances the level of control needed with any associated risks. The goal of an IPM program is to reduce pest numbers to an acceptable level in a way that is practical, cost-effective, and safe for people and the environment.

**Q. How does fumigation fit into an IPM program?**

- A. Fumigation is only one part of an IPM program. Because it is specialized, very toxic, and often expensive, fumigation is usually the last resort to a pest problem.

**Q. Why is regular observation of food and stored products important in effective pest management programs?**

- A. Sampling and regular observation allow you to check for pests in an area to determine what pests are present, how many of each kind are in the area, and how much damage they are causing. Sampling and observation will help you determine if treatment is needed and/or if previous control measures were effective.

**Q. List some of the advantages of fumigants.**

- A. 1. They are effective against insects, mites, and most other living things.  
2. Most are fast acting.  
3. They are capable of providing total eradication.  
4. Human exposure is limited.  
5. Most fumigants, when used properly, do not leave residues on surfaces.

6. There are several ways to apply fumigants.  
7. They penetrate and treat hard-to-reach areas.  
8. You can apply them without disturbing the commodity.  
9. They are usually readily available.  
10. You can use some fumigants in or near food without leaving harmful residues, tastes, or odors.

**Q. List some problems with fumigants.**

- A. 1. They are highly toxic to most living things.  
2. They require special protective equipment.  
3. They require highly trained applicators.  
4. They offer no residual control.  
5. They must be confined in a tightly sealed area to be effective.  
6. Some may injure seeds and reduce germination. Others may leave toxic residues, tastes, or odors.  
7. Response to problems and emergencies must be quick.  
8. Temperature requirements may be hard to meet.  
9. Some are expensive.  
10. Some are corrosive.  
11. Some are flammable and explosive.  
12. Some fumigants are hard to remove from treated material.

**Q. How can you prevent pesticide resistance?**

- A. As a pest control operator, you can protect the effectiveness of pesticides by:
- Using IPM
  - Using alternative controls and nonchemical controls whenever possible
  - Using pesticides only when necessary
  - Avoiding repeated use of the same pesticide
  - Doing a thorough job when applying a pesticide (do not leave behind pests that can build up resistance and reproduce), and
  - By fumigating only when nothing else works

**Q. How often should you clean grain storage bins to prevent insect infestations?**

A. Clean bins immediately after they are emptied and again at least two to three weeks before adding grain. Before storing fresh grain, clean the inside and outside of storage bins and buildings. You should also clean bins before applying “empty bin sprays.”

**Q. Name several things you can do to reduce stored grain’s susceptibility to insects and disease.**

A. 1. Clean and dry the grain before placing it into bins.  
2. Always store grain in a steel bin that is weather-tight, rodent-proof, and mounted on a moisture-proof concrete base.  
3. Remove as much fine material as possible or spread out the fines throughout the load.

4. Level the surface of the grain so that it is not peaked.  
5. When possible, store the grain in the fall when temperatures are cooler.

**Q. What technique can you use to maintain ideal moisture levels and temperatures within a load of stored grain?**

A. Aeration

**Q. Why is it important to keep stored grain cool and dry when applying insecticides?**

A. Insecticides tend to break down faster in areas with high temperatures and moisture.

**Q. True or False: Topdressing will kill insects throughout a load of grain.**

A. False

# Unit 5: Methods of Fumigation

## Learning Objectives

After studying this unit, the reader will be able to:

- Describe several methods of fumigation.
- Discuss the pros and cons associated with each method.
- Select the most appropriate fumigation method for a particular situation.
- Understand the importance of proper aeration.
- Safely and effectively aerate structures and fumigated areas following treatment.

This unit describes three of the most common fumigation methods: vault, tarpaulin, and spot fumigation. Each method has advantages and disadvantages. You will learn what these are and how to use this information to select the best type of fumigation for a particular situation. This unit also discusses the importance of proper aeration. You will learn about factors that affect the speed of aeration. You will also learn how to perform these procedures yourself.

## Terms to Know

**Absorption** – When fumigant molecules penetrate into a material (commodity, structure, or other item being fumigated).

**Adsorption** – When fumigant molecules stick to the surface of a material (commodity, structure, or other item being fumigated).

**Aeration** – When fresh air is introduced to dilute and remove fumigant-filled air. Aeration must follow all fumigation operations.

**Air Wash** – A method of aeration used in vacuum fumigation. Air washing involves drawing a second vacuum after the exposure period is complete and then breaking this vacuum with fresh air.

**Billowing** – When air or gas causes something to bulge outward. In tarpaulin fumigation, this occurs when gusting winds cause a tarp to bulge away from the item or structure that it is covering.

**Blower** – A machine that generates and directs an air stream in a particular direction.

**Boxcar** – A large, roofed container with enclosed sides used to transport freight. Boxcars usually have sliding doors on each side. Trains usually transport boxcars.

**Desorption** – The liberation or removal of a fumigant from other substances.

**Diffusion** – The process of spreading out or distributing evenly in a space.

**Dosage** – The concentration of a fumigant (ounces, ppm, etc.) x the exposure time (hours, minutes, etc.). The dosage requirements depend on the pest, the fumigant, the temperature, the rate of leakage (some leakage is inevitable), and many other factors.

**Fumigation Tape** – Strips of adhesive material used to seal doorways, windows, and other areas where gas might escape during fumigation. You can also use fumigation tape to join together two or more tarps during tarpaulin fumigation. Fumigation tape has a plastic or vinyl coating that reduces fumigant penetration.

**Fumiport** – A special opening in a transfer line, small bin, or food processing machine through which you can apply fumigants.

**Gas Detector** – A device used to check the concentration of fumigant in the air.

**Gastight** – Something that does not allow gas to enter or pass through. Gasproof.

**Ground Seal** – The sealing of tarps to the ground to prevent fumigant loss during fumigation.

**Nonsparking Fan** – A machine that safely recirculates air in potentially explosive environments.

**PPM (Parts Per Million)** – The number of parts of a substance in one million parts of another substance. For example, if a gas detector reads “5 ppm” it means that there are five parts of fumigant to every one million parts of air.

**Prepac** – Aluminum phosphide fumigant tablets that are packed in a gas-permeable material.

**Process Stream** – A commodity that is enroute to a storage facility.

**Respirator** – A device that protects the respiratory tract from irritating and poisonous gases, fumes, smokes, and dusts. Respirators may or may not have equipment that supplies oxygen or clean air.

**Seal** – To enclose an area so that fumigant gas cannot escape too quickly. A good seal will contain a lethal amount of gas for long enough to kill the target pests.

**Self-Contained Breathing Apparatus (SCBA)** – A type of respirator that supplies fresh air from an outside or portable source. Air enters a mask that tightly covers the entire face.

**Sorption** – Adsorption and/or absorption.

**Tarpaulin** – A semipermeable material used during fumigation to confine fumigant in a specific area during the exposure period.

Once you pinpoint a pest problem and decide fumigation is necessary, you are ready to choose a treatment method. There are several types of fumigation. Each has its pros and cons. Your job is to select the best method for a given situation. Your decision will be based on:

- The item, area, or structure you need to treat
- The location of the item or construction of the structure
- The budget of your client
- The proximity of the treatment area from other people
- Weather conditions, and
- The severity of the infestation

This unit describes the most common methods of fumigation used to treat food and stored products. You will learn how and when each method is normally used. You will learn how to implement each method. You will also discover basic safety considerations associated with each method. With this information, you can make educated decisions.

This unit also discusses aeration procedures. Aeration “airs out” or removes fumigant from an

item or location following treatment. Aeration must follow all fumigation operations. However, aeration procedures differ depending on the method of fumigation used and the site treated. This unit will explain several aeration techniques.

Remember that fumigation is highly toxic and dangerous. It is reserved for only the most severe infestations. Be sure fumigation is the best option for your situation.

## Types of Fumigation

The challenge of fumigation is to achieve and contain an adequate concentration of toxic gas long enough to obtain pest control. You can do this by using one of three methods of fumigation.

- **Vault Fumigation** – Vault fumigation uses atmospheric or vacuum chambers to treat infested commodities. Vaults may include trucks, boxcars, ship holds, warehouses, and other structures.
- **Tarpaulin Fumigation** – Tarpaulin fumigation places items under a tarp or covers an entire structure. Fumigant is released beneath the tarp and held until pest control is complete.
- **Spot (Local) Fumigation** – Spot fumigation is used to treat small items or areas with light to moderate infestations. Spot fumigation is also used routinely to prevent infestations from developing or recurring.

## Vault Fumigation

Vault fumigation treats infested items within an airtight or sealed structure. These structures or “vaults” may serve dual purposes such as truck trailers, boxcars, or ship holds. Others, like vacuum chambers, are specially designed for fumigation. Sealed buildings and flour bins are also fumigation vaults. While you must take basic safety precautions, fumigation in atmospheric vaults and vacuum chambers poses fewer risks than other methods. These structures are better designed to deliver, contain, and exhaust the fumigant.

For simplicity, this unit will discuss three types of vault fumigation:



- Fumigation in atmospheric chambers
- Fumigation in vacuum chambers, and
- Fumigation in sealed structures

## Atmospheric Chambers

An atmospheric chamber can be any airtight structure under normal air pressure. They are usually small buildings located away from other structures. Some are specially built for fumigation. Others are modified from existing structures.

You can construct a suitable, low-cost atmospheric chamber using a gastight room with an appropriate door. A minimum of equipment is required. You will need tools to apply, distribute, and remove the gas. Heating may also be necessary. Steam pipes are best and should be able to heat the area to 70°F during treatment. Locate the chamber so that you can easily move goods in and out of it. Also, be sure to minimize hazards to workers and the environment. Atmospheric chambers should not be within or connected to other structures where fumigant passage may occur.

### Advantages of Atmospheric Chambers

Once built or modified for fumigation, you can use atmospheric chambers again and again. Commodities can be moved in and out of the vault without special preparation. Vaults have a constant volume, so you do not have to compute the volume for each treatment. You can permanently install special equipment to monitor fumigant levels.

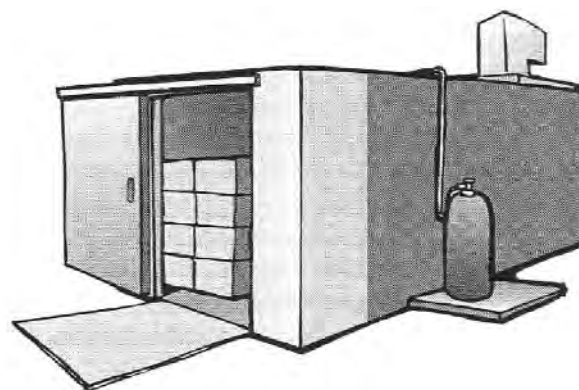
### Disadvantages of Atmospheric Chambers

Atmospheric chambers are costly to set up and hold a limited number of items. It also takes time and money to move commodities in and out of the chamber.

## Vacuum Chambers

Vacuum chambers are large, steel structures. Unlike other vaults, treatment occurs in a “vacuum” rather than at atmospheric pressure. In a vacuum, air pressure is lower. This does two things.

First, it denies oxygen to the pest. Under a vacuum, the oxygen level inside a chamber decreases. Pests become stressed and are easier to kill. Second, the vacuum helps the fumigant



**Atmospheric Vault**

penetrate the commodity. This may reduce fumigation time from 24 hours to 4 1/2 hours depending on the fumigant used. In addition, by adding an “air-wash cycle” (breaking the vacuum and drawing a second vacuum), aeration after treatment is also fast. Despite its benefits, beware. Some fumigants (such as phosphine) explode under vacuum conditions. Always read the label information to be sure your product is safe to use in a vacuum chamber.

Vacuum fumigation is used to treat densely packed items and other materials that are difficult to penetrate at atmospheric pressure.

There are two main ways to conduct vacuum fumigation: sustained-vacuum fumigation and restored-pressure fumigation. The “sustained-vacuum method” starts when you reduce the pressure inside the chamber and introduce the fumigant. The slightly reduced pressure (vacuum) is held until the end of the treatment. In the “restored-pressure method,” you would lower the pressure, introduce the fumigant, and then restore the pressure in one of four ways.

1. **Gradual Restoration** – Release the fumigant and then slowly introduce air until the air pressure returns to normal. This usually takes two to three hours.
2. **Delayed Restoration** – Hold the vacuum for about 45 minutes following discharge of the fumigant. Then, allow air to rapidly enter the chamber.
3. **Immediate Restoration** – Just after releasing the fumigant, rapidly let air into the chamber by opening one or more valves.
4. **Simultaneous Introduction of Air and Fumigant** – Use special metering equipment to release a mixture of air and fumigant into the chamber.

These four techniques to restore pressure are listed in order of effectiveness – number one being the most effective for most situations. The “sustained-vacuum method” falls between methods two and three.

“Air-washing” must follow all vacuum fumigation procedures. This process removes the fumigant/air mixture, and then flushes the chamber with clean air several times until it is safe to open the door for unloading. Air-washing is more intensive than aeration. Because vacuum fumigation forces fumigant into a commodity, adsorption of that chemical is strong. Without forcing fresh air into the chamber, the fumigant may remain within the commodity.

Vacuum fumigation requires the same safety precautions as other fumigation methods. These may include wearing a respirator and using monitoring tools to test for leaks. See Units 6 and 7 to learn more about fumigation safety.

## Portable Vacuum Chambers

When you need to fumigate small items or commodities in several locations, a portable vacuum fumigation system brings added flexibility. A portable unit consists of:

- A vacuum such as a “shop vac” or other high-capacity vacuum cleaner
- Two pieces of heavy-duty vinyl sheeting that you can clamp or zip together (similar to food storage bags)
- Fumigation dispensers
- Connecting hoses
- A security lock
- A gas concentration monitoring valve
- A carrying case, and
- A gas discharge standpipe

Portable systems allow you to develop a vacuum between the layers of vinyl. The vacuum pulls the vinyl tight around the commodity. Once the vacuum reaches the optimal level, you can apply the fumigant.

## Advantages of Vacuum Fumigation

Commodities fumigated in vacuum chambers require much shorter exposure times. The fumigant can penetrate dense commodities. Vacuum chambers have most of the other advantages of atmospheric chambers.

## Disadvantages of Vacuum Fumigation

Vacuum fumigation in chambers takes a large initial investment. Commodities must be moved into and out of the chambers. You cannot use phosphine or other fumigants that are explosive under a vacuum. In addition, more fumigant is required, and the number of commodities that can be fumigated in vacuum chambers is limited.

## Structural Fumigation by Sealing

There are two types of structural fumigation: structural fumigation by sealing also called “tape and seal” fumigation (a type of vault fumigation) and structural fumigation by tarping (a type of tarpaulin fumigation).

Both methods work by turning an entire structure – warehouse, boxcar – into a temporary fumigation chamber. To do this, it helps if the building is airtight. Structural fumigation by sealing accomplishes this by working only with buildings that are in good repair. Workers find and seal all leaky spots with fumigation tape. The goal is to create a “vault” that is as close to airtight as possible. Structural fumigation by tarping creates an airtight environment by placing a tent over the entire structure. See “Tarpaulin Fumigation” later in this unit for more information on this method.

Both types of structural fumigation are most often used to treat homes, warehouses, wheeled carriers, and other structures with severe infestations.

Structural fumigation by sealing allows you to treat many building types. You can fumigate brick, concrete, and stucco buildings in good repair if you tape and seal them first. You may need to tarp the roof if it is likely to leak. Monitor the fumigant concentrations to ensure an adequate dosage (concentration of fumigant x exposure time) is achieved to kill the target pest. In addition, you must run gas detectors throughout the structure to monitor fumigant levels in different areas. This will ensure that all areas receive an equal dosage of fumigant.

## Advantages of Structural Fumigation by Sealing

Before treatment, you need to remove from the building only contents (or items) that may be damaged by the fumigant.

Outside shrubbery is usually not at risk of exposure. Nontarget pests such as rats and mice are usually controlled along with the insects. In addition, little material is needed to make the structure relatively airtight. Unfortunately, this advantage is usually offset by the labor required to find and seal leaks.

## Disadvantages of Structural Fumigation by Sealing

Building occupants must leave the structure during treatment. You must also remove items that the fumigant may damage. Tape and seal fumigations are notoriously leaky. It is easy to overlook vents, cracks, conduits, and other areas that may permit gas to escape. The fumigant may diffuse through interior walls, making it hard to maintain the required concentration of gas. Insects in the exterior walls and eaves may survive if gas levels are too low to penetrate these sites.

Once you decide that structural fumigation is necessary, do a thorough on-site inspection. Frequently, the success of a fumigation operation will depend on what you learn, what you decide, and how you plan. Ask yourself a number of questions.

## Preparing for Structural Fumigation

### General

- If the structure itself is not infested, could you move the infested item(s) and treat it elsewhere? If removing the infested item(s) is not practical, can you fumigate it in place without treating the entire structure?
- What is the volume (cubic feet) of air space or volume (cubic feet) of the commodity? What is the cubic footage of the building? (See Appendix B for information on how to calculate volume.)

### Inside the Building

Are there any broken windows that you need to replace? Are there cracks in the ceiling, walls, or floor that you will need to seal? Are there

floor drains, sewer pipes, or cable conduits that may leak? There have been a number of fumigation failures because floor drains under stacked commodities went unnoticed. In another case, a fumigant leaked into a telephone cable tunnel that led to an occupied building. A number of people became ill.

- How will you handle air conditioning ducts and ventilation fans?
- Are there any fireplaces, flues, or stovepipes?
- Will interior partitions interfere with fumigant circulation?
- Are the interior partitions gas tight?
- Can you rely on them to keep the fumigant from entering other parts of the structure?
- Are there parts of the building that are not under the control of your customer?
- Can you shut down these operations during treatment?
- Will the fumigant damage anything in the building?
- Can you remove these items during fumigation? If not, can you protect them?
- Where are the gas shut-offs?
- Where are the pilot lights?
- Where are the electrical outlets?
- What is their voltage?
- Will circuits be live during fumigation?
- Can you use the outlets to operate your circulating fans?
- Does the building contain any high-priority items that may have to be shipped within a few hours notice?

### Outside the Building

- From what materials is the structure built? (Fumigants readily pass through certain materials such as wood.)
- Can you make the structure relatively airtight through sealing?
- Will it be necessary to tarp the entire building?
- If you tarp the structure, can you make a tight ground seal?
- Are there shrubs next to the building?
- Will they be damaged by the fumigant or by your digging to create a ground seal?
- Can you move these plants if necessary?
- How far is it to the nearest building?
- Does that building have air conditioning?
- Does it have air intakes that might draw the fumigant inside, particularly during aeration?

- How will you aerate the structure after fumigation?
- Are there exhaust fans?
- Where are the fan switches?
- Are there windows and doors that you can open for cross ventilation?
- Is the structure to be fumigated located where your operations may attract bystanders? If so, consider asking police to assist your own guards.
- Where is the nearest medical facility?
- Do you have the telephone number of a poison control center?

Once you are confident that you have covered everything, prepare a list of things to do. Make a second list of materials that you will need. See Unit 6 and Appendix A for sample checklists. Do not rely on your memory. With the checklists in hand, ask yourself one final question.

- What have I overlooked?

## Types of Sealed Structures

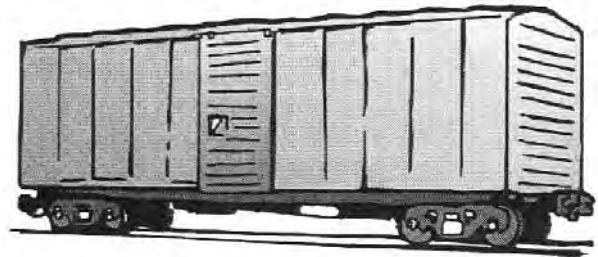
### Wheeled Carriers

Fumigating items inside wheeled carriers such as boxcars and truck trailers is one of the most common types of commodity fumigation. This method saves time and labor. It avoids extra loading and unloading. It controls the pests in the commodity. It ensures that live pests do not remain after unloading. In addition, fumigation of incoming loads prevents the introduction of pests into uninfested areas.

Boxcars and truck trailers have a high rate of insect infestation. They are also ideal vaults for fumigation. Wheeled carriers must be airtight for fumigation to be successful. Fumigants must stay inside the truck or boxcar long enough to control the pests. Well-built structures can be made relatively airtight by sealing them with fumigation tape or liquid adhesive. Structures with large holes or cracks, or structures made of permeable materials such as wood, may need to be tarped. See “Tarpaulin Fumigation” later in this unit to learn about this type of fumigation.

First, inspect and clean the boxcar or truck trailer while it is empty. Look for small holes or cracks that may allow fumigant to escape. Use fumigation tape, liquid adhesive, or caulking to

seal any gaps. Then seal the door that will not be used for loading. Secure a precut, two or four mil polyethylene sheet over the entire door. Compute the volume of the container to determine the dosage. See Appendix B for information on how to calculate volume.



**Boxcar**

Next, apply the fumigant. Every product is different. Read the label information to determine how to best apply the product you are using.

Next, cover the last door with polyethylene before closing and sealing it with fumigation tape. As required by law, place a warning sign on each door. On both signs write the date and time of fumigation and the name, address, and telephone number of the applicator. Return any unused fumigant to a locked chemical storage area. Dispose of empty fumigant containers according to the directions in the label information. See Units 6 and 8 for more information on the safe use and disposal of fumigants.

*NOTE: It is illegal to transport goods over public roads or highways if those goods are undergoing fumigation or have not completely aerated.*

### Ship Fumigation

Like fumigation of wheeled carriers, ship fumigation treats goods while they are still on board. This avoids extra loading and unloading. It controls the pests in the commodity and ensures that live pests do not remain after unloading. Fumigation of incoming loads also prevents the introduction of pests into uninfested areas. This is particularly important for products arriving from overseas.

Ship fumigation involves many people. Close cooperation with the responsible ship officer, ship agent, USDA, and Coast Guard inspector (if involved) is essential. You may also need to notify the Port Authority and the local fire and police departments.

Shipboard fumigation is highly specialized. The problems encountered and techniques used in ship fumigation are unique. In many cases, you may want to hire a company that specializes in ship fumigation.

## **Tarpaulin Fumigation**

Tarpaulin fumigation treats single items or entire structures. It works by placing a semipermeable material over an infested item or structure, sealing the edges, and then releasing fumigant beneath the tarp.

### **Advantages of Tarpaulin Fumigation**

You can use tarpaulin fumigation to treat a variety of items. It is particularly useful when only single pallets or groups of commodities are infested. Instead of fumigating an entire warehouse full of goods, tarpaulin fumigation allows you to treat only those items that are infested. This saves time and money. In addition, you can tarp and treat individual items or groups of items where they stand, if it is permitted by the label information. This also saves time and money. Because many sections of tarp can be clamped together, there is no limit to the size of the stack or structure that can be covered.

### **Disadvantages of Tarpaulin Fumigation**

The biggest problem with tarpaulin fumigation (of structures or outdoor treatments) is the weather. Weather conditions can delay fumigation. If there has been a recent heavy rain, the roof of a structure may be too slippery for safe work. Structures with wood roofs or concrete blockhouses can sorb enough moisture to cause problems after the tarps are placed on the house. In addition, if the temperature is below the labeled minimum, you must delay treatment until the structure is warm enough to comply with the label information.

### **Types of Tarpaulins**

An important aspect of tarpaulin fumigation is the type of “tarp” you select. Some tarps are

specially made for fumigation, such as impregnated nylon. Others are more generic but equally effective like sheet polyethylene. Each type has its pros and cons.

Impregnated nylon tarps are strong. They resist ripping and are reusable. In addition, you can clamp or tape together many sections of impregnated nylon tarps. This allows you to cover structures and commodities of almost any size. Unfortunately, impregnated nylon tarps are expensive. They are also heavier, which makes them more difficult to use.

Polyethylene sheeting comes in a variety of thicknesses – some are reusable and some are not. Thinner sheets (three mil or less) can be used once and are for indoor treatments only. Outdoors you can use four and six mil polyethylene. Six mil sheets can be reused if they are not worn or ripped excessively. To join together sections of polyethylene, use fumigation tape instead of clamps. Thinner sheets of polyethylene are often preferred to nylon tarps because they are less expensive and disposable. However, because they can tear easily, you must use them with care.

### **Ground Seals**

In addition to proper tarp selection, also consider the type of ground seal you will need. If they are smooth, concrete and asphalt surfaces provide the base for a good ground seal. Wood surfaces do not. With wood, and frequently with soil surfaces, it is necessary to place a section of the tarp beneath the item to be fumigated as well as over the top of the item. Otherwise, gas may escape through the wood or soil.

There are several ways to obtain a good ground seal. First, cover the infested item allowing at least 18 inches of tarp to skirt out from the base. Then, lay loose sand, sand snakes, or water snakes to hold the skirt to the ground surface. Snakes are tubes of cloth or plastic filled about three-fourths full with sand, gravel, or water. All types of snakes should overlap each other about 1 1/2 feet.

Sometimes you can attach adhesive fumigation tape directly to the floor. However,



you will still need sand, gravel, or water snakes to prevent the tarp from blowing off during treatment. Occasionally, you may need to treat an item that is too close to a wall to obtain a good ground seal. In this case, move the item and seal the tarp properly to the floor.

## Tarping Individual Items

Frequently, only single pallets or groups of commodities need treatment. With tarpaulin fumigation, you can cover and fumigate these items in place or at a nearby location.

### Basic Procedures

First, erect tarp supports one to two feet higher than the stacked commodity or item. This will create an air dome. An air dome assures adequate gas circulation during fumigation. Secure gas introduction tubes above the commodity or item. Place polyethylene sheeting under the outlet of the gas introduction tube. This will protect the commodity from any liquid fumigant that may accumulate during discharge. Next, pad all corners to prevent the tarp from tearing. The lighter the tarp material, the greater the chance for rips.

If the stack is large, use nonsparking fans to assure adequate gas circulation. Turn on the fans for 30 minutes to one hour after introducing the fumigant. Run tubing from various positions in the stack (usually, one located high in the stack, one at an intermediate location, and one at a low location) to the point where you will sample gas concentrations. Then place and seal the tarp to the floor. Determine the volume of



the space beneath the tarp to calculate the amount of fumigant to use. See Appendix B for information on how to calculate volume.

*NOTE: The air dome, tubing, and fans are not necessary or recommended when using aluminum phosphide.*

## Indoors

Tarpaulin fumigation is easiest and most effective indoors. Protection from wind and rain is critical. However, most indoor treatments require you to evacuate the entire building. Some fumigants may allow work to continue in other parts of the building, as long as the treatment area remains clear. Of course, you must post warning signs and monitor the area regularly.

If the item you wish to treat is in an unsuitable indoor site, it may be better to move the commodity to another indoor location than to fumigate outdoors. Make this decision when you first inspect the structure. For ease of movement, place all commodities on pallets for fumigation.

## Outdoors

The same procedures outlined for indoor treatments apply to fumigation outdoors. The difference is that outdoor tarps must be stronger and more durable. If you use polyethylene, it must be at least four mils thick. Six mil sheets are better. The color of the tarp also makes a difference. Clear polyethylene tends to become brittle from ultraviolet rays of the sun. In some cases, rays of sunlight can concentrate through

water drops on clear tarps and cause fires. If you plan to keep the polyethylene tarp in place after fumigation is complete, or if you will reuse it, consider black polyethylene. It is more resistant to sunlight, and it is not transparent. However, there are some dangers with black tarps. For example, if the tarp spans several stacks, it may conceal gaps between the stacks or other voids. Persons working on top of the tarp must be careful not to fall through. Once fumigation begins, a fall could be fatal.

There are several challenges with outdoor fumigation. First, it is more difficult to obtain a good ground seal outdoors. Sand and water snakes are often less effective because the ground is usually porous and uneven. Instead, place a layer of loose sand on the tarp skirt to obtain a good seal. You will also need to plan for bad weather. If you know it will be stormy, delay fumigation. Place braces over the item(s) (but under the tarp) so that rain will not accumulate in any low spot. Also, place sand snakes or sandbags over the tarp to protect it against wind.

## Tarpping an Entire Structure

Sometimes, you may need to treat an entire building.

### Basic Procedures

When fumigating an entire structure, good preparation is critical. First, remove all items that the fumigant may damage or that the label information requires. Evacuate the building for the entire fumigation and aeration period. Turn off pilot lights, flames, and electrical heating elements. Place tubing to draw air samples from several places within the structure. Use these tubes to administer the fumigant, and test its concentration during the treatment and aeration. It is best to introduce the fumigant at several locations. Place electric fans so that the fumigant will circulate throughout the structure and achieve rapid equilibrium. Local fire authorities may require the use of nonsparking fans.

If landscape plants are too close to the structure to permit a good ground seal, move the plants. Pad all edges of the structure that may puncture or tear the tarp. To be safe, ask all workers to wear shoes with nonskid surfaces.

Slips or falls can be very dangerous during fumigation. All ladders should be strong and braced. Use these to carry tarp sections to the rooftop. If you use impregnated vinyl or nylon tarps, roll together the edges of two tarp sections. Place clamps approximately 8 inches apart (4 inches apart if windy) along the seam. Drop the tarp over the sides of the structure. Complete any additional clamping or taping at this point.



Excessive “billowing” of a tarp can speed the loss of fumigant from a structure. Billowing occurs when air beneath a tarp causes the tarp to bulge outward. Prevent this by keeping the tarp tight against the structure. For example, if the building top is flat, use sand snakes to hold down the tarp. If the roof is peaked, throw weighted ropes over the tarp. Draw the tarp as close to the building as possible. One technique involves a high-capacity electric fan. Place the fan in one doorway and direct it outward. This may create a partial vacuum that will draw the tarp against the structure. Then, you can gather and tape down the excess material at the corners of the structure.

As in any fumigation, the ground seal is very important. The ground should be level and free of vegetation. If the soil is porous or dry, soak the soil around the perimeter of the building with water. This will help prevent fumigant from escaping through the soil. Make sure the tarp skirt is at least 24 inches and weighted down by loose sand, water snakes, or sand snakes. If you use water or sand snakes, double or triple them in windy weather.

## Spot (Local) Fumigation

Spot fumigation is the short-term treatment of machinery and small storages with toxic gases. It is used to control pests that infest whole foods and food particles that remain within processing equipment. Spot treatments work by interrupting the life cycles of insect pests. Since one or more stages of the insect (egg, larvae, nymph, adult) may survive, you must repeat spot fumigation regularly to maintain control. Use spot fumigation to control stored product pests in:

- Bins, silos, and holding tanks
- Elevator boots and heads
- Filters
- Conveyors
- Spouting
- Purifiers
- Food processing equipment
- Sifters, rollers, and dusters, and
- Related equipment in mills, food and feed processing plants, breweries, and similar industries

Spot fumigation is most useful where there is an accumulation of static or nonmoving stock. In an industrial setting, the following sites are susceptible:

- In elevator boots behind the feeder rolls on older style roll stands
- On the feeder rolls on newer type rolls
- In purifier conveyors on old-style wooden purifiers
- Pickup converters, screw conveyors, or the air chambers and feeders of the newer type Buhler or Miag purifiers
- The rear side of Draver feeders
- The top of each sifter section
- The inlets of feed finishers
- Directly below the elevator heads in each side of an elevator leg
- The canted 01: sloped area directly beneath the elevator head pulley (in most conventional or bucket-type mills, this area is not accessible for cleaning and is often overlooked during spot treatments)
- Automatic flour and feed scales
- The inlets leading to cyclone dust collectors
- Vertical air trunks, and
- Horizontal air trunks

## Advantages of Spot Fumigation

Insect infestations are usually not uniform. They concentrate in specific locations within equipment and storage areas. Spot fumigation allows you to treat only those areas where insects exist. This saves time and money, and it puts less fumigant into the environment.

## Disadvantages of Spot Fumigation

Spot fumigation is often labor intensive. Without fumiports, you must cut up and insert prepackaged fumigant such as phosphine Prepacs into the machinery at several locations. In addition, when treatment is complete, you must retrieve each Prepac or risk contaminating product during future processing. Spot fumigation can also be time consuming. Calculating the volumes of several small locations is cumbersome. Finally, disposal of spot fumigants like phosphine is difficult because you must deactivate the chemical before transporting it off site.

## Basic Procedures

Several things can affect the success of spot fumigation. Most important is your understanding of the equipment you treat and the airflow patterns within a warehouse. Always review diagrams of the facility and inspect the machinery. Determine whether you can make the site sufficiently gastight. Next, develop an application plan. Be sure your plan includes:

- The necessary staff and supplies.
- An application route. This route should be quick and efficient. It should also minimize applicator exposure.
- Security provisions during treatment. Post appropriate signage and notify the facility's personnel. Do not allow unauthorized persons to enter the treated area(s) prior to aeration.
- A procedure for sealing the equipment before treatment. Repair machinery, transfer lines, bins, or other equipment before treatment. This may improve the equipment's ability to retain gas.
- Dosage rates and application points.
- Safety provisions. Respiration protection is often required during spot fumigation. Always preplan ways you and other



applicators can reduce your exposure to the fumigant. These methods may include wearing respiratory protection, working near an open window, or using fans or forced ventilation.

- A record or log detailing the procedure. The log should include dates, dosage rates, and application points.
- Recommendations for the permanent installation of fumiports. Place fumiports inside the equipment to eliminate the possibility of contamination.
- A procedure for monitoring fumigant concentrations. Using an approved gas detector, take readings at regular intervals. Note fumigant concentrations during application to be sure fumigant levels get high enough for long enough to kill the pest. Note fumigant concentrations during aeration. Allow reentry only when gas levels are safe.
- A procedure for recovery, deactivation, and disposal of the fumigant when using phosphine. This plan must include emergency monitoring procedures.

Clearly mark all application points, particularly those that may not be visible from the floor level. Also, mark points where ladders are needed to reach overhead areas. Prepare a checklist or chart for each facility. Show the location and number of application points on each floor. As you treat each point, check off the appropriate location on the chart. In this way, you can be sure you did not miss any points before moving to the next floor.

Before treatment, run the machinery to empty the process stream. In mills, turn off the feed and allow the mill to run for 30 to 45 minutes. During this period, use rubber mallets to tap on the spouting, elevator legs, and sifters. This will help to loosen product that is trapped inside. Check outlet channels in the sifters to be sure they are not blocked or choked.

Next, seal the equipment. This will prevent fumigant from escaping. Eliminate drafts inside the equipment by closing off sections that have openings. Then, seal these openings with tape, caulk, tarps, or other materials. Seal dust collector vents with polyethylene sheeting or large plastic bags. Close dust collectors and filter vents to keep the fumigant within the machinery. Thermal currents and drafts can

cause a spot fumigation to fail. Gas may escape before reaching a lethal concentration within the machinery.

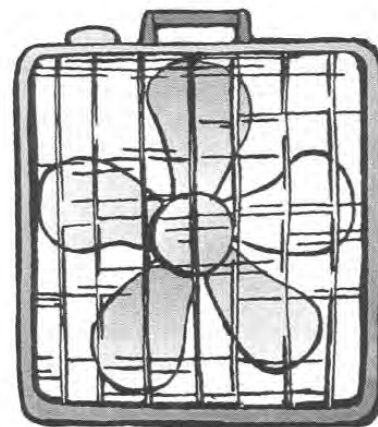
While spot fumigation is less intensive than other methods of fumigation, proper safety is equally important. During application, open windows in rooms that house equipment to allow ventilation. When possible, use a fan or hood to reduce your exposure. Read the label information of each product you use to determine what PPE is required. Approved respiratory protection is required for many spot fumigations. See Units 6 and 7 to learn more about fumigant safety and respiratory equipment.

## Aeration After Fumigation

Aeration follows all types of fumigation: vault, tarpaulin, and spot. It is the process by which fumigated air is replaced with fresh air. This can occur in a large warehouse or in an individual piece of equipment. Sometimes aeration involves opening doors and windows. Other times you can use fans and ventilators. Aeration procedures vary according to:

- The fumigant you use
- The area in which you fumigate, and
- The item(s) you treat

Every situation is different.



Proper aeration is important for your safety, the safety of your crew, and the safety of your clients. Read and follow the instructions in the label information for your product exactly.

## Factors Affecting Aeration Time

The rate of aeration is affected by several factors. Three of the most important factors are:

- The rate of air exchange
- Air temperature, and
- Sorption and desorption

### Rate of Air Exchange

The rate of air exchange within a treated area is the most important factor affecting aeration. The faster air flows through a structure, the faster aeration can occur. Exchange rates are proportional to wind speed and the size and layout of the fumigated area. In atmospheric chambers, an exchange rate of one “air change” per minute is desirable. An air change occurs when 100 percent of the air in a given space is replaced by fresh air. Nonsparking fans are useful for this purpose. They also help to stir up the air in “pockets” or “dead spaces.”

Areas loaded with commodities aerate much slower than empty areas.

### Temperature

Temperature can also affect the speed of aeration. As temperature increases, the rate of aeration increases. This is because higher temperatures increase the rates of diffusion and desorption of fumigants. For example, when you aerate areas during colder months, you may use cold outside air. These lower air temperatures will slow desorption. The rate of diffusion will also decrease. Longer aeration time will be needed. For commodity fumigation, it may be necessary to close the area and heat it to 76°F (24°C) (the optimal aeration temperature for most fumigants). Then repeat the aeration process to adequately remove the fumigant.

### Sorption and Desorption

As you learned in Unit 3, sorbed fumigant is not available to control pests. It is adsorbed and/or absorbed by materials in the treated area. Still, you must remove it during the aeration process. Some commodities are more sorptive than others are. Some fumigants are

more subject to sorption than others are. The greater the sorptive capacity of the fumigant and the item fumigated, the longer the desorption process and the greater the aeration time needed.

To determine how sorptive a fumigant is, read the label information. Then follow these two rules of thumb:

1. Generally, the lower the boiling point of a fumigant, the lower the sorption rate and the more rapid the aeration.
2. The greater the surface area of the items being fumigated, the greater the sorption rate and the longer the aeration period needed for desorption. For example, the surface area of grain is high. (A load of grain consists of many small pieces, each with a surface area. Together these add up.) Because of its high surface area, the desorption rate of grain is slow. It is usually advisable to hold grain an additional 24 hours after the satisfactory aeration period. Other highly sorptive materials include flour, meals, and burlap bags (used to hold many stored products). You will need to increase aeration times when treating these materials as well.

## Aeration Procedures

Procedures for aeration vary with the fumigant, the area, and the items fumigated. Read the label information for aeration procedures specific to each product that you use. Follow the instructions exactly.

### Aeration of Fumigation Chambers

The way you aerate a fumigation chamber depends on whether the chamber is indoors or outdoors. When a fumigation chamber is within a building where people are likely to be present, install intake and exhaust pipes for safe aeration. These pipes lead to the outside. The intake pipe will draw fresh air in while blowing fumigant-treated air outside. Turn on air circulation equipment in the chamber to exchange air between the chamber and the outside.

When a fumigation chamber is outside, aeration is straightforward. Simply open the door slightly and turn on the blower. Be sure to prop open the door so it does not accidentally close. If the door closes, the partial vacuum created by the blower may damage the chamber. Channel the air from the blower to the outside of the chamber.

Do not stand near the chamber door or exhaust when the blower is on. Check gas levels regularly during aeration. Be sure to use a gas detector that is approved for the product you are using. If fumigant levels are too high, stay out of or away from the treated area unless you are wearing the appropriate respiratory protection.

After aeration, collect all empty fumigant containers, packaging materials, and solid residues (such as those from metal phosphide fumigants). Transport these materials to an appropriate site for further deactivation and disposal. Follow the disposal instructions outlined in the label information.

## Aerating Buildings

After fumigation, aerate buildings by opening doors and windows and turning on ventilators. First, open ground floor windows and doors from the outside. Allow buildings to air out for a minimum of 30 to 60 minutes before entry. Then open other windows and doors. Check detectors to be sure fumigant levels are safe. Read the label information for other aeration requirements.

At the beginning of the aeration procedure, only enter the building for short periods. Always enter in pairs and wear approved respirators. Once inside, open doors and windows on the first floor first. Target windows that provide thorough cross ventilation. Then return to the outside. If ground floor ventilation occurred before entry, work upward floor by floor. Open windows. Turn on nonsparking fans and allow them to run until aeration is complete. Take concentration readings to determine if exposures are within allowable limits.

After the building has been partially aerated, reenter with a partner wearing approved respirators. Open as many of the remaining windows as needed to complete aeration.

When the building has completely aerated, begin testing gas levels. Using approved detectors, test closets, appliances, equipment, stacked commodities, and other items to make sure that no gas is remaining. While wearing a respirator, beat mattresses and upholstered furniture to release any gas present. Aerating the building and its contents is extremely important. Follow the directions in the label information closely. The first rule of reentry is “check it first.”

## Tarpaulin Aeration

Safe tarpaulin aeration can be trickier than it seems. When aerating loads under tarps on still, humid days, follow these steps. Place a blower on one end of the load. Make an opening on the opposite end by lifting the tarp. Then turn on the blower and discharge the fumigant. If a breeze or steady cross ventilation is available, a blower may not be necessary. If you choose not to use a blower or cross ventilation, aerate the item or area by lifting the tarp at the corners. Then, slowly raise the sides until the tarp is completely removed.

If aeration occurs outside and there is a breeze, pay attention to which way the breeze is blowing. Always lift the end or side of the tarp opposite the direction of wind movement first. Then lift the portion of the tarp on the windward side. If the first opening is on the windward side, fumigant vapors will be forced backward and may endanger workers.



**Tarpaulin Aeration**

Wear a respirator or gas mask during all phases of tarpaulin aeration. Evacuate occupants, other than fumigation workers, before aerating tarped items.

## **Aeration After Spot Fumigation**

Initiate aeration after spot fumigation by turning on ventilators and opening doors and windows in the treated area(s). Remove covers from bins, vessels, and other equipment. Turn on dust collector fans.

Aeration after spot fumigation is generally complete in less than one hour. Wear respiratory protection during aeration as directed by the label information. Always check gas levels with an approved gas detector before reentry.

For fumigation and aeration to be safe and effective, you must select the appropriate fumigation method and follow the procedures outlined in this unit. You should also know how to select and use the equipment described in the next unit.

## Test Your Knowledge

**Q. What is the purpose of fumigation?**

- A. To achieve and contain an adequate concentration of the gas for the time needed to kill pests.

**Q. Name the three main types of fumigation.**

- A. 1. Vault fumigation  
2. Tarpaulin fumigation  
3. Spot (or local) fumigation

**Q. Describe two types of vaults used for fumigation.**

- A. 1. Vacuum chamber – A large steel structure in which fumigation is conducted at a reduced air pressure.  
2. Atmospheric chamber – A small, isolated building built or modified for fumigation at normal air pressure.

**Q. Give three examples of specialized vault fumigation.**

- A. 1. Ship fumigation  
2. Truck and boxcar fumigation  
3. Tape and seal fumigation

**Q. What is the biggest problem with tape and seal fumigations?**

- A. They are notoriously leaky.

**Q. True or False: Impregnated nylon tarps can be used again and again due to their strength.**

- A. True.

**Q. What extra step do you need to take when fumigating on a soil or wood surface and sealing tarps? Why?**

- A. Spread a section of the tarp beneath the material to be fumigated. Otherwise, fumigant can leak through the soil or wood.

**Q. Describe how you would achieve an adequate seal when performing tarpaulin fumigation on a pallet of goods.**

- A. Cover the item. Allow at least 18 inches of the tarp to skirt out from the base of the stack. Place overlapping sand or water snakes on the tarp around the perimeter of the stack. Try to work on a level surface.

**Q. How is outdoor tarpaulin fumigation different from indoor tarpaulin fumigation?**

- A. When fumigating outdoors, the tarp must be of stronger material. Obtaining a good ground seal is more challenging. You must protect against unexpected bad weather outdoors. In general, indoor tarpaulin fumigation is preferred.

**Q. Spot fumigation is primarily used to treat \_\_\_\_\_.**

- A. Infested processing machinery and equipment

**Q. Name several things needed for a spot fumigation application plan.**

- A. 1. The necessary staff and supplies.  
2. An application route.  
3. Security provisions during treatment (ex., warning signs and security personnel).  
4. A procedure for sealing the equipment before treatment.  
5. Dosage rates and application points.  
6. Safety provisions (ex., PPE and ventilation equipment).

7. Logs for recording dosage and points of application.
8. Recommendations for the permanent installation of fumiports.
9. A procedure for monitoring fumigant concentrations during fumigation and aeration.
10. A procedure for recovery, deactivation, and disposal of the fumigant.

**Q. What are three important variables impacting fumigant aeration?**

- A.
  1. Rate of air exchange
  2. Temperature
  3. The rate of desorption

**Q. Under what conditions can you enter a partially aerated structure?**

- A. If you are wearing a respirator that is approved for the fumigant you are using and if you are accompanied by at least one other person.

**Q. Describe how to aerate a tarped stack of commodities.**

- A. Place a blower on one end of the load. Make an opening on the opposite end by lifting the tarp. Then turn on the blower and discharge the fumigant. If a breeze or steady cross ventilation is available, a blower may not be necessary. If you choose not to use a blower or cross ventilation, aerate the item or area by lifting the tarp at the corners. Then, slowly raise the sides until the tarp is completely removed.

# Unit 6: Public and Personal Safety

## Learning Objectives

After reading this unit, the reader will be able to:

- Understand the risks fumigation poses to people and the environment.
- Practice safe fumigation procedures that eliminate personal risk and risk to the public.
- Select appropriate tools and equipment to make fumigation safer and more effective.
- Use safety checklists before, during, and after a fumigation operation.
- Recognize the signs and symptoms of fumigant exposure.
- Administer basic first aid in the event of fumigant exposure.

The Arkansas Core Manual, **Applying Pesticides Correctly**, is a comprehensive guide to pesticide safety. The Core Manual discusses basic safety considerations for all applicators.

This unit covers safety practices specific to food and stored commodities. By reading it, you will learn how to reduce or eliminate fumigation exposure to yourself and to the public. It will teach you how to use personal protective equipment (PPE), warning gases, and threshold limits. You will discover the importance of posting warning signs and writing an application plan. At the end of this unit are several safety checklists. This unit will explain why it is critical to use these checklists before, during, and after every fumigation.

## Terms to Know

**Aerate** – Introduce fresh air into a treated area to dilute and remove fumigant-filled air. Aeration must follow all fumigation operations.

**Antidote** – A remedy that may counteract the effects of a pesticide.

**Exposure** – When a person or organism comes in contact with a pesticide.

**Overexposure** – When a person or organism comes in contact with enough pesticide over a long enough period to cause harm.

**PPE (Personal Protective Equipment)** – Clothing or devices used to protect the human body from exposure to pesticides and pesticide residues.

**Threshold Limit Value (TLV)** – The maximum amount of fumigant that can be in the air before conditions are considered unsafe. The TLV is expressed in parts per million (ppm). It is used to monitor short-term exposure.

**Threshold Limit Value-Time Weighted Average (TLV-TWA)** – The average concentration of fumigant for a normal 8-hour workday and a 40-hour workweek to which workers may be repeatedly exposed without adverse effect. The TLV-TWA is expressed in parts per million (ppm). It is used to monitor long-term exposure.

**Volatility** – The ability of a substance to turn into a gas at relatively low temperatures.

**Warning Gas** – A chemical that can be added to an odorless fumigant to help workers detect the fumigant. Warning gases give off strong smells or have an irritating effect.

Fumigants are the most hazardous of all pesticides. They are highly volatile, penetrating, and poisonous. Even experienced fumigators can be injured, can injure others, or can damage items because of these hazards:

- Fumigants can kill humans.
- Fumigants can kill rodents, bats, birds, pets, and other animals that are on site during treatment.
- Fumigants can cause severe burns and damage internal organs.
- Fumigants can cause fires and explosions.
- Fumigant use can result in illegal residues in foods.
- Some fumigants can inhibit the germination of seeds.
- Some fumigants can corrode metals.
- Some fumigants react with certain materials to produce off flavors and bad odors.
- Some fumigants can kill plants.

Three agencies set regulations for the safe use of fumigant pesticides – the Environmental Protection Agency (EPA), the Arkansas State

Plant Board (ASPB), and the Occupational Safety and Health Administration (OSHA). Each agency administers regulations concerning fumigant handling.

You must follow all directives issued by the EPA, ASPB, and OSHA, and the instructions in the fumigant label information. These agencies may fine you for misusing a fumigant or for failing to properly care for your protective equipment.

This unit discusses safety issues, general precautions, and emergency procedures related to fumigation. It will describe how to protect the public, your co-workers, and yourself from exposure. It will also provide safety checklists for all stages of fumigation. However, no publication can cover all situations for all products. Follow the instructions in the label information specific to each product that you use. Remember there is no substitute for good common sense.

Unit 7 will cover safety equipment and its proper use.

## Protecting the Public and the Environment

Fumigants are some of the most toxic pesticides available. Their safe use and handling require skill and care. This manual discusses fumigants that control pests in food and stored commodities. Some commodities are edible-corn, wheat, rye, etc. Others are stored where people work and animals live, grain bins, silos, etc. In nearly all cases, fumigants control pests on items or in areas with which people and animals have direct contact. Your ability to apply fumigants safely is critical. You must protect the public and the environment from exposure.

There are several important ways to protect others from fumigant exposure. These include:

- Reading and following the label directions
- Posting warning signs
- Monitoring for the fumigant
- Safely transporting, storing, and disposing of fumigants and their containers
- Following tolerance levels, properly aerating the treatment area, and
- Preparing and planning well before application

## Read the Label Information



The most important thing you can do to ensure personal and public safety is to read the label.

Fumigant labels include both an abbreviated sticker label and an extended label, often in booklet form. Treat these two documents as you would any pesticide label. Follow their instructions to the letter. It is the law. This manual refers to the sticker label and the label booklet together as “label information.”

The label information will tell you how and where to use the product. It will give you detailed application and aeration instructions. You will discover how to store the chemical properly. The label information may note specific sites that you should avoid or application methods that are not permitted. It will also describe specific safety precautions. Read all of the label information completely before using any fumigant for any purpose.

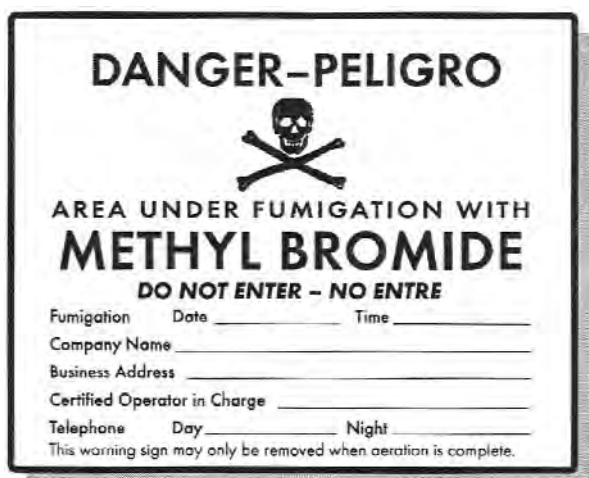
## Signage for Fumigated Areas

Warning signs or “placards” protect the public during and after fumigation. They are also posted during transportation and storage of a fumigant. A warning sign provides a barrier between people and the fumigated site or item. Federal and state laws require you to post warning signs at all accesses leading to areas or commodities under fumigation. Only authorized fumigators wearing the proper personal protective equipment (PPE) may enter treated areas before and during aeration.

Follow label directions regarding posting warning signs before and during fumigation. Most fumigant labels have specific directions regarding signage:

- What the sign should say
- How many signs to use
- Where to post the signs, and
- How long to leave the signs in place





Posting warning signs will help to keep unauthorized persons away. Do not remove the signs until the treated equipment and surrounding area have been completely aerated.

## Monitoring for the Fumigant

There is always a risk that fumigant gas will escape from a treatment area. Monitoring for these leaks is critical. When treating commodities that are next to work areas, be sure to take air samples during treatment. Use appropriate gas detectors to verify that fumigants are not leaking. This is particularly important during indoor treatments. See Unit 7 for more information about gas detectors.

## Transporting Fumigants

Transporting a fumigant is dangerous. Leaks and spills caused by accidents are sometimes beyond your control. However, by taking the following precautions and using common sense, you can prevent many accidents.

- Do not use public transportation (subways, buses, trains, or taxis) to transport fumigants.
- Do not transport fumigants through tunnels unless you get permission from the Arkansas Department of Transportation (ADOT).
- Do not transport fumigants and people together in a closed vehicle.
- Be sure you have the required drivers license with any appropriate endorsements for the specific fumigant you plan to transport.
- Read the label information and/or the Material Safety Data Sheet (MSDS) to

determine the signage requirements for transporting each fumigant that you use. You can also contact the fumigant manufacturer for more information on placarding for transportation.

- Be sure cylinders are upright and secured during transport.
- Mount cylinders so they are protected from rear end collision.
- Do not remove protective valve covers until just before use.

*NOTE: It is illegal to transport goods over public roads or highways if those goods are undergoing fumigation or have not been completely aerated.*

Always follow federal and state department of transportation regulations when transporting fumigants and/or their containers. Contact your local Arkansas Department of Transportation office for further information.

## Storage and Disposal of Fumigants

Storage of fumigants is hazardous. Whenever possible, buy them just before you need them to shorten the storage period. Store all fumigants on sturdy shelves in an area apart from feed or seed. A separate building that is well ventilated or has a mechanical exhaust system is best. Be sure that all fumigant storage areas are locked and posted as pesticide storages. Warning signs should indicate the presence of fumigants.

Fumigants can escape from faulty valves or damaged or corroded cans. Leaks can cause dangerous concentrations to build up in closed storerooms. Check valves and containers regularly for leaks. Before entering any storage area, run an exhaust fan to remove vapors that may have built up inside.

Do not risk contamination of water supplies. Dispose of all empty containers, residues, and rinsates according to state waste management procedures. Keep all pesticides and their empty containers out of the reach of children.

## Tolerance Levels

Fumigants should not change or impair treated material in any way. Nor should they

leave any residues on raw agricultural products that could be hazardous during processing. The EPA has determined the amount of pesticide residue that may safely remain in or on agricultural products. This is called the “tolerance level.” Be sure fumigant residues never exceed these levels by following label directions to the letter. Consult the label information or the registrant for tolerance levels specific to the product(s) you use and commodity(ies) you treat. Tolerance levels come from the Code of Federal Regulations. If you have additional questions about tolerance levels, contact Arkansas State Plant Board (ASPB).

## Proper Aeration

Proper aeration is important for your safety, the safety of your crew, and the safety of your clients. Poor aeration is one of the most common problems associated with fumigation. Read and follow the instructions in the label information exactly. When treating raw agricultural products, be sure the rate of air exchange during the aeration phase will adequately remove the fumigant. If necessary, use fans or other ventilation equipment. Also, check air temperatures. The treatment area should be warm enough to allow the fumigant to completely desorb from the treated agricultural product. Heat the area or increase the aeration time if necessary. Finally, check the sorptive capacity of the commodity you are treating. Highly sorptive materials require longer aeration periods. Adjust your aeration time as needed.

## Preparation and Planning

Preventing public and environmental exposure also relies on how well you prepare. How well have you sealed an area? Have you inspected all equipment thoroughly? Are you applying the fumigant at or below the label rate? Have you set aside enough time to completely aerate the site or item? Have you set up fences and posted warning signs to keep people, livestock, and pets out of the treatment area? Details about proper application methods are described in Unit 5 and Unit 8. Use this information to develop a solid application plan. Review your plan several times. Then use the checklists at the end of this unit to be sure nothing has been overlooked. Appendix A contains safety checklists that you can copy and use.

Remember, you, the applicator, are the most important variable in fumigation. Your education and training will directly affect the safety and success of your operation.

## Personal Safety

Safety is always a concern for you as a fumigant applicator. You must consider your own safety, as well as that of your co-workers, your clients, and the people who will use the areas you treat.

Human safety is addressed throughout the Arkansas Core Manual, **Applying Pesticides Correctly**. Review these sections of the Core Manual for basic pesticide safety information. Besides taking the precautions outlined in the Arkansas Core Manual, you must also consider the specific risks associated with fumigants.

## Always Work in Pairs

One of the most important things you can do to protect yourself during fumigation is to always work with another person when applying fumigants. This person can assist you immediately if you become injured or incapacitated while working around these products. In fact, many fumigant labels require fumigators to work in pairs during application or gas monitoring.

## Routes of Exposure

As a fumigant applicator, you may be exposed to fumigants in several ways. Fumigants can enter your body through your lungs (inhalation), your eyes (ocular exposure), your mouth (ingestion), and even your skin (dermal exposure). The most dangerous and common type of fumigant exposure is inhalation. Most fumigants are highly toxic. Breathing even small amounts of some fumigants can cause serious illness or death. To protect yourself, read the label information. Find out what personal protective equipment (PPE) the manufacturer requires. Then, learn what to do in case of exposure. See “First Aid for Fumigant Poisoning” later in this unit for details about how to handle different types of fumigant exposure.

## PPE

Personal protective equipment (PPE) is the name given to clothing and devices that protect you from contact with pesticides. The

label information for each product lists the minimum PPE required for using that pesticide. Federal and state laws require pesticide users to follow all instructions on the product label, including wearing the appropriate PPE.

The most important PPE for fumigators is the respirator. Respirators provide you with clean air to breathe when you are surrounded by toxic gas. There are several types of respirators. Each one has its pros and cons. Read the fumigant label to determine which type of respirator you will need. See Unit 7 to learn more about the selection, use, and maintenance of respirators.

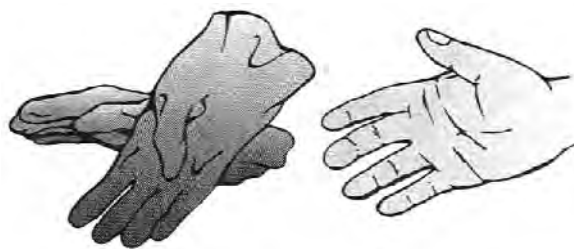


**Respiratory equipment**

Fumigation also requires other types of PPE. These include protective clothing and gloves. Requirements vary with the fumigant. Read the label information carefully.

If skin absorption is a problem, some fumigants require you to wear thick cloth coveralls or impermeable clothing. Other products direct you to wear short sleeves and loose-fitting clothing.

The need for gloves also varies. For example, some solid fumigants require fumigators to wear gloves because of possible skin irritation. Read the label information to be sure you use the right kind of glove. Other fumigants, particularly liquid products, do not require gloves. Some may even prohibit you from wearing gloves.



**Some fumigants require you to wear gloves during fumigation. Others do not.**

Read the label information to learn which items are required for the product(s) you plan to use.

## Other Tools for Personal Safety

Because inhalation exposure poses the greatest risk to fumigant applicators, the following safety information will focus on preventing this type of exposure. Several tools are available to reduce or prevent inhalation exposure. These include:

- Threshold limits, and
- Gas detectors

*NOTE: The safe and effective use of gas detectors is covered in Unit 7 (Safety Equipment).*

## Threshold Limits

One of the most important tools you can use to protect yourself and others during fumigation is the “threshold limit value” (TLV). The TLV is the maximum amount of fumigant that can be in the air before conditions are considered unsafe. Concentrations at or below the TLV represent conditions that workers may be exposed to on a daily basis. These levels are considered safe. Concentrations above the TLV may lead to “overexposure” of a fumigant. This can cause discomfort, sickness, or even death. These levels are considered unsafe. The TLV is usually expressed in parts per million (ppm).

Every fumigant has a specific TLV. Read the label information to find the TLV for each product you use.

By monitoring the TLV throughout treatment you can prevent illness and injury caused by overexposure. Unfortunately, people's susceptibility to fumigants varies widely. For example, a small number of workers may experience discomfort from fumigant concentrations at or below the TLV. Others may suffer a more serious aggravation due to a preexisting condition. Even when the TLV is low, observe yourself and your co-workers for any signs of exposure.

To monitor long-term exposure, use the threshold limit value-time weighted average (TLV-TWA). This value is the average concentration for a normal 8-hour workday and a 40-hour workweek to which workers may be repeatedly exposed without adverse effect. Every fumigant has a specific TLV-TWA. Consult the label information for the TLV-TWA of each product you use. If you will be exposed to a fumigant for several days or weeks, be sure the fumigant concentration stays at or below the recommended TLV-TWA.

## Warning Gases

It is often helpful to add warning chemicals to odorless fumigants. These products give off an odor that can help you detect the presence of harmful gas. However, you should never rely on warning gases alone. Keep the following facts in mind:

- Individuals vary in their ability to detect and quantify odors.
- Odors only indicate whether the fumigant is present. They do NOT tell you the concentration of the fumigant.
- You may suffer olfactory fatigue. Over time, you may lose the ability to smell a particular warning agent.

Warning gases serve a useful purpose, but they are not foolproof. Use them as one of many safety tools.

## Exposure Limits

You can also reduce your risk of inhalation overexposure by monitoring fumigant concentrations during treatment and aeration. Be sure your exposure stays below established exposure limits such as the TWA, STEL, and PEL.

An exposure limit is the highest level of fumigant that you may be exposed to without being required to use any controls to reduce your exposure. The American Conference of Governmental Industrial Hygienists (ACGIH), OSHA, and the National Institute of Safety and Health (NIOSH) are all agencies that establish these limits. Each agency uses different terms to refer to long- and short-term exposure limits. Refer to the fumigant label information to find out what the different exposure limits are for each product you use.

The three most common terms used to express the exposure limit of a fumigant are the:

- Threshold limit value-time weighted average (TLV-TWA)
- Threshold limit value-short term exposure limit (TLV-STEL), and
- The permissible exposure limit (PEL)

TLV-TWA or "TWA" is an ACGIH term that refers to the average concentration of a fumigant to which most workers may be repeatedly exposed 8 hours a day, 40 hours a week without adverse effects. Concentrations at or below the TWA represent conditions that you may be exposed to on a daily basis. These levels are considered safe. Concentrations above the TWA may lead to "overexposure" to a fumigant. This can cause discomfort, sickness, or even death. These levels are considered unsafe. The TWA is usually expressed in parts per million (ppm) or milligrams per cubic meter (mg/m<sup>3</sup>).

By monitoring fumigant levels throughout treatment and keeping your exposure level below the TWA, you can prevent injury and illness caused by overexposure. However, people's susceptibility and response to fumigants varies widely. For example, a small number of workers may experience discomfort or minor irritation from fumigant concentrations at or below the TWA. Others may suffer more serious health effects – even death – due to a pre-existing condition. Even when the TWA is low, observe yourself and your co-workers for any signs or symptoms of exposure.

For short-term exposure, look for the TLV-STEL on the product label. Like the TLV-TWA, this ACGIH term is often shortened to "STEL." Specifically, STEL is the concentration of fumigant to which most workers can be exposed

continuously for a short period without suffering from:

- Irritation
- Chronic or irreversible tissue damage, or
- Narcosis (drunkenness) that may increase the chance of accident or injury

Exposure to concentrations at the STEL should not be longer than 15 minutes and should not occur more than four times per day. The STEL is expressed in ppm or mg/m<sup>3</sup>.

PEL is an OSHA standard that designates the maximum exposure permitted as an 8-hour TWA. OSHA sets PELs to protect workers against the health effects of exposure to fumigants.

Usually, OSHA PELs are not as conservative as are ACGIH TLVs. With this in mind, it is always wise to comply with the most stringent exposure limit. This will ensure the highest degree of safety and health. In the absence of any exposure limits, you should always strive to minimize your exposure.

## Safety Checklists

Keep safety foremost in your mind when planning any fumigation operation. Focus on protecting lives and preventing fires. Plan ahead – especially when working in a remote location. Know how to get help if something goes wrong.

The following checklists will help you organize the many aspects of fumigation. This information is general. It does not apply to all fumigants in all situations. Always read the label information first. Become familiar with the dangers of the product you intend to use. Some manufacturers provide checklists specific to their products. Use these checklists as well.

### Preliminary Planning

(Appendix A contains a version of this checklist that you can photocopy and use.)

- ✓ Draw or locate a sketch of the structure you plan to fumigate. Indicate the layout of the structure, connecting structures, and escape routes above and below ground.
- ✓ If you are in an industrial setting, inspect the equipment. It should be as tight as

possible to prevent drafts and leaks. Be sure that production has stopped.

- ✓ Seal all spouts, conveyors, conduits, heating ducts, and other possible openings leading from the areas that you plan to fumigate.
- ✓ Record the number and names of everyone who routinely enters the area. Note the proximity of other nearby people and animals. Keep children, unauthorized persons, and pets away from the application site.
- ✓ If you plan to treat a commodity, learn about it. Find out its mode of storage and its condition. If possible, obtain a previous treatment history.
- ✓ If you plan to treat a structure, learn about it. What does it consist of – wood, brick, concrete? Note the locations of doors, windows, and dividing walls. Check airflow patterns.
- ✓ Locate connections and shut-offs for electricity, water, and gas. Find the nearest telephone or communication device.
- ✓ Obtain and have handy telephone numbers for local health, fire, police, and medical emergency services. Know how to contact the parties responsible for the structure and/or commodity you plan to fumigate.
- ✓ ONLY select a fumigant registered by the EPA and with the ASPB.
- ✓ Read and reread the label information. Study the directions and precautions. Make sure the fumigant is approved for the required work (site, commodity, etc.).
- ✓ Check, mark, and prepare (tarp, seal, etc.) the points of application if the job involves spot fumigation.
- ✓ Notify the local health and fire departments, police and security personnel, and the poison control center. Give them the following information: the location, the chemical name(s), the date and time of application, the type of gas mask and other safety equipment required, the fire hazard rating, and literature about the safety measures you plan to use.

- ✓ Inform the occupants of the structure where treatment will occur. Also, notify the occupants of neighboring structures.
- ✓ Arrange for standby equipment and replacement parts. Outline an alternate plan of action.
- ✓ Review the fumigation plan with all workers. Explain the potential hazards to life and property, required safety measures, and emergency procedures.
- ✓ Prepare warning signs to post near treated areas. Arrange for someone to monitor all entrances and exits during treatment.
- ✓ Have first aid equipment (including antidotes and plenty of fresh water) handy.
- ✓ If possible, plan for application from outside the structure.
- ✓ Seal all cracks, crevices, open fireplaces, broken windows, holes, pipes, chutes, and conveyors.
- ✓ When necessary, obtain fans to evenly distribute the fumigant.
- ✓ Preplan how you will ventilate the area after treatment.
- ✓ Identify areas where you can store any excess fumigant(s). Be sure conditions in the storage area match those required by the label information.
- ✓ Make sure no open fires, motors, or hot surfaces (heat pipes or electric fixtures) are within the space that you plan to treat.
- ✓ Know how to operate the gas detection devices.

## Pre-Application Safety

(Appendix A contains a version of this checklist that you can photocopy and use.)

- ✓ Open all doors and drawers inside the area you plan to treat.
- ✓ Shut off pilot lights and gas lights. Disconnect electrical equipment.

- ✓ Remove plastic covers from mattresses.
- ✓ Make a final check. Be sure all occupants, pets, fish, and plants have been removed from the structure.
- ✓ Place warning signs at all entrances and exits.
- ✓ Assign someone to observe all entrances and exits.

## During-Application Safety

(Appendix A contains a version of this checklist that you can photocopy and use.)

- ✓ Apply all fumigants according to the directions in the label information.
- ✓ Apply the fumigant from outside where appropriate.
- ✓ Consider the weather. You may need to delay or cancel outdoor treatments on windy or stormy days.
- ✓ Do not enter the area where fumigant gas is being discharged, except in extreme emergencies.

## Post-Application Safety

(Appendix A contains a version of this checklist that you can photocopy and use.)

- ✓ Aerate according to structural limitations.
- ✓ Turn on ventilation fans where appropriate.
- ✓ Before reentering a treated area, use a suitable gas detector to determine the fumigant concentration. Some fumigants do not provide an adequate odor warning. Other areas aerate slowly.
- ✓ Remove warning signs only when aeration is complete.
- ✓ Dispose of or return empty containers per the manufacturer's instructions.
- ✓ When using metal phosphide fumigants, return any unused, solid chemicals to clearly labeled containers. Store them properly.

## Personal Safety

(Appendix A contains a version of this checklist that you can photocopy and use.)

To protect yourself and others, be sure you and your supervisor(s) always:

- ✓ Know the location of all entrances and exits.
- ✓ Know the location of all fumigant containers and aerating fans.
- ✓ Rehearse the fumigation plan so that each worker knows what to do.
- ✓ Remove all rings, jewelry, and watches as required by the label.
- ✓ Have current health records for all employees. All workers that take part in fumigations must have a physical exam at least once a year. During fumigation, no worker should have a cold or other condition that may impair breathing. Nor should any worker be undergoing medical or dental treatment, unless a physician certifies that they may work with fumigants.
- ✓ Survey workers to make sure they have abstained from alcoholic beverages 24 hours before and will abstain 24 hours after a fumigation job.
- ✓ Instruct all workers about first aid, emergency procedures, antidotes, and decontamination.
- ✓ Work in pairs – especially when entry into a fumigated area is necessary. Stay in sight of one another while inside a treatment area.
- ✓ Report any accidents to your employer or supervisor.
- ✓ Report any signs of illness or physical discomfort, regardless of how minor they may seem. This includes dizziness, diarrhea, nausea, headaches, and lack of coordination.
- ✓ Teach all workers how to select, operate, and maintain protection devices. Warn them

about the hazards that they may encounter if the chemicals are misused.

- ✓ Have and use the necessary personal protective equipment (PPE). Know where emergency equipment is located.
- ✓ Make sure there is enough water on site to wash or flush skin and eyes if an accident should occur.

## First Aid for Fumigant Poisoning

Even when you take all of the proper precautions, human exposure can still occur. Be prepared. Know what to do for all types of fumigant poisonings.

First, read the label information. The label information is often your best source of first aid information. Federal regulations require that first aid information appear in the label information if a particular hazard exists. Because most fumigants are highly toxic, first aid information is usually listed. Additional first aid information appears on the product's "Material Safety Data Sheet" (MSDS).

First aid information in the label information is usually specific to the product. Therefore, you must also be familiar with basic first aid procedures for fumigant exposure.

## Basic First Aid

First aid is just that – it is your first response to fumigant exposure. First aid is not a substitute for medical help. To protect yourself and your co-workers, know when medical attention is needed and seek it right away.

How you respond to a fumigant poisoning depends, to some extent, on whether you or someone else is the victim. In either case, however, you must follow the same basic principles.

If you have been exposed to a fumigant or if you begin to feel ill, remain calm. Get to a doctor right away. Even when the fumigant is less toxic

than others are, you may need medical attention – particularly if you were exposed to a large amount of the chemical. Do not go alone. Have someone take you to the doctor. Be sure to give the label information to the doctor. Keep an extra copy of the label and MSDS on file for each fumigant that you use. You can take this information to the hospital in case of a medical emergency without risking container transport.

If you are with someone who has been exposed to a fumigant, begin first aid treatment immediately. When possible, get help. First, decontaminate the victim. Take him or her to fresh air. Remove any contaminated clothing. Be careful not to contaminate yourself in the process. If the victim needs medical attention, either call a doctor or take the victim directly to a doctor.

Before, during, and after the fumigation process, watch for unusual behavior of yourself and others. It could be a sign of exposure. If you feel sick, do not stay to finish the job. Get to fresh air immediately and get help. If you are with someone who has been exposed to a fumigant, and if his or her breathing stops or is labored, give artificial respiration. Never give anything by mouth to an unconscious person besides air.

Specific first aid treatment varies according to the type of exposure. Learn all of the appropriate procedures. You will not have time or the opportunity to look them up during an emergency.

The two main types of fumigant exposure are inhalation and skin contact.

## Inhalation Exposure

The greatest risk during fumigation is inhalation exposure. Inhalation exposure occurs when someone breathes fumigant gas. Mild exposure by inhalation can cause malaise (a feeling of sickness), ringing in the ears, fatigue, nausea, and pressure in the chest. Exposure to fresh air will usually relieve these symptoms. Moderate inhalation poisoning can cause weakness, vomiting, chest pain, diarrhea,

difficulty breathing, and pain just above the stomach. Symptoms of severe poisoning may occur within a few hours to several days after exposure. Severe poisoning may result in pulmonary edema (fluid in the lungs). This can lead to dizziness, cyanosis (blue or purple skin color), unconsciousness, and even death.

Do not attempt to rescue someone in an enclosed area if you do not have the proper respiratory equipment. If you are with someone who is suffering from inhalation exposure, carry him or her to fresh air immediately. Do not let the victim walk. Then do the following:

- Loosen all tight clothing.
- If breathing has stopped or is irregular, give artificial respiration.
- Keep the victim as quiet as possible.
- Prevent chilling by wrapping the victim in blankets. However, take care not to overheat the victim.
- If the victim is convulsing, protect his or her head from striking the floor or wall.
- Watch for breathing irregularities that may require CPR. Keep the victim's chin up so that the air passage remains free. Do not put anything in the mouth of an unconscious person.
- Do not give alcohol in any form to the victim.
- Get medical attention immediately. Take the victim to a doctor or emergency treatment facility. Take the fumigant's label information with you.

## Skin Exposure

Skin (dermal) exposure occurs when a pesticide contacts the skin. This type of contamination is most often associated with liquid and solid pesticides. However, some fumigant gases can also cause serious injury to the skin. This usually occurs if clothing or jewelry holds the gas tight against the skin.



This is the reason that gloves are often not recommended for fumigant application. Most labels suggest that you remove all jewelry and wear loose-fitting clothes. Always consult the label to determine what precautions you should take.



**Blisters caused by fumigant exposure**

If skin exposure does occur, take the following steps:

- Get to fresh air.
- Remove contaminated items (clothing, jewelry, gloves, shoes, bandages, etc.) immediately.
- Drench the skin with water.
- Wash the skin, hair, and fingernails thoroughly with soap and water.
- Rinse thoroughly and wash again.
- Dry and wrap the affected skin in a blanket.
- If exposure causes a burn, cover the area loosely with a clean, soft cloth. Avoid using ointments, powders, and other medications.
- Do not wear contaminated clothes again until you wash them and air them out for several days.

You can never entirely eliminate the risks associated with fumigation. However, if you take precautions, you can significantly reduce them. Take steps to protect the public, yourself, and your co-workers. Use the checklists from this manual. Read the label information. Learn about the specific risks of each product you use. Find out what PPE your product requires. Unit 7 will teach you how to select, use, and maintain respiratory and gas detection equipment.

# Test Your Knowledge

**Q. Name the three agencies that set regulations for the safe use of pesticides.**

A. The Environmental Protection Agency (EPA), the Arkansas State Plant Board (ASPB), and the Occupational Safety and Health Administration (OSHA)

**Q. List several things you can learn from reading the label information of a fumigant.**

A. The label information will tell you how and where to use the product. It will give you detailed application and aeration instructions. It may note specific sites that should not be treated or application methods that are not permitted. The label information also describes specific safety precautions including what PPE to wear and basic first aid procedures.

**Q. How long should warning signs remain posted?**

A. Do not remove warning signs until the treated equipment and surrounding area have completely aerated.

**Q. Name several precautions you must take when transporting a fumigant.**

A. 1. Do not transport fumigants and people together in a closed vehicle.  
2. Make sure fumigant containers are upright, secured, and protected against rear end collision.  
3. Mark vehicles in which fumigants are being transported.  
4. Do not use public transportation to transport fumigants.  
5. Do not transport fumigants through tunnels unless you get permission from ADOT.  
6. Do not remove valve protective covers until just before use.

**Q. What are the two main routes of fumigation exposure?**

A. Inhalation and skin contact

**Q. What PPE protects you from inhalation exposure to fumigants?**

A. A respirator

**Q. True or False: You should always wear gloves when working with fumigants.**

A. False. Gloves are not recommended with some fumigants. Others require gloves made of specific materials.

**Q. Explain the difference between a TLV and a TLV-TWA.**

A. A threshold limit value (TLV) is the maximum amount of fumigant that can be in the air before conditions are considered unsafe. It is used to monitor “short-term” exposure.

A threshold limit value-time weighted average (TLV-TWA) is the average concentration of fumigant for a normal 8-hour workday and a 40-hour workweek, to which workers may be repeatedly exposed, without adverse effect. It is used to monitor “long-term” exposure.

**Q. Describe some symptoms of mild inhalation exposure to a fumigant. What should you do if you or a co-worker is experiencing any of these symptoms?**

A. Mild exposure by inhalation can cause malaise (a feeling of sickness), ringing in the ears, fatigue, nausea, and pressure in the chest. Exposure to fresh air will usually relieve these symptoms.

**Q. Why do some fumigant labels recommend that you remove jewelry and wear loose-fitting clothes during application?**

A. Jewelry and tight clothing can trap fumigant gas next to the skin causing irritation or a burn.

# Unit 7: Safety Equipment

## Learning Objectives

After reading this unit, the reader will be able to:

- Choose the most appropriate equipment to perform safe and effective fumigations.
- Test, fit, maintain, and use a respirator properly.
- Recognize danger signals of respiratory equipment failure.
- Select and operate gas detection devices properly.

Fumigants are some of the most toxic pesticides available. Even moderate exposure can be lethal to you and others. Proper use of safety equipment is critical.

This unit describes some of the basic safety equipment used in food and stored commodity fumigation. By reading it, you will learn how these devices work and how to use them properly. When safety equipment fails, consequences can be deadly. This unit will help you recognize danger signals of equipment failure. You will also learn how to prevent these failures by properly selecting and maintaining equipment.

## Terms To Know

**Aerate** – To replace fumigant-containing air or water with fresh air and/or water that contains little or no fumigant. Aeration must follow all fumigation operations.

**Air-Purifying Respirator** – A device that uses special canisters to remove particles and toxic vapors from the air. The canisters fit on a facepiece and are specific for one type fumigant. Air-purifying respirators are also called gas mask/canister combinations.

**Ambient Air Analyzer** – A gas detection device that measures the amount of infrared light absorbed by a gas at a selected wavelength. This tells you what gas is present and its concentration.

**Antidote** – A remedy that may counteract the effects of a pesticide.

**Atmosphere** – The body of air that surrounds a given area. Breathable atmosphere consists largely of nitrogen and oxygen with small amounts of carbon dioxide and other gases.

**Atmosphere-Supplying Respirator** – A device that draws air from outside a fumigation area or uses canisters of pressurized air to supply a worker with breathable air.

**Calibrate** – To measure and adjust a gas detector so that it reads accurately for the fumigant you use.

**Exposure** – When a person or organism comes in contact with a pesticide by inhalation, ingestion, skin contact, or any other method.

**Facepiece** – The part of a respirator that fits over your nose, mouth, face, or entire head.

**Fumiscope®** – A type of thermal conductivity analyzer (TCA) that measures the concentration of specific fumigants. It is lightweight, portable, and operates on 115 volt AC (alternating current) or battery power.

**Material Safety Data Sheet (MSDS)** – A printed report that details information on the fumigant manufacturer, identity of hazardous ingredients, physical and chemical characteristics, fire and explosion hazard data, reactivity data, precautions for safe handling and use, and control measures.

**Neutralize** – To counteract the effect of a harmful substance such as a pesticide.

**Permissible Exposure Limit (PEL)** – An OSHA standard that designates the maximum exposure permitted as an 8-hour time-weighted average (TWA).

**Personal Protective Equipment (PPE)** – Clothing or devices used to protect the human body from exposure to pesticides and pesticide residues.

**PPM (Parts Per Million)** – The number of parts of a substance in one million parts of another substance. For example, if a gas detector reads “5 ppm,” it means that there are five parts of fumigant to every one million parts of air.

**Respirator** – A device that protects the respiratory tract from irritating and poisonous gases, fumes, smokes, and dusts. Respirators may or may not have equipment that supplies oxygen or clean air.

**Self-Contained Breathing Apparatus (SCBA)** – A type of respirator that supplies fresh air from an outside or portable source. Air enters a mask that tightly covers the entire face.

**Supplied-Air Respirator (SAR)** – A device that supplies air from a compressed air tank that is located outside of the fumigation area.

**Thermal Conductivity Analyzer (TCA)** – An instrument designed to measure the concentration of fumigant gases within a chamber or other enclosure during fumigation.

**Threshold Limit Value-Short Term Exposure Limit (TLV-STEL)** – The concentration of fumigant to which most workers can be exposed continuously for a short period without suffering from:

- Irritation
- Chronic or irreversible tissue damage, or
- Narcosis (drunkenness) that may increase the chance of accident or injury
- Exposures to concentrations at the STEL should not be longer than 15 minutes and should not occur more than four times per day. The STEL is expressed in parts per million (ppm) or milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ).

**Threshold Limit Value-Time Weighted Average (TLV-TWA)** – The average concentration of fumigant to which most workers may be repeatedly exposed 8 hours a day, 40 hours a week without adverse effect. The TLV-TWA is expressed in parts per million (ppm) or milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ).

**Volatility** – The ability of a substance to turn into a gas (vapor) at relatively low temperatures.

## Respiratory Equipment

A respirator is as important to a fumigator as a parachute is to a paratrooper. Both are critical to on-the-job safety. If either device is not

regularly inspected, maintained, and used correctly, results could be deadly. Remember that fumigants are some of the most toxic pesticides. Breathing even small amounts of some chemicals can be fatal.

Training is crucial for the safe and effective use of respirators. To use respirators during fumigation, you must establish a formal respiratory protection program. Your program must meet all of the requirements outlined in the Occupational Safety and Health Administration (OSHA) Respiratory Protection Standard (29 CFR 1910.134). These include written operating procedures for the maintenance, cleaning, and storage of the respiratory equipment. Your program must also contain guidelines for educating respirator users. The information in this manual is not a substitute for the OSHA requirement.

There are two main types of respirators used in fumigation: atmosphere-supplying respirators and air-purifying respirators.

*NOTE: All respirators used by fumigant applicators must be full-face gas masks approved by the NIOSH/MSHA (National Institute of Safety and Health/Mine Safety Health Administration).*

## Atmosphere-Supplying Respirators

Atmosphere-supplying respirators draw air from outside a fumigation area or use canisters of pressurized air to supply a worker with breathable air.

Fumigators use two main types of atmosphere-supplying respirators: self-contained breathing apparatus (SCBA) and supplied-air respirators (SAR).

## Self-Contained Breathing Apparatus (SCBA)

A self-contained breathing apparatus (SCBA) consists of a full-face mask attached to a tank of air carried on the back of the worker. The cylinder of compressed air supplies air to a

regulator. The regulator reduces the pressure and delivers breathable air to the facepiece.

Because you carry your air supply, you do not need to be connected to a stationary source of breathable air. This gives you the mobility of a canister mask (described later in this unit) and does not restrict movement. One person can carry enough air for up to 60 minutes. However, the weight and bulk of a SCBA often makes strenuous work difficult.

Do not confuse SCBA with SCUBA (self-contained underwater breathing apparatus). These systems are very different. You cannot interchange their uses.

There are two types of SCBA respirators: a demand regulator and a positive pressure regulator.

## Demand Regulator

A demand or negative pressure regulator supplies air to the facepiece when the wearer inhales. This creates a vacuum. Facepieces must fit snugly or contaminated air may leak in.

## Positive Pressure Regulator

A positive pressure regulator allows continuous airflow into the facepiece. A pump supplies air on demand when you inhale. The constant positive pressure in the facepiece forces any leaks out of the facepiece.

## Supplied-Air Respirators (SAR)

Like SCBAs, supplied-air respirators are equipped with a full-face mask that delivers air to the fumigator from a compressed air tank. With supplied-air respirators, however, the air tank is located outside the fumigation area.

The most common supplied-air respirator used by fumigators is the “airline respirator.” Airline respirators supply compressed air from a



**Self-contained breathing apparatus (SCBA)**

stationary source through a long hose. Airline respirators have demand, pressure-demand, or continuous-flow designs. Air is supplied to a facepiece, helmet, hood, or a complete suit depending on the level of protection needed.

The demand or pressure-demand airline respirator operates much like the demand SCBA respirator. The difference is that the airline system supplies air through a hose connected to a stationary air source. The fumigator carries the SCBA air supply.

Continuous-flow airline respirators provide breathing air continuously, rather than on demand. These are much like the positive pressure SCBA respirators. Instead of a regulator, however, these respirators have an airflow valve that partially controls the airflow. In addition, air is supplied by a stationary source, whereas SCBA air tanks are portable.

There are several advantages to airline respirators. Unlike SCBA respirators, airline respirators provide long, continuous use. They are lightweight and offer minimal breathing resistance and discomfort. Airline respirators also have a moderate initial cost and a low operating cost.

Unfortunately, there are drawbacks to airline respirators as well. For example, if something cuts, burns, kinks, or crushes the hose, the wearer has no air. Also, compressors may fail or the storage tank may become empty. For these situations, there are airline respirators with auxiliary air supplies. Airline respirators can also restrict movement. Because the wearer is attached to a long hose, there are limits to how far and in what direction he or she can move.



**Airline respirator**

## Air-Purifying Respirators

Air-purifying respirators or “gas mask/canister combinations” remove particles and toxic vapors from the air. When you breathe

in, you draw air from outside the respirator, through air-purifying canisters or cartridges, and into the mask. The cartridges or canisters absorb impurities as the air passes through. Like SCBAs and SARs, gas mask/canister combinations are full-face gas masks.



**Canister respirator**

Gas mask/canister combinations are approved only for specific fumigants. There are many different types of canisters. Each one is color coded with stripes. The stripes indicate limitations and approved uses for quick and easy recognition. For example, a gray stripe around the top of a canister indicates the presence of a filter that removes dust and other particles. Other color combinations identify canisters for specific fumigants. Before using any air-purifying respirator, make sure the same manufacturer that makes your mask also produces the canister. If not, the canister may not fit snugly and the mask may leak.

How long a canister will last depends on several things:

- The type of canister
- The size of the canister
- The type and concentration of gas in the surrounding air
- The length of exposure
- The rate of breathing
- Whether there is more than one gas present, and
- The temperature and humidity at the time of use

Never use a canister after the expiration date. An expiration date is usually listed somewhere on the canister. Several signs will alert you to an expiring canister. Feel the canister regularly. If it is hot to the touch, you may be in an area richer in fumigant gas than is recommended. An expired canister may feel cool to the touch. If you find it hard to breathe, detect an odor, taste something strange, or experience eye or nose irritation, your canister may be expiring or your mask may be leaking. Return to fresh air immediately. If you start to feel ill (ex., nauseous, dizzy, fatigued, etc.), get medical help right away.

## How It Works

When properly assembled and fitted, the gas mask/canister combination is a compact air-purifying unit. It protects against the gases or vapors listed on the canister label. During inhalation, air enters the canister. The canister then physically or chemically purifies the air, neutralizing or absorbing harmful gases and vapors. The purified air then passes through corrugated rubber tubing into the molded channels of the facepiece. Some of these channels direct the purified air to the lenses to reduce fogging.

When you exhale, air expels from the facepiece through a valve designed to permit normal conversation. This valve also serves as a drain for moisture produced by breathing. An inhalation valve at the bottom of the canister prevents the exhaled air from passing out through the canister.

Always read the label information to determine which type of respirator to use. Wearing the proper PPE will protect you and your co-workers. It is also the law.

## Care of Respiratory Equipment

All applicators should have their own respirator and canister. Do not share your canisters with others. In fact, it is best if you do not reuse canisters at all. If you must reuse a canister, keep a written record of the date used, length of time used, and gas concentration. Destroy or mutilate the tops of canisters that are no longer usable. Never reuse a canister if it has been used in an emergency.

Clean and disinfect your respiratory mask after each day's use and at least once a month. To sanitize masks, prepare a solution of cleaner-sanitizer (available through your respiratory protection supplier) and warm water. Immerse the mask in this solution. Scrub the interior and exterior of the mask with a sponge. Rinse the mask with warm water and air dry. If you are not able to sanitize the mask immediately, wipe out the interior with a clean cloth, preferably one saturated with isopropyl alcohol.

During cleaning, inspect the mask. Look for any loose connections and rubber deterioration.

Check the integrity of the facepiece seal. Keep a record of all cleanings and inspections.

After cleaning and inspection, place the mask in its carrying case to protect it against dust, sunlight, heat, extreme cold, moisture, or damaging chemicals.

If your respirator needs repairs, be sure to use parts designed for that particular respirator. Only experienced persons should repair a respirator.

## Fitting and Testing the Respirator

To obtain a firm and comfortable fit of your face mask, adjust the headbands in this order:

1. Make sure the straps lie flat against your head.
2. Tighten the lower or neck straps.
3. Tighten the side straps.
4. Place both hands on the headband pad and push it toward the neck.
5. Repeat steps one and two.
6. Tighten the forehead or front strap a few notches.

The mask should feel comfortable, while forming a tight seal against your face. Facial hair will prevent a tight seal. Workers with beards and/or large mustaches must shave. OSHA requires that respirators fit properly and that you test their facepiece-to-face seal. There are three methods currently acceptable for fit testing: the taste test, the odorous vapor test, and the irritant smoke test. All three tests require you to be exposed to the test agent before putting on the respirator. This ensures that you can detect the test agent.

**Taste Test** – First, put on the respirator and adjust it until the fit seems tight. Then, place an enclosure over your head and shoulders. Have someone spray a test agent, usually saccharin, inside the enclosure. If you note a sweet taste, the fit is poor and needs adjustment.

**Odorous Vapor Test** – With this test, banana oil is the test agent. Again, put on the respirator and adjust it until the fit seems tight. In a separate room, have someone release the test agent. If you cannot smell the chemical, the fit is fine.

**Irritant Smoke Test** – With the respirator on and fitted, have someone direct an irritant smoke such as stannic chloride towards the respirator. These chemicals produce a strong, involuntary reaction, usually coughing or sneezing. If you do not react, your respirator fit is good.

Once you find a respirator with a good fit, testing is not over. You will also need to check the respirator each time you wear it. Here are two quick field tests.

**Negative Pressure Test** – This test checks gas masks for a tight fit. First, pinch off the breathing tube or close off the inlet of the canister with the palm of your hand. Then, inhale to create “negative pressure.” The facepiece should collapse. Then hold your breath for 10 seconds. A respirator with a tight seal will remain collapsed while you hold your breath. If it is leaking, adjust the head straps and repeat the test.

**Positive Pressure Test** – This test is usually included in the manufacturer’s instructions. First, place the palm of your hand or thumb over the valve guard and press lightly. Then, exhale gently into the respirator causing “positive pressure” inside the facepiece. If you do not feel any air leaking out of the facepiece, the respirator fits properly. If it is leaking, adjust the straps and test again. If the leak persists, inspect the respirator for problems. Check the hoses and connections to make sure they are tight and in good condition. A new rubber washer for the mask hose is supplied with each new canister. This washer must be in place when attaching the hose to the canister. Otherwise, vapors can enter through the mask hose. Be sure to check for this washer. If the leak still exists, try installing a new corrugated breathing tube. If this takes care of the leak, destroy the defective breathing tube. If, after removing your hand from the canister inlet, you find you cannot breathe, the canister has a blockage. Destroy and replace the canister. If the respirator is an air-supply type, check the facepiece and breathing tube. If the respirator is a SCBA, check the air tank for amount of air, leaks, and valve efficiency. For SARs, test the valves, connections, and hoses.

# Use of Respiratory Equipment

Your respirator should be ready for use at all times. When it is not in use, have it on hand for emergencies. Keep the following list nearby. It will help you to inspect and use your mask properly.

- First, monitor the air quality. If the air contains less than 19.5 percent oxygen, it is deficient. Use an air-supplying respirator and not a gas mask/canister combination. When in doubt, always use an air-supplying respirator.
- If you use a gas mask/canister combination, check the canister for an expiration date. If canisters are used more than once, be sure enough time remains. When in doubt, use a new canister.
- Select the proper canister for the fumigant you plan to use. The canister label will indicate for which fumigants it is approved. Also, make sure the same manufacturer that makes your mask produces the canister. If not, the canister may be loose and the mask may leak.
- If you use a new canister, install the new washer that comes with it.
- Remove the tape that covers the intake port on the bottom of the canister.
- Connect the mask and canister.
- Put the mask on while you are in fresh air.
- Check for proper fit and leaks.
- Check the time. Note when you should be out of the fumigated area.
- Enter the contaminated area slowly. Return to fresh air immediately if you notice irritating gases, odors, or symptoms of distress.

After completing the job:

- Clean and inspect the respirator.
- Record the date of cleaning. If you plan to reuse the canister, record how long you used it. Also, indicate the fumigant and its concentration.
- If you used all of the canister's time, mutilate the top so that it cannot be reused. Discard the canister.
- Return the respirator to its carrying case. Place both items in a proper storage area.

# Gas Detection Equipment

Gas detectors monitor and record gas concentrations before, during, and after treatment. They are a part of every fumigator's operational and safety equipment. You can use detectors to eliminate some of the common hazards associated with fumigation. Use them to:

- Indicate fumigant levels during treatment
- Detect excessive leaks in a building or poor tarp seals, and
- Determine the dosage requirements for future fumigation

Detectors also measure the success of aeration by monitoring the presence or absence of fumigant vapors.

Be sure the accuracy and range of your detector is suitable for the fumigant you plan to use. Some detectors are more sensitive than others are. Calibrate your detector for each fumigant you use. Be sure you know how to read it.

There are several gas detectors from which to choose. The following are some of the most common used in fumigation.

## Halide Gas Detectors

The halide gas detector indicates the presence and approximate concentration of halide gases. It is most commonly used to measure levels of methyl bromide. It reliably measures gas concentrations of 50 parts per million (ppm) or greater.

Halide detectors consist of:

- A fuel tank
- A valve assembly (to regulate fuel flow)
- A burner head assembly (where the fuel and air mix and unite), and
- The reaction place or cone assembly (where the visible flame reacts to halogen gases)

An attached search hose feeds the air mixture to the burner head assembly for testing. The fuels used include kerosene, alcohol, acetylene, and propane. These are available at refrigeration supply dealers.



To operate a halide detector, hold a lit match in the window opening of the burner tube. Turn the valve slowly to the left. After the copper plate or cone turns red, adjust the flame to the smallest size to maintain that color. The detector is now ready to test the air. Hold the open end of the search hose on, in, or near the article or area to be tested. As air passes over the heated plate or cone, the flame color will change if a halogen gas is present. The color and intensity of the flame indicates the concentration of the gas. A color chart with corresponding gas concentrations comes with each detector.

*NOTE: If you use a halide detector at night, the flame will have a bluish cast. You must consider this when reading the results.*

Unfortunately, no halide detectors are accurate for determining exactly how much gas is present. They will only give you an estimate.

Because halide detectors have an open flame, you must adhere to all safety precautions. Even when the detector is not in operation, do not store it in a frequently inhabited room. The fuel is a flammable gas under pressure and may explode. Do not use halide detectors in the presence of flammable or explosive gases such as gasoline vapors. Do not use halide detectors in mills, elevators, or other enclosures where there is a possibility of a dust explosion. Always read the label to determine the flammability of the product you are using.

Halide detectors need little maintenance. The burner head orifice is very small. Prevent dust and other debris from clogging it. Occasionally, you will need to replace the reaction plate or cone.

The halide gas detector has been used for many years. It is an operational as well as a safety device. By detecting leaks, it can help you to reduce harmful gas levels outside the treatment area. This will increase the safety and efficacy of your operation. As a precaution, use a halide detector regularly in rooms that house fumigation chambers. This is particularly important when the building also contains offices or other work areas.

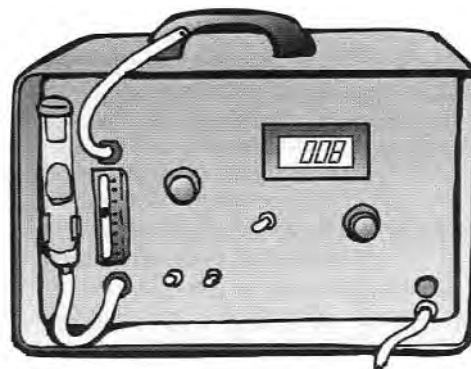
*NOTE: Do NOT use a halide detector to determine whether fumigant levels are safe for reentry. While the halide detector is useful for detecting low levels of halogenated fumigants, it should NOT be used to detect harmful*

*concentrations of these fumigants. The reentry threshold concentrations for a number of fumigants are lower than the detection limit of the halide detector.*

## Thermal Conductivity Analyzers

Thermal conductivity analyzers (TCAs) measure the concentration of fumigant gases within a chamber or other enclosure during fumigation. Several types of TCAs are available.

The Fumiscope® is one of the most common TCAs. It is primarily used to measure methyl bromide concentrations. The Fumiscope® is lightweight, portable, and comes in a compact cabinet. It operates on 115 volt AC (alternating current) or battery power. In a Fumiscope®, electrical currents pass through a wire exposed to the sampled air. The temperature of the wire is affected by the composition of the air around it. The hotter the wire, the higher the fumigant concentration. The fumigant concentration is displayed on the Fumiscope® meter.



Fumiscope®

When using TCAs, keep in mind that most of them are sensitive to several gases, not just the one for which you are testing. For a true reading, you must eliminate other gases. For example, carbon dioxide (CO<sub>2</sub>) may occasionally be a problem. If a prefumigation test indicates high levels of CO<sub>2</sub>, place a tube of sorbing material such as sodium hydrate in the sampling line. It will absorb CO<sub>2</sub>, allowing the TCA to give you a more accurate reading.

When you run long sample lines into the fumigated area, use a small pump to draw air from the test point to the end of the line. This speeds up the readings.

*NOTE: Like the halide detector, TCAs should NOT be used to determine whether fumigant levels are safe for reentry. They cannot measure gas concentrations below 5 ppm.*

## Glass Detector Tubes

Glass detector tubes or “color diffusion detector tubes” are another gas detection option. Unlike other detectors, glass tubes are disposable. You can only use them once. Glass detector tubes are often more sensitive and more specific than halide detectors and TCAs. They can detect specific fumigants at lower levels than other gas detectors.



Glass detector tubes are “fumigant specific.” That means you will need to purchase a different set of tubes for each type of fumigant you use. Their operation is simple. Place one tube in the area you wish to test. Break the seal. A sample pump will draw a measured amount of air through the tube. A color reaction will occur indicating the fumigant concentration.

A color chart with corresponding concentrations is printed directly on the tube.

Detector tubes are available for many fumigant gases. Both high-range and low-range tubes are available for some fumigants. Use the high-range tubes to determine gas concentrations during fumigation. Use the low-range tubes to assure safe working conditions after aeration and before reentry.

## Ambient Air Analyzers

Some ambient air analyzers or “infrared detection systems” use infrared spectrophotometers to detect and measure gas

concentrations. This is how they work. When infrared radiation strikes a gas, certain wavelengths of the radiation are absorbed. The spectrophotometer measures this absorption. The amount of radiation absorbed determines the gas concentration. Most ambient air analyzers can be calibrated at the factory to detect a single gas. Others are equipped with a fixed infrared filter.

Portable units weigh about 18 pounds. They are equipped with both AC (alternating current) and battery power. Each unit has two scales. The lower scale is accurate from 0 to 15 ppm. Use it to check fumigation sites before reentry. The upper scale functions as a leak detector during fumigation. It detects concentrations from 0 to 150 ppm.

## Gas Analyzers

Gas analyzers detect leaks during fumigation. They also determine if a site is ready for reentry. Several models are available. The most popular are lightweight and battery powered. Most are designed to monitor concentrations of a particular gas. One model uses a pump to draw an air sample through a tiny furnace. Any fumigant present passes through a sensor that detects how much gas is present. Readings are given in parts per million (ppm).

## Other Protective Equipment

Whenever possible, provide two-way radio communication between workers applying fumigants and those outside. Also, keep on hand:

- An emergency air-supplying respirator, especially if canister-type respirators are being used
- Antidotes where applicable
- A safety harness or rescue belt, and
- Basic first aid equipment

# Test Your Knowledge

**Q. Name the two types of respirators most often used by fumigators. Describe the difference between them.**

- A. Atmosphere-supplying respirators draw air from outside a fumigation area or use canisters of pressurized air to supply a worker with breathable air.

Air-purifying respirators (gas mask/canister combinations) use special canisters to remove particles and toxic vapors from the fumigated air.

**Q. Name two types of atmosphere-supplying respirators. Explain the advantages and disadvantages of each one.**

- A. A self-contained breathing apparatus (SCBA) gives the operator greater mobility but offers a limited amount of air. One tank of air usually lasts about one hour. The weight and bulk of a SCBA apparatus can also make strenuous work difficult.

A supplied-air respirator (SAR), such as an airline respirator, has the advantages of longer continuous use and a lighter weight. However, because you are connected to a stationary source, movement may be restricted. In addition, if something cuts, burns, kinks, or crushes the hose, the wearer has no air.

**Q. What does the stripe around the top of an air-purifying canister indicate?**

- A. The type of material the filter in the canister will remove from the air.

**Q. What can the temperature of an air-purifying canister tell you?**

- A. If the canister is hot to the touch, you may be in an atmosphere richer in fumigant gas than is recommended. If the canister feels cool, it may be completely expired (no longer able to purify the air).

**Q. If an air-purifying canister has expired, what should you do to it before you throw it away?**

- A. Destroy or mutilate the top so that it is no longer usable.

**Q. Describe the procedure for fitting a respirator mask.**

- A. 1. Make sure straps lie flat.  
2. Tighten neck straps.  
3. Tighten side straps.  
4. Push headband pad downward.  
5. Repeat steps one and two.  
6. Tighten front strap a few notches.

**Q. Describe two “quick” ways you can make sure a respirator facepiece fits properly.**

- A. 1. Pinch off the breathing tube and inhale so the facepiece collapses. Hold your breath for 10 seconds. The facepiece should stay collapsed for this time. If it does not, the mask does not fit properly and fumigant may leak in.  
2. Press your thumb over the valve guard and exhale. Do you feel any air leaking out? If so, the mask does not fit properly and fumigant may leak in.

**Q. Describe the three methods currently accepted by OSHA to fit test a respirator.**

- A. 1. The taste test: With the facepiece on, a test agent with a strong flavor is sprayed around the wearer. If the wearer detects the taste, the mask does not fit properly.  
2. The odor test: With the facepiece on, a test agent with a strong smell is sprayed around the wearer. If the wearer detects the smell, the mask does not fit properly.  
3. The irritant smoke test: With the facepiece on, an irritant smoke is released around the wearer. If the wearer suffers from involuntary reactions such as coughing and sneezing, the mask does not fit properly.

**Q. What information do gas detectors provide?**

- A. Gas detectors indicate fumigant levels during treatment and aeration. They can detect leaks in structures or under tarps during fumigation. They can help determine the dosage requirements for future fumigation.

Detectors also measure the success of aeration by monitoring the presence or absence of fumigant vapors.

**Q. What type of gas is dangerous to measure with a halide detector? Why?**

- A. A flammable gas, because halide detectors operate with an open flame. Always read the label information to determine the flammability of the product(s) you use.

**Q. What is the most common type of thermal conductivity analyzer (TCA)?**

- A. The Fumiscope®

**Q. When using a TCA, how can you avoid a false reading due to the presence of gases other than the one you are measuring?**

- A. Place some type of sorbing material into the sampling line.

**Q. What type of gas detector is disposable?**

- A. Glass detector tubes

# Unit 8: Common Fumigants

## Learning Objectives

For each fumigant discussed in this unit, the reader will be able to:

- Describe basic application and aeration techniques.
- Understand its mode of action.
- Use it safely and effectively.
- Know which detection equipment best measures its concentration.
- Dispose of its residues and empty containers in a safe and legal manner.

This unit discusses some of the most common fumigants used to fumigate food and stored commodities. By reading it, you will understand how each of these fumigants works and how to use them effectively. This unit will explain basic application and aeration procedures. You will learn the risks of each chemical. You will discover how to protect yourself and others from exposure. Selection and use of detection equipment are discussed. This unit will also outline how to properly dispose of leftover fumigant and associated residues.

## Terms to Know

**Bonnet** – The cap that covers the valve and safety cap on a fumigant cylinder. The bonnet protects the valving system from damage and prevents accidental release of the fumigant.

**Corrosive** – Able to weaken or destroy something gradually.

**Deactivate** – To make something ineffective. For example, by deactivating fumigant residue, you would be neutralizing its toxic effects.

**Formulation** – The form in which a pesticide is offered for sale to the user (tablets, pellets,

Prepacs, etc.). A formulation contains both the active ingredient and inert materials.

**Inert Gas** – A gas that does not have toxic effects.

**Prepac** – Metal phosphide fumigant tablets that are packed in a gas-permeable material.

**Residue** – Traces of fumigant that remain after treatment.

**Threshold Limit Value-Time Weighted Average (TLV-TWA)** – The average concentration of fumigant for a normal 8-hour workday and a 40-hour workweek to which workers may be repeatedly exposed without adverse effect. The TLV-TWA is expressed in parts per million (ppm). It is used to monitor long-term exposure.

There are a limited number of fumigants on the market. Each has its own advantages, disadvantages, uses, and limitations. This unit does not intend to indicate a preference toward any one fumigant. You must make your own choice based on the pest, the commodity, or structure that is infested, and the label information.

## Disclaimer

Just because a fumigant appears in this manual does not mean that it is legal to apply. Laws and regulations governing pesticides change often. Fumigants described here may no longer be legal. Always check current laws and regulations before using any fumigant for any purpose. For example, at the time of this writing, methyl bromide has been labeled an ozone-depleter. As a result, this widely used fumigant may soon be banned. Keep up-to-date on the state and federal laws and regulations that apply to you.

# Methyl Bromide

Methyl bromide is a colorless gas. At normal concentrations, it is odorless, tasteless, and has no irritating qualities to indicate its presence. However, at concentrations higher than those normally used in fumigation, methyl bromide

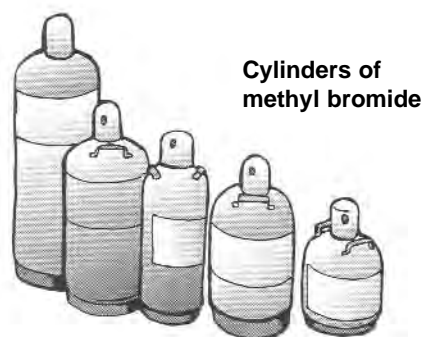
gives off a sickly sweet odor. Methyl bromide is toxic to all stages of insect life. The gas is 3.3 times heavier than air and tends to stratify, settling out in low places. Fans are needed to ensure thorough mixing of the gas with air. With fans, methyl bromide penetrates most commodities very well.

## EPA Alert

At the time of this printing, methyl bromide is believed to contribute to the depletion of the earth's ozone layer. For this reason, the EPA has initiated action under the Clean Air Act to phase out the production and use of this fumigant. A 70-percent reduction in production was mandated by January 1, 2003. The complete phaseout of production was scheduled for January 1, 2005. The Environmental Protection Agency (EPA) is amending the regulations governing the phaseout of methyl bromide (MeBr) to allow for exempted production and import beyond the phaseout date of January 1, 2005, for critical uses and to address sales of pre-January 1, 2005 stocks of methyl bromide for critical uses. This rule makes approximately 8,942 metric tons of methyl bromide available for critical uses in 2005, which is 35 percent of the U.S. methyl bromide 1991 consumption baseline. The 1991 consumption baseline was established in the 1993 rulemaking, to cap and phase out methyl bromide production and import. An additional 2.5 percent of baseline was recently authorized for 2005 critical uses by the Parties to the Montreal Protocol at their meeting on November 26, 2004. EPA is beginning the notice-and-comment rulemaking process on the supplemental amounts to make them available for critical uses as quickly as possible. It is your responsibility to keep up-to-date on any changes that affect the legal use of products you intend to use.

## Formulations

Methyl bromide is available as a compressed liquid in 1 1/2-pound cans or in cylinders containing up to 200 lbs. It is also formulated with chloropicrin. **Do not use chloropicrin on food or stored commodities.**



Cylinders of methyl bromide

## Uses

Use methyl bromide to control pests in processed food or feed. There are established tolerances for methyl bromide residues on many commodities. Pure methyl bromide is not labeled for use in empty structures. It is strictly for the treatment of raw or processed commodities and some nonfood products. When mixed with chloropicrin, do not use methyl bromide on processed foods; in dairy, cheese, or meat plants; or where there are living plants. You can use the methyl bromide/chloropicrin combination to treat empty grain bins and warehouses.

There are several materials that should not be exposed to methyl bromide. Some react with the gas and create long-lasting odor problems. Others may be damaged by the gas. Do not use methyl bromide to treat the following items:

- Iodized salt
- Full fat soya flour

- Items that may contain reactive sulfur compounds such as some soap powders, some baking sodas, and some salt blocks used for cattle licks
- Sponge rubber
- Foam rubber as in rug padding, cushions, and mattresses
- Reclaimed rubber such as rubber stamps
- Furs
- Horsehair
- Pillows (especially feather pillows)
- Leather goods (particularly white kid or any other leather goods tanned with sulfur processes)
- Woolens
- Viscose rayons (rayons produced or manufactured by a process that uses carbon bisulfide)
- Paper (especially silver polishing paper and writing paper cured by the sulfide process)
- Photographic materials used in dark rooms, and
- Cinder blocks

It is also important to remove all charcoal products before fumigating with methyl bromide. Charcoal can absorb methyl bromide reducing its effectiveness.

## Application

Small cans of methyl bromide are ideal for small jobs. A special apparatus is required. The apparatus punctures the can, and polyethylene tubing transfers the gas from the can into the fumigation enclosure. It is usually not necessary to heat the fumigant.

For larger jobs, use cylinders. First, attach 1/4-inch copper tubing to the cylinder using a gastight fitting. Then, form the tubing into a 25-foot coil and immerse it in water heated to 150°F. The tubing from the heater to the fumigation chamber should be either copper or polyethylene. Use as few fittings as possible. It is difficult to keep fittings from leaking. Because methyl bromide is heavier than air, be certain that you place the outlet of the introduction tube high within the fumigation enclosure.

When methyl bromide changes from liquid to gas, it becomes very cold. Even when heated, there is a chance that the low temperature created will change a part of the gas back to a liquid. To protect the commodity from any dripping methyl bromide, place a pan beneath the outlet end of the tubing.

Methyl bromide works quickly. Exposure times of 24 hours or less are normal. If the cylinders are outdoors, it is not necessary to wear a respirator during the introduction of the fumigant. However, you must have a SCBA ready and available.

Methyl bromide liquid vaporizes into gas at temperatures above 39°F. For this reason, do not use methyl bromide when the temperature in the fumigation area is below 40°F.

## Precautions

If the concentration of methyl bromide is unknown or exceeds 5 ppm, each person in the exposed area must wear a SCBA. You may supplement the SCBA with a hose that provides air from an outside source as a backup. Regardless of the fumigant concentration, appropriate respiratory protection must be available at the fumigation site in case it is needed.

Do not wear jewelry, gloves, goggles, tight clothing, a chemical protective suit, or rubber boots when using methyl bromide. The gas can become trapped inside clothing and cause skin damage.

Methyl bromide is not a fire hazard at normal application rates. In fact, it used to be an ingredient in fire extinguishers. Still, you must extinguish all open flames and pilot lights before using methyl bromide. It produces corrosive acid when it reacts with moisture near a heat source. In addition, while methyl bromide does not corrode most metals, it can react with aluminum or magnesium in the absence of oxygen to form an explosive mixture. Therefore, aluminum or magnesium tubing should never be connected to

a methyl bromide cylinder. Be sure neither metal is present during vacuum fumigation with methyl bromide.

## Aeration

During fumigation with methyl bromide, commodities absorb inorganic bromide residues. Aeration does not remove these compounds. After repeated treatments (as may occur with flour), these residues may exceed legal tolerances. The Food and Drug Administration (FDA) may seize the product. If this occurs, the last fumigator may be held responsible. Always check residue levels before fumigating any product. Be sure your treatment will not increase residue levels past legal limits.

## Detection

You can measure methyl bromide concentrations with halide gas detectors, color diffusion detector tubes, and thermal conductivity analyzers (TCAs) such as the Fumiscope®. Always consider the sensitivity of the detection device when making your selection. For example, the halide gas detector and Fumiscope® only provide an indication of methyl bromide presence. They do not indicate concentration. Use these devices to detect leaks. Halide detectors and TCAs do not read low enough to detect gas levels for reentry purposes. To check fumigant levels before reentry, use color diffusion detector tubes.

## Disposal

Dispose of methyl bromide containers according to label directions. Return cylinders, empty or partially used, to the manufacturer. Cans are not usually returnable. Instead, keep empty cans in a well-ventilated, secure location for 12 hours before disposal. If local authorities allow, you may be able to recycle the cans. Otherwise, dispose of them according to local regulations.

## Phosphine

**Aluminum phosphide and magnesium phosphide at a glance: (also called hydrogen phosphide and PH<sub>3</sub>)**

### Required clothing:

- Dry cotton gloves if you contact the pellets, tablets, or dust.

### Respiratory protection:

- Respiratory protection is required if exposure is likely to exceed the 8-hour TWA of 0.3 ppm during application, or is above 0.3 ppm at any time after application is complete.
- Concentrations less than 0.3 ppm: no respiratory protection required.
- Concentrations 0.3 to 15 ppm: NIOSH-approved full-face gas mask and hydrogen phosphide canister.
- Concentrations 15.1 to 1,500 ppm: NIOSH-approved full-face gas mask and hydrogen phosphide canister for escape only.
- Concentrations greater than 15 ppm or when concentrations are unknown: NIOSH-approved SCBA or supplied-air respirator.

### Uses:

- What: Raw agricultural commodities such as grains, nuts, seeds, cotton, wool, and tobacco. Animal feeds and feed ingredients, processed foods, and nonfood items.
- Where: Boxcars, containers, ships, and other transport vehicles, bins, silos, barges, under tarpaulins, in small sealable structures and enclosures, mills, food processing plants, and warehouses.



There are two main types of phosphine fumigants: aluminum phosphide and magnesium phosphide. These “metal phosphides” are formulated as solids that react with moisture in the air to produce “hydrogen phosphide” (phosphine gas). Phosphine also comes as a bottled product (phosphine dissolved in liquid carbon dioxide).

Phosphine gas is colorless and highly toxic to all stages of insect and animal life. It has a distinct garlic or carbide odor that is readily detectable at levels below worker protection limits (0.3 ppm). The odor is due to an impurity rather than the phosphine gas itself. However, odor is not a reliable indicator of the presence or absence of phosphine. This is especially true when phosphine has been in contact with a commodity for a considerable length of time.

## Formulations

Both aluminum phosphide and magnesium phosphide fumigants are available in a number of formulations. These include pellets, tablets, Prepacs, bags, and plates. Since metal phosphide fumigants react readily with moisture, they must be packaged in gastight containers. Phosphine can also be applied from cylinders containing phosphine in liquid carbon dioxide.

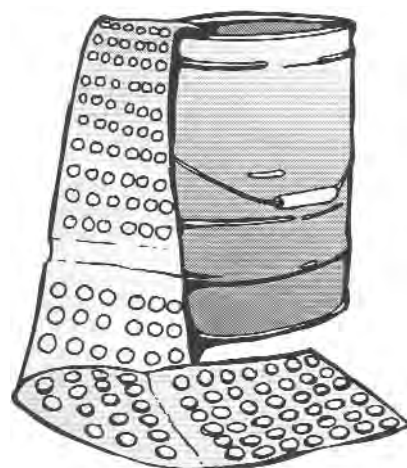
Most aluminum phosphide formulations yield about 1/3 of their weight in phosphine. Aluminum phosphide is available in 0.6 gram pellets and 1.0 gram tablets.

Magnesium phosphide comes as Prepacs for spot fumigation, and in polyethylene plates and strips for space and commodity treatments.

**Pellets:** Pellets weigh 0.6 grams. They yield 1/3 (0.2 grams) of their weight in phosphine. They are available in resealable flasks.

**Tablets:** Each tablet weighs 3 grams and releases 1 gram of phosphine. Tablets are available in resealable flasks. Tablets are also used in Prepacs and Prepac Ropes.

**Packaged Fumigants:** Packaged fumigants are available in several forms. These include bags, Prepacs, and plates. In all cases, the metal phosphide is encased in a gas-permeable material, which is then overpacked in gastight



Aluminum phosphide Prepac rope

containers. Bags containing powdered aluminum phosphide formulation are available. Each bag will release 11 grams of phosphine. Many of these packaged fumigants are not resealable. Once opened, you must use the entire contents.

## Uses

You can use metal phosphides to treat spaces and commodities and to control certain burrowing pests. Commodities treated with phosphine include processed foods, nonfood items, animal feed, and feed ingredients.

Aluminum phosphide is the main form used to treat agricultural commodities. Magnesium phosphide is more reactive than aluminum phosphide. It is preferred when rapid release is desired and when treatment is performed at lower temperatures and humidities.

## Application

One advantage of aluminum and magnesium phosphide products is that they are easy to use. Start by calculating the cubic volume of space you intend to treat. (See Appendix B for information on calculating volume.) Then, count out the required number of pellets, tablets, plates, Prepacs, or bags. Always wear gloves when handling phosphide tablets or pellets. Packaged metal phosphides such as bags and Prepacs do not require gloves. Place the pellets, tablets, or bags onto a tray or sheet of cardboard. Slip the tray under the fumigation tarp or inside the fumigation chamber or structure. The moisture in the air will liberate phosphine in about one day, depending on the

temperature and humidity. When treatment is complete, usually in two or more days, aerate the commodity or area. Aeration is rapid.

Fumigation with phosphine takes time. Buildup of the fumigant is slow. It may take 12 to 48 hours to reach the desired concentration of gas. If the atmosphere or commodity is very dry, the process may take even longer. In areas where the relative humidity is low, you can increase the speed of gas liberation by placing a pan of water under the fumigation tarp. You can also spray water onto the floor or dirt. Be very careful. Do not allow any water to contact the phosphine. An explosive mixture may result. Normal exposure periods can take three to five days. If gas concentrations are lower than required after 72 hours, extend the fumigation period.

Magnesium phosphide releases phosphine faster than does aluminum phosphide. Therefore, you are more likely to need respiratory protection when applying magnesium phosphide.

Phosphine is not effective at temperatures below 40°F. Be sure to keep aluminum phosphide and magnesium phosphide products dry during storage. Since magnesium phosphide is more reactive than aluminum phosphide, it is usually recommended for fumigation in cool and/or dry conditions.

Pure phosphine is about 17 percent heavier than air. However, since it is given off slowly, it does not tend to stratify. Fans are not needed to ensure even distribution except when treating bulk commodities. Because of its low sorption and good penetration capacity, phosphine tends to leak from bins that are not gastight. Phosphine will go where the airflow goes.

## Precautions

Phosphine does not accumulate within body tissues as do other fumigants. Any phosphine gas entering the body will be completely eliminated within 48 hours. Even so, phosphine is very toxic to humans. The threshold limit value-time weighted average (TLV-TWA) is only 0.3 ppm. This means the gas is about 60 times as toxic as methyl bromide. However, because of the way phosphine is liberated and because of its distinct odor, it is far safer to handle than other fumigants.

Applicators and other workers must wear approved respiratory protection if the concentration of phosphine in the work area is likely to exceed an 8-hour time-weighted average (TWA) of 0.3 ppm. A gas mask/canister combination may be used at concentrations up to 15 ppm. Above this level, or when the concentration is unknown, a SCBA must be worn.

After the application, workers must wear respirators whenever the concentration of phosphine is unknown or exceeds 0.3 ppm. The TWA applies only during application. "Application" is the period covering the opening of the first container, applying the appropriate dosage of the fumigant, and closing the site to be fumigated. At all other times, anyone exposed to fumigant concentrations exceeding 0.3 ppm must wear respiratory protection.

Always wear gloves when handling aluminum phosphide pellets, tablets, and the residue that remains after fumigation. Aerate used gloves and other contaminated clothing in a well-ventilated area before washing them. Wash your hands thoroughly after handling phosphide materials.

Phosphine is extremely flammable. Never open metal phosphide containers near an open flame or in a flammable atmosphere. Fire or an explosion can occur if the phosphine concentration is too high. It is better to open containers outdoors or near a fan. Phosphine may also ignite spontaneously at concentrations above 18,000 ppm. If you conduct the fumigation properly, however, concentrations will not approach this level. Phosphine is also explosive under vacuum conditions. Never use it for vacuum fumigation. Finally, do not stack or pile phosphine pellets or tablets as this can create a fire hazard.

To reduce the risk of flammability, some phosphine products contain ammonium carbamate in their formulation. This helps to produce a gaseous mixture that will not burn or explode at normal application rates.

Both aluminum phosphide and magnesium phosphide can react violently if they contact water.

Never allow aluminum or magnesium phosphide or their residues to directly contact

any processed food. To prevent the residue from contacting a commodity, place the aluminum phosphide pellets or tablets on a tray instead of adding them directly to the commodity. Aerate foods and feeds that have been treated with phosphine for 48 hours before giving them to the consumer. Dispose of any residue according to the label instructions. (See “Disposal” later in this section.)

Phosphine gas, especially at high temperatures and humidities, will corrode silver, copper, and copper alloys. Copper-containing equipment, such as computers, telephones, and other electrical devices, may be severely damaged. Protect or remove items that contain these metals during treatment. Exercise care.

## Aeration

Areas treated with phosphine aerate rapidly. To be safe, open all doors and windows first to assure good ventilation. Then, while wearing respiratory protection, open the fumigated space or remove seals from the edges of a tarp. Some aerations will be complete in one to two hours. Others will require much longer aeration periods. Take gas readings to be sure concentrations are below 0.3 ppm.

## Detection

Several reliable gas detectors are available to measure phosphine gas. Glass detector tubes are the most common. Two types of glass tubes are available. The first measures low levels of gas (0.1 to 40 ppm). Use this type of detector to determine worker exposure levels and to locate leaks. The second type of detector measures high levels of gas (50 to 2,000 ppm). Use it to determine if phosphine levels during treatment are high enough to kill the target pest.

## Disposal

Metal phosphide fumigants leave a white powdery residue. This residue contains a small amount of unreacted phosphide that may or may not need to be deactivated. The deactivation process differs somewhat for aluminum phosphide and magnesium phosphide.

*NOTE: If the fumigant residue is grayish green, the metal phosphide is only partially spent. Extend the fumigation period until the residue turns white, or use extreme care during the deactivation process.*

Always deactivate metal phosphide fumigants outdoors. Respiratory protection may be required.

To deactivate residue from aluminum phosphide pellets or tablets, prepare a deactivating solution. Fill a small to large container with water. Fifty-five gallon drums work well for large amounts of aluminum phosphide. Add enough nonsudsing detergent to create a 2-percent solution. Fill the container to within a few inches of the top with the deactivating solution. Then, stir in the aluminum phosphide. Do not add more than about 45 to 50 pounds of aluminum phosphide to 15 gallons of water-detergent mixture.

To deactivate magnesium phosphide pellets or tablets, no detergent is needed. Instead, fill a container to within a few inches of the top with water ONLY. Add the phosphide residues until they are saturated and sink to the bottom. Because unreacted or partially reacted magnesium phosphide reacts vigorously with water, be sure to add the residues slowly.

To deactivate residue from bag formulations, first cut or tear open the bag(s). Then stir the contents into a bucket containing a mixture of water and nonsudsing detergent (2 percent by volume). This deactivation procedure must take place outdoors. Wear the appropriate respiratory equipment. Never place residue in enclosed containers. It could cause a fire hazard. After deactivating the residues, dispose of the rinsate in a storm sewer, sanitary landfill, or by other approved methods. The solid may be buried or spread out on the ground. These actions will not harm the environment. However, check with local authorities for disposal regulations.

# Sulfuryl Fluoride

## Sulfuryl fluoride at a glance:

### Required clothing:

- Use splash-resistant goggles or full-face shields when handling the liquid, such as opening the cylinder to introduce gas into a structure. Liquid sulfuryl fluoride can freeze the eye tissue.
- Wear a loose-fitting or well-ventilated long-sleeve shirt, long pants, shoes, and socks.
- Do not wear gloves.
- Do not wear rubber boots.

### Respiratory protection:

- For ProFume use in commodities, concentrations of 1 ppm or less require no respiratory protection. Concentrations above 1 ppm require NIOSH/MSHA approved SCBA or combination air-supplied respirator/SCBA, such as those manufactured by Ranger, Survivair, Scott, or MSA.
- If (emergency) reentry into a structure under fumigation, prior to complete aeration, with sulfuryl fluoride is required, the proper respiratory protection (SCBA) must be used.

- What – For control of insects pests for the commodities listed on label, such as confused flour beetle, red flour beetle, sawtoothed grain beetle, warehouse beetle, Indianmeal moth, Mediterranean flour moth, codling moth, navel orangeworm, granary weevil, rice weevil, and other moths and beetles as well as rodents. Area around fumigation must be monitored using a detection device such as INTERSCAN gas analyzer or MIRAN vapor analyzer to ensure that workers without respiratory protection are not exposed to concentrations of sulfuryl fluoride exceeding **1 ppm**.
- Where – Non-residential structures (for the food commodities listed on the label) such as mills, warehouses, stationary transportation vehicles (railcars, trucks, etc., excluding aircraft and passenger railcars), temporary and permanent fumigation chambers, and storage structures. For use in food processing establishments containing only those commodities listed on the label. Not for use in other food-handling establishments.

Sulfuryl fluoride (ProFume®) is a colorless, odorless, and tasteless toxic gas. It is heavier than air and tends to initially settle in low areas. It is nonflammable; however, heaters, pilot lights, and open flames must be extinguished as temperatures above 752°F will cause decomposition products to be formed which can be corrosive and can etch glass and metal. Refer to ProFume fumigation manuals and labels before usage and for any changes in use that may have occurred from the registration process. Sulfuryl fluoride is toxic to most living organisms including humans. In case of over exposure, get medical attention immediately.

## Formulations

Sulfuryl fluoride comes in pressurized cylinders (containers). ProFume is a restricted use product. Cylinders are under pressure, 303 psi at 90°F, and must not be stored near heat or open flame. Exposure to temperatures above 158°F will cause a fusible plug to melt, and the contents will be released. Always store and transport cylinders in a secure upright position. Cylinders of sulfuryl fluoride should be stored in a dry, cool, well-ventilated, secure and locked area. Post as pesticide storage area.

## Uses

This fumigant is very effective against insect larvae and adults but requires higher doses for insect eggs. Do not use for insect control when temperature at the site is below 40°F.

## ProFume Uses

- What – For control of insects pests for the commodities listed on label, such as confused flour beetle, red flour beetle, sawtoothed grain beetle, warehouse beetle, Indianmeal moth, Mediterranean flour moth, codling moth, navel orangeworm, granary weevil, rice weevil, and other moths and beetles as well as rodents. Area around fumigation must be monitored using a detection device such as INTERSCAN gas analyzer or MIRAN vapor analyzer to ensure that workers without respiratory protection are not exposed to concentrations of sulfuryl fluoride exceeding **1 ppm**.
- Where – Non-residential structures (for the food commodities listed on the label) such as mills, warehouses, stationary transportation vehicles (railcars, trucks, etc., excluding aircraft and passenger railcars), temporary and permanent fumigation chambers, and storage structures. For use in food processing establishments containing only those commodities listed on the label. Not for use in other food-handling establishments.
- Do not use ProFume without the Fumiguide Program for ProFume Gas Fumigant. The ProFume Fumiguide is part of labeling for ProFume and must be used to calculate the dosage. Never allow untrained individuals to apply ProFume gas fumigant.
- **Read product label for any usage changes and further definition of uses prior to fumigation.**

## Application

Sulfuryl fluoride does not adversely react with other compounds. However, all flames,

including pilot lights, must be extinguished. All electrical heating elements must be turned off or unplugged. Temperatures above 752°F will cause decomposition products to be formed which can be corrosive and etch glass and metal.

Introduce sulfuryl fluoride from the outside through tubes. Use polyethylene, polypropylene, or strong nylon tubing with an internal diameter of 1/8 to 1/4 inch. The tubing should have a minimum burst pressure of 500 pounds per square inch (PSI). The rate of fumigant released through larger tubing would be too great for good gas distribution. Place fans throughout the fumigation area. Run the fans during introduction and for at least 60 minutes afterward. For ProFume, Dow recommends leaving the fans running for the duration of the fumigation. Fans aid in the introduction, distribution, and the aeration process for sulfuryl fluoride. Fans will circulate the gas ensuring good distribution. If desired, use a remote shutoff such as a timer to turn off the fans.

Do not use sulfuryl fluoride at temperatures below 40°F. To prevent damage, do not apply sulfuryl fluoride directly to any surface.

## Precautions

If the concentration of sulfuryl fluoride is unknown or exceeds 1 ppm for ProFume, all persons in the exposed area must wear a self-contained breathing apparatus (SCBA) or a combination air-supplied/SCBA respirator.

Always wear (safety) splash-resistant goggles or a face shield while releasing sulfuryl fluoride. However, you **should not wear rubber boots or gloves** when introducing sulfuryl fluoride. These may trap the liquid against your skin and cause injury.

Because the gas can get into frost-free refrigerators and freezers, you must either bag the contents of these appliances or remove their contents from the fumigated space. Additionally, open or remove items that might slow fumigant aeration, such as waterproof mattress covers. Do not use sulfuryl fluoride on living plants.

In-transit fumigation, including aeration, of any vehicle is prohibited on public roads or waterways.

Product labels require that the structure be posted with specific warning signs on all entrances and all sides during the exposure and aeration period until the building is cleared for reentry by the fumigator.

## Aeration

Aeration is rapid. Sulfuryl fluoride desorbs quickly. Follow the aeration procedures in the label information to determine your aeration time.

## Detection

Use the Fumiscope® (a thermal conductivity analyzer) to monitor sulfuryl fluoride levels during application. The Fumiscope® can detect sulfuryl fluoride at levels greater than 240 ppm.

When measuring gas concentrations for reentry, however, you will need to use a different type of gas detector. Only approved detection

devices of sufficient sensitivity, such as specific types of gas analyzers or infrared detection systems (ambient air analyzers), can be used to confirm a concentration of sulfuryl fluoride of 1 ppm or less. At the time of this writing, the sulfuryl fluoride product label requires the use of an INTERSCAN or MIRAN analyzer or similar approved devices to measure gas concentrations for reentry.

## Disposal

When a sulfuryl fluoride cylinder is empty, close the valve, screw the safety cap onto valve outlet, and replace the protection bonnet. Return the empty cylinder promptly to the distributor. Do not use the cylinder for any other purpose.

**As with any Restricted Use Pesticide, carefully read and follow all label instructions. When using ProFume Gas Fumigant, the fumigator must also read and follow the ProFume Gas Fumigant Fumigation Manual as it is part of the label. All persons desiring to use sulfuryl fluoride, must comply with Dow AgroSciences product stewardship policies.**

# Test Your Knowledge

**Q. Name a fumigant that should not be used to treat food products.**

A. Chloropicrin

**Q. Which fumigants do not have an odor at normal treatment concentrations?**

A. Methyl bromide and sulfuryl fluoride

**Q. Which of the fumigants discussed in this unit is most flammable?**

A. Phosphine

**Q. Name a fumigant that is corrosive to metal discussed in this manual.**

A. Phosphine

**Q. List four things you should not wear when working with methyl bromide.**

A. Goggles, jewelry, gloves, contact lenses, sandals, or rubber boots

**Q. Which of the fumigants discussed in this unit might be phased out in the future? Why? When might this occur?**

A. At the time of this printing, methyl bromide is believed to contribute to the depletion of the earth's ozone layer. For this reason, the EPA has initiated action under the Clean Air Act to phase out the production and use of this fumigant. A 70-percent reduction in production was mandated by January 1, 2003. The complete phaseout of production was scheduled for January 1, 2005. The Environmental Protection Agency (EPA) is amending the regulations governing the phaseout of methyl bromide (MeBr) to allow for exempted production and import beyond the phaseout date of January 1, 2005, for critical uses and to address sales of pre-January 1, 2005 stocks of methyl bromide for critical uses.

**Q. Describe the difference between aluminum phosphide and magnesium phosphide.**

A. Aluminum phosphide is the main form of metal phosphide used to treat agricultural commodities. Magnesium phosphide is more reactive than aluminum phosphide. Magnesium phosphide is preferred when rapid release is desired and when treatment is performed at lower temperatures and humidities. In addition, when deactivating phosphide residues, nonsudsing detergent is required for aluminum phosphide, whereas you only need to use plain water to deactivate magnesium phosphide.

**Q. What is responsible for liberating phosphine gas from its solid form?**

A. Moisture in the air (humidity)

**Q. What detection device is sensitive enough to check levels of methyl bromide before reentry into the treatment area?**

A. Glass detector tubes

**Q. What detection device is sensitive enough to check levels of sulfuryl fluoride before reentry into the treatment area?**

A. Only approved detection devices of sufficient sensitivity, such as specific types of gas analyzers or infrared detection systems (ambient air analyzers), can be used to confirm a concentration of sulfuryl fluoride of 1 ppm or less. At the time of this writing, the sulfuryl fluoride product label requires the use of an INTERSCAN or MIRAN analyzer or similar approved device to measure gas concentrations for reentry.

# Appendix A: Sample Safety Checklists

## Safety Checklist

**The following safety checklists will help you organize the many aspects of fumigation. They are organized so that you can photocopy them directly from this manual. This information is general. It does not apply to all fumigants in all situations. You can modify these checklists to meet your specific needs. Some manufacturers provide checklists specific to their products. Use these as well.**

### Preliminary Planning: A Safety Checklist for Fumigators

- ✓ Draw or locate a sketch of the structure you plan to fumigate. Indicate the layout of the structure, connecting structures, and escape routes above and below ground.
- ✓ If you are in an industrial setting, inspect the equipment. It should be as tight as possible to prevent drafts or leaks. Be sure that production has stopped.
- ✓ Check all spouts, conveyors, conduits, heating ducts, or other possible openings leading from the areas that you plan to fumigate.
- ✓ Record the number and names of everyone who routinely enters the area. Also, note the proximity of other nearby people and animals. Keep children, unauthorized persons, and pets away from the application site.
- ✓ If you plan to treat a commodity, learn about it. Find out its mode of storage and its condition. If possible, obtain a previous treatment history.
- ✓ If you plan to treat a structure, learn about it. What does it consist of – wood, brick, concrete? Note the locations of doors, windows, and dividing walls. Predict airflow patterns.
- ✓ Locate connections and shut-offs for electricity, water, and gas. Find the nearest telephone or communication device.
- ✓ Obtain and have handy telephone numbers for local health, fire, police, and medical emergency services. Know how to contact the parties responsible for the structure and/or commodity you plan to fumigate.
- ✓ ONLY select a fumigant registered by the EPA and ASPB.
- ✓ Read and reread the label. Study the directions and precautions. Review the manufacturer's instruction manual. Make sure the fumigant is approved for the required work (site, commodity, etc.).
- ✓ Check, mark, and prepare (tarp, seal, etc.) the points of application if the job involves spot fumigation.
- ✓ Notify the local health and fire departments, police and security personnel, and the poison control center. Give them the following information: the location, the chemical name(s), the date and time of application, the type of gas mask and other safety equipment required, the fire hazard rating, and literature about the safety measures you plan to use.



- ✓ Inform the occupants of the structure where treatment will occur. Also, notify the occupants of neighboring structures.
- ✓ Arrange for standby equipment and replacement parts. Outline an alternate plan of action.
- ✓ Review the fumigation plan with all workers. Explain the potential hazards to life and property, required safety measures, and emergency procedures.
- ✓ Prepare warning signs to post near treated areas. Arrange for someone to monitor all entrances and exits during treatment.
- ✓ Have first aid equipment (including antidotes and plenty of fresh water) handy.
- ✓ If possible, plan for application from outside the structure.
- ✓ Seal all cracks, crevices, open fireplaces, broken windows, holes, pipes, chutes, and conveyors.
- ✓ When necessary, obtain fans to evenly distribute the fumigant.
- ✓ Preplan how you will ventilate the area after treatment.
- ✓ Identify areas where you can store any excess fumigant(s). Be sure conditions in the storage area match those required by the label.
- ✓ Make sure no open fires, motors, or hot surfaces (heat pipes or electric fixtures) are within the space that you plan to treat.
- ✓ Know how to operate the gas detection devices.

## **Pre-Application Safety: A Checklist for Fumigators**

- ✓ Open all doors and drawers inside the area you plan to treat.
- ✓ Shut off pilot lights and gas lights. Disconnect electrical equipment.
- ✓ Remove plastic covers from mattresses.
- ✓ Remove food, feed, drugs, and medicines or place them in airtight containers. Sealing freezers and refrigerators will NOT prevent fumigant gas from getting inside.
- ✓ Make a final check. Be sure all occupants, pets, fish, and plants have been removed from the structure.
- ✓ Place warning signs at all entrances and exits.
- ✓ Assign someone to observe all entrances and exits.

## **During-Application Safety: A Checklist for Fumigators**

- ✓ Apply all fumigants according to label directions.
- ✓ Apply the fumigant from outside where appropriate.
- ✓ Consider the weather. Delay or cancel outdoor treatments on windy or stormy days.
- ✓ Do not enter the area where fumigant gas is being discharged, except in extreme emergencies.

## **Post-Application Safety: A Checklist for Fumigators**

- ✓ Aerate according to structural limitations.
- ✓ Turn on ventilation fans where appropriate.
- ✓ Before reentering a treated area, use a suitable gas detector to determine the fumigant concentration. Some fumigants do not provide an adequate odor warning. Other areas aerate slowly.
- ✓ Remove warning signs only when aeration is complete.
- ✓ Dispose of or return empty containers per the manufacturer's instructions.
- ✓ When using metal phosphide fumigants, return any unused, solid chemicals to clearly labeled containers. Store them properly.

# Personal Safety:

## A Checklist of Fumigators

To protect yourself and others, be sure you and your *supervisor(s)* always:

- ✓ Know the location of all entrances and exits.
- ✓ Know the location of all fumigant containers and aerating fans.
- ✓ Rehearse the fumigation plan so that each worker knows what to do.
- ✓ Remove all rings, jewelry, and watches as required by the label.
- ✓ Have current health records for all employees. All workers that take part in fumigations must have a physical exam at least once a year. During fumigation, no worker should have a cold or other condition that may impair breathing. Nor should any worker be undergoing medical or dental treatment, unless a physician certifies that they may work with fumigants.
- ✓ Survey workers to make sure they have abstained from alcoholic beverages 24 hours before and will abstain 24 hours after a fumigation job.
- ✓ Instruct all workers about first aid, emergency procedures, antidotes, and decontamination.
- ✓ Work in pairs – especially when entry into a fumigated area is necessary. Stay in sight of one another while inside a treatment area.
- ✓ Report any accidents to your employer or supervisor.
- ✓ Report any signs of illness or physical discomfort, regardless of how minor they may seem. This includes dizziness, diarrhea, nausea, headaches, and lack of coordination.
- ✓ Teach all workers how to select, operate, and maintain protection devices. Warn them about the hazards that they may encounter if the chemicals are misused.
- ✓ Have and use the necessary personal protective equipment (PPE). Know where emergency equipment is located.
- ✓ Make sure there is enough water on site to wash or flush skin and eyes if an accident should occur.

# **Preliminary Planning: A Safety Checklist for *Raw Commodity* Fumigators**

- ✓ Draw or locate a sketch of the structure you plan to fumigate. Indicate the layout of the structure, connecting structures, and escape routes above and below ground.
- ✓ Seal all spouts, conveyors, conduits, heating ducts, pipes, cracks, crevices, broken windows, and other possible openings leading from the areas that you plan to treat.
- ✓ Record the number and names of everyone who routinely enters the area. Note the proximity of other nearby people and animals. Keep children, unauthorized persons, and pets away from the application site.
- ✓ If you plan to treat a commodity, learn about it. Find out its mode of storage and its condition. If possible, get a previous treatment history.
- ✓ If you plan to treat a commodity within a structure, learn about the structure. What does it consist of – wood, brick, concrete? Note the locations of doors, windows, and dividing walls. Check airflow patterns.
- ✓ Study the pest(s) you plan to control. When is it most vulnerable to fumigants? Where are its numbers the highest?
- ✓ Check and adjust all safety and application equipment. Be sure the components can withstand the corrosiveness of the fumigant(s). When applying compressed gas, use pressure-approved components. Seal them tightly.
- ✓ Locate connections and shut-offs for electricity, water, and gas. Test these shut-offs to be sure they are working. Find the nearest telephone or communication device.
- ✓ Obtain and have handy telephone numbers for local health, fire, police, and medical emergency services. Know how to contact the parties responsible for the structure and/or commodity you plan to fumigate.
- ✓ ONLY select a fumigant registered by the EPA and with the ASPB.
- ✓ Read and reread the label information. Study the directions and precautions. Make sure the fumigant is labeled for the required work (site, commodity, etc.).
- ✓ Notify the local health and fire departments, police and security personnel, and hospital. Give them the following information: the location, the chemical name(s), the date and time of application, the type of gas mask and other safety equipment required, the fire hazard rating, and literature about the safety measures you plan to use.

- ✓ Inform the occupants of the structure where treatment will occur. Also, notify the occupants of neighboring structures.
- ✓ Arrange for standby equipment and replacement parts for application equipment and PPE. Outline an alternate plan of action.
- ✓ Review your treatment plan with all workers. Explain the potential hazards to life and property. Identify the safety measures and emergency procedures that are required by the label.
- ✓ Prepare warning signs to post near treated areas. Arrange for someone to monitor all entrances and exits during treatment.
- ✓ Have first aid equipment (including antidotes and plenty of fresh water) handy.
- ✓ If possible, plan for application from outside the structure.
- ✓ When necessary, obtain fans to evenly distribute the fumigant.
- ✓ Preplan how you will aerate the area after treatment.
- ✓ Identify areas where you can store any excess fumigant(s). Be sure conditions in the storage area match those required by the label information.
- ✓ Make sure no open fires, motors, or hot surfaces (heat pipes or electric fixtures) are within the space that you plan to treat.
- ✓ Know how to operate the gas detection devices.
- ✓ Have on hand all the PPE you would need to enter a treated area in an emergency. Check to be sure that this equipment is working properly.

# Application Safety: A Checklist for *Raw Commodity* Fumigators

## Pre-Application

- ✓ Open all doors and drawers inside the area you plan to treat.
- ✓ Turn off pilot lights and gas lights. Disconnect electrical equipment.
- ✓ Make a final check. Be sure all occupants, pets, and livestock have been removed from the structure.
- ✓ Place warning signs at all entrances and exits.
- ✓ Assign someone to observe all entrances and exits.

## During-Application

- ✓ Apply all fumigants according to the directions in the label information.
- ✓ Apply the fumigant from outside where appropriate.
- ✓ Consider the weather. You may need to delay or cancel outdoor treatments on windy or stormy days.
- ✓ Do not enter the area where fumigant gas is being discharged, except in extreme emergencies.

## Post-Application

- ✓ Aerate according to structural limitations.
- ✓ Turn on ventilation fans where appropriate.
- ✓ Before reentering a treated area, use a suitable gas detector to determine the fumigant concentration. Some fumigants do not provide an adequate odor warning. Others aerate slowly.
- ✓ Remove warning signs only when aeration is complete.
- ✓ Dispose of or return empty containers per the manufacturer's instructions.
- ✓ When using metal phosphide fumigants, return any unused, solid chemicals to clearly labeled containers. Store them properly.

# Personal Safety:

## A Checklist for Commodity Fumigators

**To protect yourself and others, be sure you and your supervisor(s) always:**

- ✓ Know the location of all entrances and exits.
- ✓ Know the location of all fumigant containers and aerating fans.
- ✓ Rehearse the fumigation plan so that each worker knows what to do.
- ✓ Remove all rings, jewelry, and watches as required by the label.
- ✓ Have current health records for all employees. All workers that take part in fumigations must have a physical exam at least once a year. During fumigation, no worker should have a cold or other condition that may impair breathing. Nor should any worker be undergoing medical or dental treatment, unless a physician certifies that they may work with fumigants.
- ✓ Survey workers to make sure they have abstained from alcoholic beverages 24 hours before and will abstain 24 hours after a fumigation job.
- ✓ Instruct all workers about first aid, emergency procedures, antidotes, and decontamination.
- ✓ Work in pairs – especially when entry into a fumigated area is necessary. Stay in sight of one another while inside a treatment area.
- ✓ Report any accidents to your employer or supervisor.
- ✓ Report any signs of illness or discomfort, regardless of how minor they may seem. This includes dizziness, diarrhea, nausea, headaches, and lack of coordination.
- ✓ Teach all workers how to select, operate, and maintain protection devices. Warn them about the hazards that they may encounter if the chemicals are misused.
- ✓ Have and use the necessary personal protective equipment (PPE). Inspect PPE for defects. Know where emergency equipment is located.
- ✓ Make sure there is enough water on site to wash or flush skin and eyes if an accident should occur.

# Appendix B. Volume Calculations

There are several important factors to consider when preparing for a fumigation. One of the most important is calculating the volume of the space you plan to treat.

## Calculating the Volume of Rectangular Structures

In simple terms, to determine the cubic content of a rectangular structure multiply the length by the width and then multiply the result by the height. Use this calculation for truck trailers, boxcars and other simple structures. Measure the inside of these structures if the structure will be sealed and treated on the inside. Measure the outside of the structure if the structure will be tarped. The entire area enclosed by the tarp must be calculated.

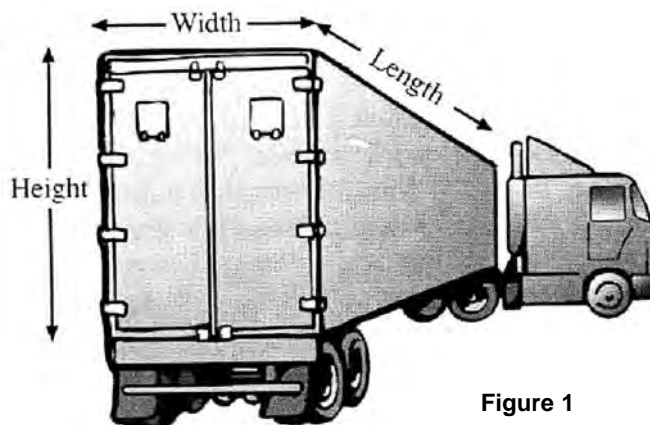


Figure 1

## Calculating the Volume of Buildings

Calculating the volume of a tobacco warehouse, flat grain storage building or similar structure is usually more involved. Most buildings are irregular in shape. They also may have peaked or gable roofs. To calculate the cubic content of such structures, first determine the area (square feet) of the space you plan to treat. Then multiply the area by the average height (feet).

**Example 1:** The rectangular building shown in Figure 2 is 80 feet long and 20 feet wide, with an average height of 25 feet. Calculate the volume (cubic content) of the building.

$$\begin{aligned}\text{Area} &= \text{length} \times \text{width} \\ &= 80 \text{ ft} \times 20 \text{ ft} \\ &= 1,600 \text{ sq ft} \\ \text{Volume} &= \text{area} \times \text{average height} \\ &= 1,600 \text{ sq ft} \times 25 \text{ ft} \\ &= 40,000 \text{ cu ft}\end{aligned}$$

This is a very basic example. A fumigator must be able to calculate the cubic content of buildings much more complicated than this. He or she also must understand how to determine average height. The building in Figure 3 is still simple, but a little more complicated than Figure 2. A lean-to has been added to the main structure, and there is a crawl space, or “subarea.”

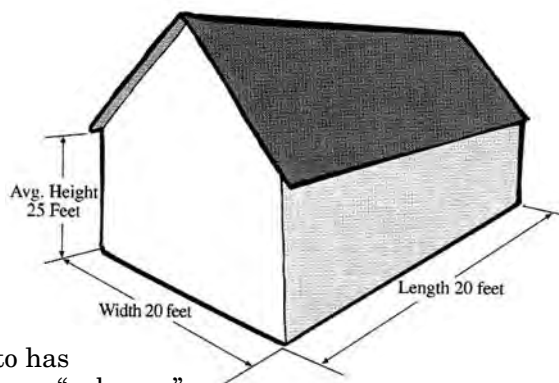


Figure 2

**Example 2:** To figure the volume in Figure 3, (cubic content) of this structure, use the same procedure outlined in Example 1, but calculate the volume of each section separately. Section 1 is the main section, not including the loft and subarea. Section 2 is the lean-to, not including the loft and subarea of that section. Section 3 is the loft area of the main structure. Section 4 is the loft area of the lean-to, and section 5 is the combined subareas below the main structure and the lean-to.

$$\begin{aligned}\text{Volume of Section 1:} \\ 40 \text{ ft} \times 30 \text{ ft} &= 1,200 \text{ sq ft} \\ 1,200 \text{ sq ft} \times 8 \text{ ft} &= 9,600 \text{ cu ft}\end{aligned}$$



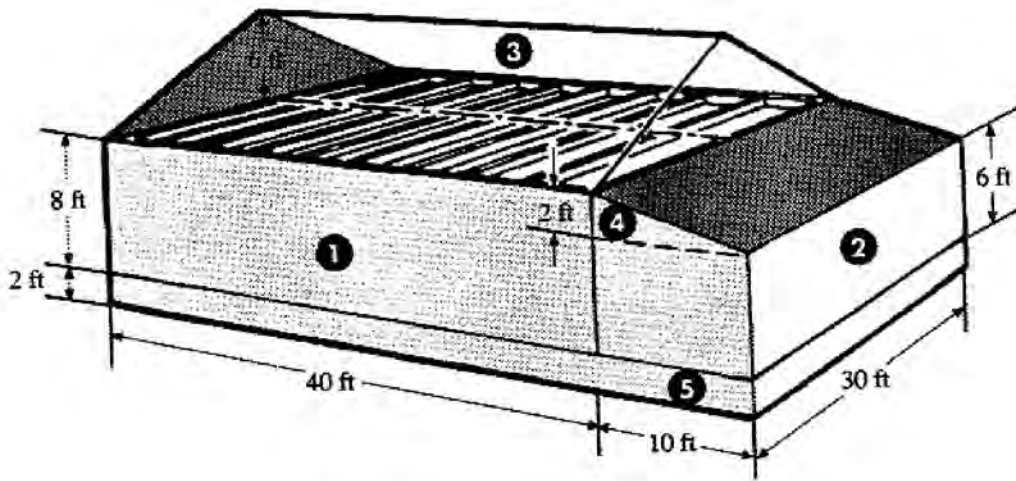


Figure 3

**Volume of Section 2:**

$$\begin{aligned} 30 \text{ ft} \times 10 \text{ ft} &= 300 \text{ sq ft} \\ 300 \text{ sq ft} \times 6 \text{ ft} &= \mathbf{1,800 \text{ cu ft}} \end{aligned}$$

**Volume of Section 3:**

$$\begin{aligned} 40 \text{ ft} \times 30 \text{ ft} &= 1,200 \text{ sq ft} \\ 1,200 \text{ sq ft} \times 3 \text{ ft (1/2 of loft height)} &= \mathbf{3,600 \text{ cu ft}} \end{aligned}$$

**Volume of Section 4:**

$$\begin{aligned} 30 \text{ ft} \times 10 \text{ ft} &= 300 \text{ sq ft} \\ 300 \text{ sq ft} \times 1 \text{ ft (1/2 of loft height)} &= \mathbf{300 \text{ cu ft}} \end{aligned}$$

**Volume of Section 5:**

$$\begin{aligned} 40 \text{ ft} \times 30 \text{ ft} &= 1,200 \text{ sq ft} \\ 30 \text{ ft} \times 10 \text{ ft} &= 300 \text{ sq ft} \\ 1,200 \text{ sq ft} + 300 \text{ sq ft} &= 1,500 \text{ sq ft} \\ 1,500 \text{ sq ft} \times 2 \text{ ft (height of subarea)} &= \mathbf{3,000 \text{ cu ft}} \end{aligned}$$

Total volume would be the sum of all area volumes:

$$\begin{array}{r} 9,600 \\ 1,800 \\ 3,600 \\ 300 \\ \underline{3,000} \\ \text{Total square feet} = 18,300 \end{array}$$

## Calculating Average Height

Calculating the average height of a building is a critical step in figuring volume. Several methods are available. To figure the average height of a building with a gable roof, multiply one-half the distance from the ground-floor ceiling to the peak of the roof by the number of square feet in the loft. Another method is to multiply the maximum height at the peak by the number of square feet and divide the result by two.

If the building has a simple roof, without dormer or extra gables, as in Figure 4, you can calculate the average height of the total building by adding the wall height and one-half of the loft height.

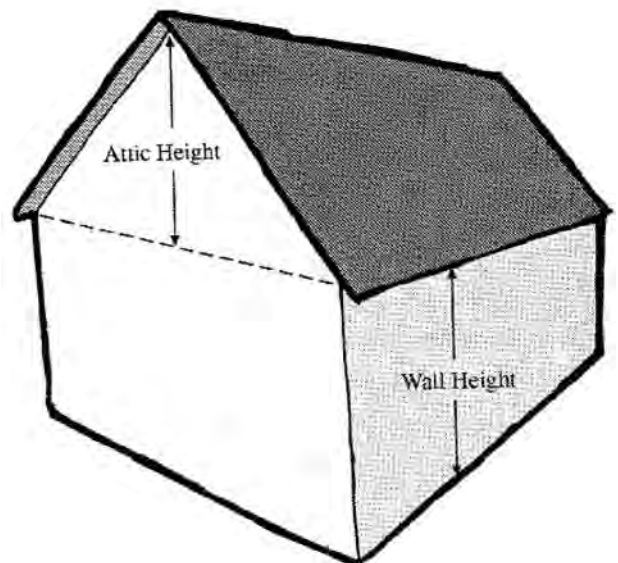


Figure 4

To measure the average height of the building in Figure 5, find the midway point between roof peak and eave. From there, measure to the ground. If the terrain is sloping or access to the outside is difficult, it is useful to measure the roof from inside while making the inspection.

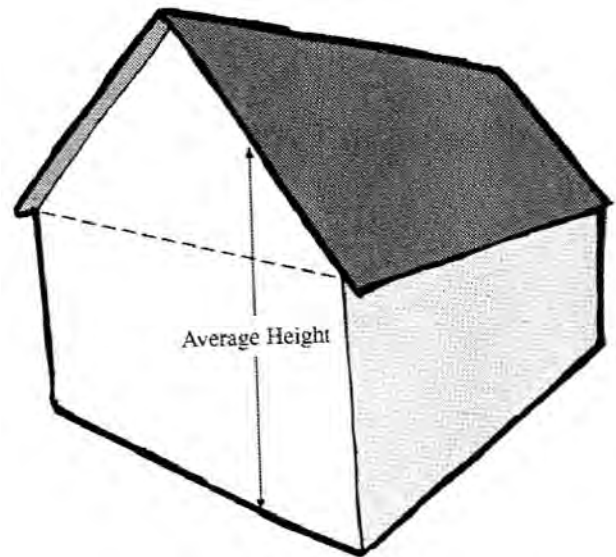


Figure 5

## Calculating the Volume of Grain Bins

Grain bins are usually cylindrical, with cone-shaped caps. To calculate the volume (cubic content) of a grain bin, you must know how to figure the volume of a cylinder and a cone:

$$\text{Volume of a cylinder} = 3.14 \times r^2 \times h$$

$$\text{Volume of a cone} = \frac{3.14 \times r^2 \times h}{3}$$

$r$  = radius (1/2 of the diameter of the circular base of the bin)

$h$  = height of the cylindrical part of the bin

3.14 is a constant often called "pi" and represented as  $\pi$

**Example 1:** Figure 6 shows a basic grain bin. The height of the cylindrical part of the bin is 25 feet. The diameter of the circular base of the bin is 20 feet. The height of the cone-shaped cap is 5 feet. With these dimensions, calculate the total volume (cubic content) inside the bin.

$$\begin{aligned} \text{Volume of the cylindrical portion} \\ \text{of the bin} &= 3.14 \times (10 \text{ feet})^2 \times 25 \text{ feet} \\ &= 7,850 \text{ cubic feet} \end{aligned}$$

$$\begin{aligned} \text{Volume of the cone-shaped cap} &= 3.14 \times (10 \text{ ft})^2 \times 5 \text{ feet} \\ &= \frac{1,570 \text{ cubic feet}}{3} \end{aligned}$$

Total volume

$$\begin{array}{r} 523.3 \text{ cubic feet} \\ 7,850.0 \text{ cubic feet} \\ + \quad 523.3 \text{ cubic feet} \\ \hline 8,373.3 \text{ cubic feet} \end{array}$$

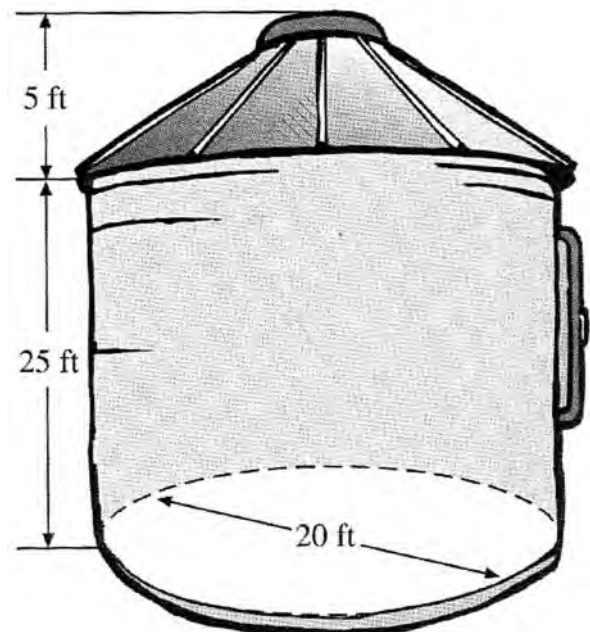


Figure 6

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Director, Cooperative Extension Service, University of Arkansas. The Arkansas Cooperative Extension Service offers its programs to all eligible persons regardless of race, color, national origin, religion, gender, age, disability, marital or veteran status, or any other legally protected status, and is an Affirmative Action/Equal Opportunity Employer.

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