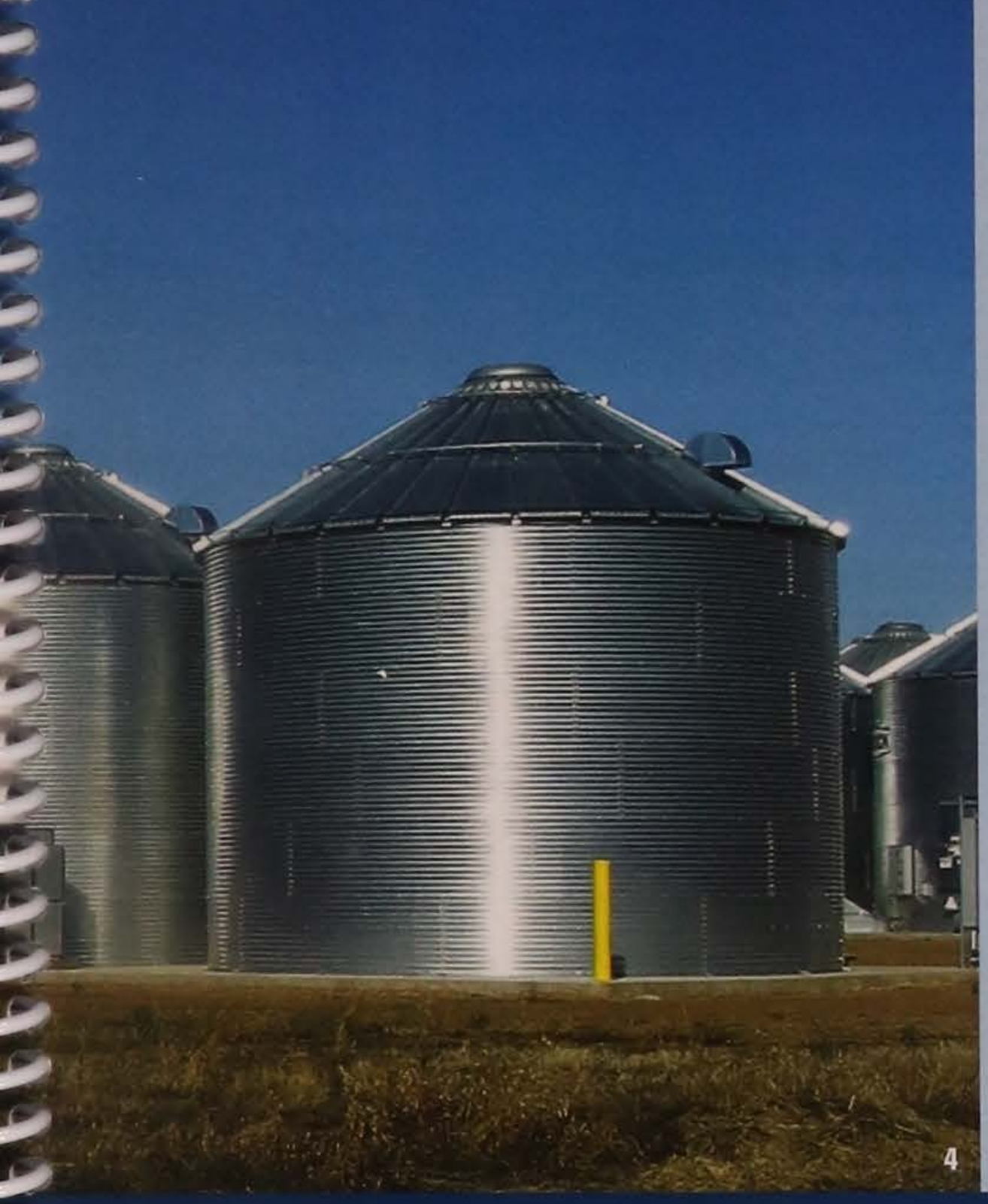
Fumigation Category 7C

Iowa Commercial Pesticide Applicator Manual



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Introduction

PURPOSE OF THIS MANUAL

This manual is for individuals seeking to be certified in Iowa as **private** or **commercial pesticide applicators** in Category 7C, Fumigation. This manual contains general information on how to fumigate effectively, safely, and in compliance with federal and state regulations.

PRIVATE APPLICATOR CERTIFICATION

According to the Iowa Department of Agriculture and Land Stewardship (IDALS), to purchase and use any fumigant classified as a **restricted use pesticide (RUP)** on property you own or rent, you must be certified as a private applicator and add a fumigation status to your certification. To become certified, you must pass a closed-book exam based on the Private Pesticide Applicator Study Guide (PSEP 1) and pass a separate closed-book private fumigation exam based on this manual. The private fumigation exam consists of 30 multiple-choice questions. At least 21 questions (70%) must be answered correctly to pass the exam. Upon passing the fumigation exam, your private applicator's certification card will indicate that you are certified to purchase and apply fumigants. Fumigation certification is valid for three years. To renew your certification, you must retest every third year of certification or attend an approved Category 7C Continuing Instructional Course (CIC) every year.

COMMERCIAL APPLICATOR CERTIFICATION

According to IDALS, if you apply any fumigants for hire or compensation for the following, you need to be certified as a commercial pesticide applicator in Category 7C, Fumigation:

- To control stored **commodity** pests including, but not limited to: insects and similar organisms, pest birds, and vertebrate pests in, on, or around areas where grain, food, or feed is stored, processed, manufactured, or produced.
- Within enclosed airtight spaces including, but not limited to: tents, vaults, stacks, storage structures, semi-truck trailers, railroad cars, vessels, storage structures, greenhouses, dwellings, and other containment or structures included in labeled approved sites for the protection of stored, processed, or manufactured products.

If you apply fumigants into buildings or other structures for the control of general household pests, vertebrate pests, or wood-destroying insects, you must also review the Appendix of this manual and be certified in Category 7A, General and Household Pest Management and/or Category 7B, Termite control.

To become certified, you must pass the core manual exam and the Category 7C fumigation exam. The core manual exam is based on the Iowa Core Manual (IC 445). The Category 7C, fumigation exam consists of 35 multiple-choice questions. At least 28 questions (80%) must be answered correctly to pass the exam. Category 7C exam questions will come from both this manual and the Iowa Core Manual. Commercial certification is renewable by either retesting every third year of certification or attending approved Category 7C CIC every year.

INDIVIDUALS EXEMPT FROM COMMERCIAL CERTIFICATION

Employees of food processing and distribution establishments are exempt from certification requirements of Iowa Code section 206.5 if the following conditions are met and all label directions on the fumigant being applied are followed:

- The employer has at least one person holding a supervisory position that is a **certified applicator**.
- The employer provides a program approved by IDALS for training, testing, and certification of personnel who apply, as an incidental part of their duties, any RUP on property owned or rented by the employer.
- The exempt employee applies pesticides under the direct supervision of a certified applicator. The supervisor does not have to be present but must be immediately available.

COMMERCIAL LICENSING REQUIREMENTS

An example of a non-commercial license is a cooperative that only fumigates their own grain with RUPs and does not have a custom pesticide application business.

Before you can fumigate as a commercial applicator, you must be employed by a company that has a pesticide applicator license. The license is not valid unless the company has a certified applicator. A company that applies any pesticide on the property of another for payment would need a commercial pesticide applicator license. A company that applies RUPs, only on property(s) owned, rented or leased by the company would need a non-commercial pesticide applicator license. A non-commercial license does not allow you to apply pesticides for hire.

There is a 21-day grace period from the day of initial employment at a licensed company to meet certification requirements. During the 21 days, you must operate under the direct supervision of a certified pesticide applicator who is within sight and hearing distance.

STEWARDSHIP TRAINING

Many fumigant manufacturers require certified applicators to attend a fumigant stewardship training before purchasing or using their products. This training, separate from IDALS certification, may include classroom, hands-on training demonstrations, and/or testing requirements. Contact your manufacturer or distributor for more information on stewardship training.

USING THIS MANUAL

Information in this manual will supplement that of the Iowa Core Manual (IC 445), and should not be used for commercial certification purposes without reference to the Iowa Core Manual.

- Each chapter includes a list of learning objectives describing the material covered in the text. Each learning objective tells you what you are expected to know before taking the fumigation exam.
- Terms in bold type throughout the manual are defined in the glossary found near the end of the manual. The number after each glossary term represents the chapter in which the term is defined.
- A list of abbreviations used in this manual can be found at the end of the manual.

PREPARING FOR THE EXAM

Some suggestions for studying the manual are:

- Find a place and time for study where you will not be disturbed.
- Read and understand the set of learning objectives that are at the beginning of each chapter. These will help you focus on what you should learn from the chapter.
- Read each chapter of the manual.
- Answer, in writing, the learning objectives after reading each chapter.
- Review any sections of the manual you do not fully understand.

Chapter 1
Overview of Fumigants

LEARNING OBJECTIVES

After studying this chapter, you should be able to
- Define fumigant
- Explain why fumigants are used
- Identify three factors that influence fumigant effectiveness and performance
- List properties of phosphine, sulfuryl fluoride, and methyl bromide (available formulations, flammability, common use sites, incompatibilities)

Pesticides are chemicals used to directly control pest populations or to prevent or reduce pest damage. Classification of pesticides includes herbicides, insecticides, rodenticides, and others. In stored commodities, the primary pesticides used are rodenticides and insecticides, including grain protectants, residual sprays, fogging products, and fumigants. This manual primarily deals with non-residential, stored commodity fumigants.

WHAT IS A FUMIGANT?

Fumigants are pesticides that kill in the gaseous form. As gases, fumigants penetrate into cracks and crevices, into the commodity treated, and throughout the area to be treated. The objective of fumigation is to introduce a lethal concentration of gas into all parts of the product mass or structure (e.g., facility, warehouse) and to maintain that concentration long enough to kill all stages of pests present.

Fumigants are typically applied directly into the fumigated space as gases from pressurized cylinders. They also can be generated from solids (e.g., pellets and tablets) that react with moisture and heat from the air to release the fumigant.

Fumigants should not be confused with smokes (solid particles in air) or with mists, aerosols, or fogs (liquid droplets of various sizes in air). Smokes, mists, aerosols, and fogs are not fumigants because they are not true gases and do not penetrate **infestations** in commodities or structures.

WHY FUMIGATE?

When used correctly, fumigants are an important tool to help manage pest problems that other methods cannot solve. While highly toxic, fumigants are often the best way to control pests in hard-to-reach areas or food/grain products and leave little, if any residue.

FACTORS AFFECTING FUMIGANT PERFORMANCE

The effectiveness and performance of fumigation is determined by the concentration of the gas, the temperature at which the fumigation is conducted, and the length of time the gas can be held on the target pest.

CONCENTRATION AND EXPOSURE TIME

Concentration is the amount of fumigant in a given volume (e.g., ounces per 1,000 cubic feet or milligrams per liter) acting on the pests. It is a function of the **dosage** applied and achieving a target concentration throughout the fumigated space. The exposure time is the length of time a fumigant can be held in a confined space. Exposure time is a function of quality sealing or using a reasonably gas tight confinement of some type and maintaining appropriate gas concentrations for the required time.

It is important to maintain the critical amount of gas in the target pest area for a certain period of time to accumulate the required "concentration x time" dosage to kill the target pests (see Figure 1). Although most fumigants are fast acting, concentrations need to be maintained for several hours to days or weeks, depending on the fumigant, to allow effective control. There is a general relationship for most fumigants between concentration and time: high concentrations require shorter exposure time and low concentrations require long exposure to achieve comparable kill.

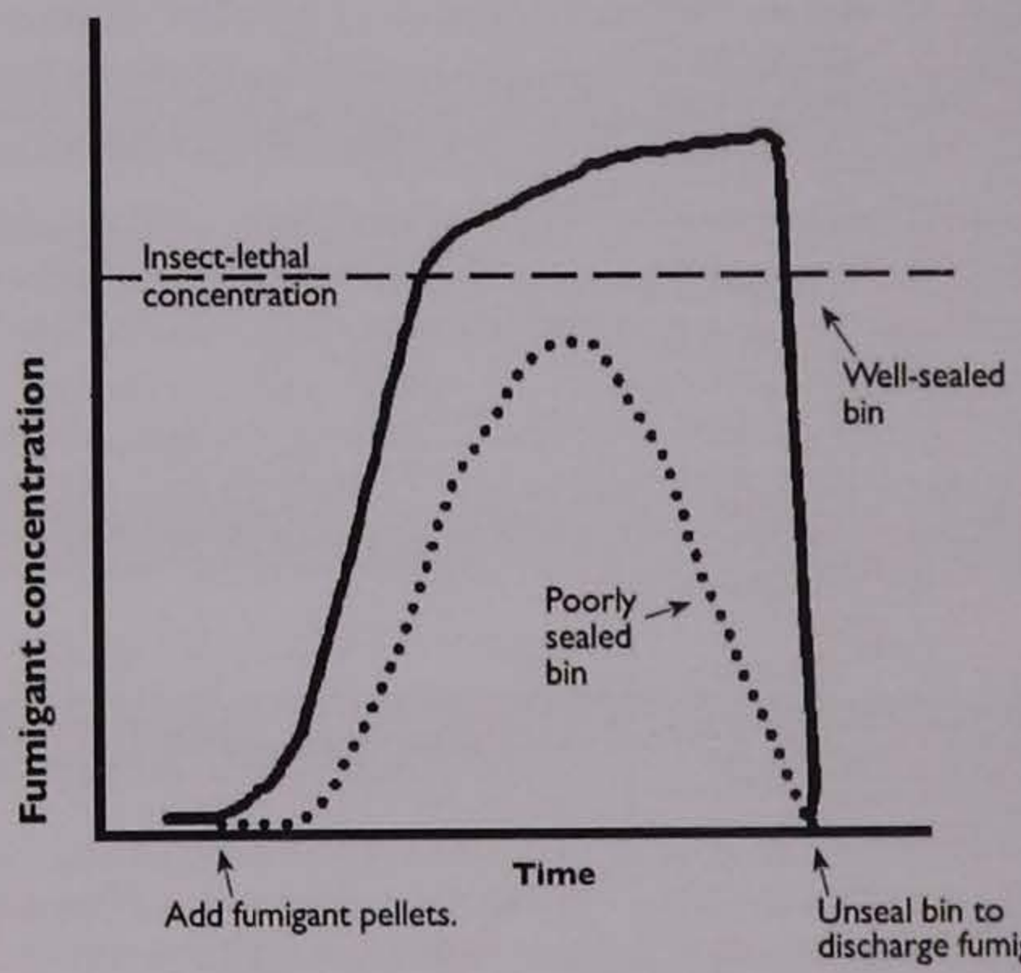


Figure 1. Relationships between concentration and time for a solid phosphine fumigant. Fumigation failure in grain bins is often caused by poor sealing.

TEMPERATURE

Temperature at the treatment site affects both the fumigant and the target pest. In general, insects are more difficult to control at lower temperatures. At temperatures below 50°F, most stored commodity insects exhibit little or no activity. The majority of insects develop most rapidly and successfully at temperatures ranging from 80 to 105°F, depending on the insect species.

Although many label requirements state a minimum of 40°F to fumigate, fumigating at temperatures of 60°F or higher are generally more effective. Increasing the temperature increases the metabolic activity of all insect life stages and reduces the amount of fumigant and/or exposure time required for control. Preferred fumigation temperatures usually range between 50 and 95°F. Check the label of the fumigant being used for its optimum temperature and acceptable temperature range.

COMMON FUMIGANTS

The primary fumigant gases used to carry out stored commodity fumigation in Iowa at the time of this writing are phosphine, sulfuryl fluoride, and methyl bromide (See Table 1). Sulfuryl fluoride is the only fumigant with separate registration for fumigation of dwellings, passenger railcars, household contents, and similar structures and materials.

Laws and regulations governing pesticides change often. Fumigants described here may no longer be legal. Always check current federal and state laws and regulations before using any fumigant for any purpose.

PHOSPHINE

Phosphine is a colorless gas with an odor at low levels that is often described as similar to garlic or decaying fish. The odor may be due to impurities.

Do not rely on odor as a warning of toxic amounts of phosphine gas.

Phosphine is only slightly heavier than air, 1.17 times as heavy. Phosphine sometimes requires mechanical mixing with a fan in stored grain or other densely packed commodities to distribute molecules evenly through the **fumigation enclosure**. Use low volume recirculation fans to minimize gas loss since phosphine has a high vapor pressure.

Phosphine has no adverse effects on seed germination when applied according to label directions and at labeled rates. Phosphine does react with certain metals such as copper, brass, bronze, gold, and silver. Reactions result in discoloration and cumulative corrosive effects. This is a problem with electrical and mechanical systems that utilize these metals.

ALUMINUM AND MAGNESIUM PHOSPHIDE

Solid formulations of aluminum or magnesium phosphide react with atmospheric moisture to create hydrogen phosphide gas. This reaction is known as hydrolysis.

Aluminum phosphide is formulated into pellets or tablets and is used commonly to fumigate grain storage facilities (see Figure 2). Magnesium phosphide products contain the solid magnesium phosphide material attached to a polyethylene matrix that can be put in place very quickly. Magnesium phosphide can be used effectively in warehouse fumigations. Magnesium phosphide is sometimes more effective than aluminum phosphide in colder temperatures due to its chemical reactivity. Both aluminum and magnesium phosphide may ignite on contact with water and may leave partially spent dust that must be deactivated (see Chapter 5).

Figure 2. Aluminum phosphide tablet rope.

Application labels for these formulations indicate that application should be done when the commodity air temperature is above 40°F. The time required for solid phosphine release is shorter under warm, humid conditions and longer under cool, dry conditions. Solid phosphide fumigants leave a white powdery residue.

Figure 3. Cylinderized phosphine gas formulation of 2% phosphine plus 98% carbon dioxide.

CYLINDERIZED PHOSPHINE

Phosphine also can be delivered directly as a gas to a commodity or space from a phosphine generator or from formulations of hydrogen phosphide gas released from a pressurized gas cylinder. Cylinderized phosphine is available as a premixed, ready to use formulation of 2% phosphine plus 98% carbon dioxide (see Figure 3) or as pure phosphine gas that must be diluted in the air or with carbon dioxide using special equipment (see Figure 4). The addition of carbon dioxide makes cylinderized phosphine nonflammable.

The rate at which phosphine is dispensed is not dependent on temperature or humidity, but on the dispensing equipment used. Unlike solid phosphide fumigants, cylinderized phosphine is not generated through a chemical reaction and its release is instantaneous. Dispensing phosphine from cylinders allows you to work outside the treated facility by delivering gas through tubes or pipes, rather than requiring entrance to the treatment area to apply fumigant. Cylinder-based phosphine leaves no substantial residual material like that left following fumigation with aluminum or magnesium phosphide solid formulations. Cylinderized phosphine also allows you to reach the target concentration quicker and to maintain these levels throughout the fumigation without ever entering the structure.

Figure 4. The Horn Diluphos System (HDS) allows the blending of pure cylinderized phosphine gas into air.

SULFURYL FLUORIDE

Sulfuryl fluoride is a colorless, odorless gas. It is sold in steel cylinders as a liquid under pressure that volatilizes readily (see Figure 5). Sulfuryl fluoride is 3.52 times as heavy as air, has a high vapor pressure, and low boiling point. Fans or blowers are used to introduce, distribute, and aerate sulfuryl fluoride. It is noncorrosive and unreactive to most materials. Sulfuryl fluoride is nonflammable, but in the presence of an open flame and glowing heat elements, it forms a very corrosive gas. Do not apply sulfuryl fluoride when the temperature of the treatment area is below 40°F.

METHYL BROMIDE

Figure 5. Sulfuryl fluoride cylinders.

Methyl bromide is a colorless, odorless gas that is sold as a liquid under pressure. Upon release, it vaporizes at temperatures above 38.5°F to form a gas that is 3.28 times heavier than air. **Recirculation** is used to ensure even distribution of the fumigant. Under most conditions, fumigation with methyl bromide will adversely affect seed germination. It is not recommended to use methyl bromide if moisture is high or at temperatures below 40°F. Like sulfuryl fluoride, methyl bromide is nonflammable, but in the presence of an open flame and glowing heat elements, it forms a very corrosive gas.

Methyl bromide has been phased out of production for most uses due to its role in ozone depletion. However, it still has uses for quarantine fumigation and critical use exemptions. These exemptions are for specific uses that currently have no feasible alternatives to methyl bromide available.

Table 1. Properties of Fumigants

	Phosphine	Sulfuryl Fluoride	Methyl Bromide
Formulation	• As a liquid: Phosphine and mixtures of phosphine and carbon dioxide contained in pressurized cylinders; becomes a gas when released • As a solid: Aluminum phosphide or magnesium phosphide pellets or tablets; becomes a gas when exposed to moisture in air	• As a liquid: Contained in pressurized cylinders; becomes a gas when released	• As a liquid: Contained in pressurized cylinders; becomes a gas when released
Boiling point*	-125°F	-67°F	38°F
Flammability	Flammable if exceeds 1.79% of the air volume	Nonflammable	Normally nonflammable except in the presence of an intense source of ignition
Fumigation commodities/sites	Raw agricultural commodities, processed foods, nonfood items, stored tobacco, and animal feeds	• Commodity: Non-residential structures, food handling establishments (e.g., pet food facilities, bakeries, food production facilities, mills, warehouses, etc.), stationary transportation vehicles (railcars, shipping containers, trucks, etc., excluding aircraft and passenger railcars), temporary and permanent fumigation chambers, and storage structures • Non-commodity: Dwellings (including mobile homes), buildings, construction materials, furnishings (household effects), shipping containers, and vehicles including automobiles, buses, surface ships, passenger railcars, and recreational vehicles (but not including aircraft)**	Quarantine and Preshipment (QPS) exemptions, which includes quarantine treatments and preshipment treatments (see Chapter 3) where an agency within the country you are exporting to requires fumigation with methyl bromide, and must be performed within 21 days of export
Incompatibilities	• As a gas: Can corrode copper, brass, copper alloys, and precious metals such as gold and silver • As a solid: Can spontaneously ignite if contacted by water, acids, or chemicals; solid phosphine formulations produce ammonia as a byproduct; ammonia is also corrosive to copper and copper alloys	• As a liquid: Fog-out within a structure, which results from applying sulfuryl fluoride too quickly or in a small application area, causes condensation of water particles containing small amounts of hydrofluoric acid, which may cause etching of glass, metals, and other surfaces within a structure	• As a liquid: Reacts with aluminum, magnesium, zinc, and alkali metals, some plastics • As a gas: Exposure to sulfur-containing materials may cause odors

*The boiling point is the temperature at which the liquid form boils (under specific atmospheric conditions) to become a gas.
**See Appendix.

Chapter 2
Stored Commodity Pests

LEARNING OBJECTIVES

After studying this chapter, you should be able to
- Define Integrated Pest Management
- Define resistance
- List ways to delay resistance to fumigants
- Describe the physical diffferences between insects and mites
- Distinguish between gradual and complete metamorphosis
- Explain how pest biology influences the effectiveness and timing of a fumigant application (stage of growth, activity level, feeding habits, infestation size)
- Define internal, secondary, and mold feeders
- List the identifying features of the stored commodity pests listed in this chapter
- Indicate the type of metamorphosis of the stored commodity pests listed in this chapter
- Identify stored commodity pests by feeding type (internal, secondary, and mold feeders)

If you apply sulfuryl fluoride for non-commodity fumigations, see "Structural pests for fumigation" in the Appendix.

Fumigants are used to eliminate insects, vertebrates, and other pests. The main part of this manual covers only insects and mites in, on, or around areas where grain, food, or feed is stored, processed, manufactured, or produced. For information on vertebrate pests, household pests, or wood-destroying insects, please refer to the Category 7A, General and Household Pest Management and/or Category 7B, Termite Control commercial pesticide applicator manuals.

PEST MANAGEMENT

This manual discusses fumigation as the management tactic you have selected. Fumigation should be implemented as part of an IPM program.

Fumigation is one of a number of methods that can be used for controlling pests in stored products. Fumigants should be used in combination with other management strategies. The coordinated use of multiple tactics is called **integrated pest management (IPM).**

An IPM program for stored grain should include exclusion of the pest (e.g., insect screens, door sweeps); sanitation (e.g., removal of debris); physical control (e.g., aeration, heat treatment); and chemical control (e.g., fumigation).

Identification and exclusion are the first steps to true pest management. Other management strategies include:
- thorough sanitation
- application of insecticides to empty storage structures
- proper cleaning and drying of commodities
- application of protectant insecticides where extended storage is planned
- adequate **aeration** for temperature and moisture management

Controlling existing infestations of stored commodity pests can be accomplished through fumigation, heat treatment, or a combination of both.

RESISTANCE

Stored commodity pests can develop **resistance** to fumigants that are not used properly. Ineffective fumigations occur when proper gas concentrations are not achieved or maintained (e.g., length of time held not adequate, improper dosing, or gas leaks that are not addressed). These ineffective fumigations may allow some pests to survive. The survivors of repeated applications will, over time, produce resistant strains of pests that become increasingly difficult to kill.

Reports of phosphine resistance in the United States have been reported for the red flour beetle and lesser grain borer.

Minimizing resistance is of great importance for the pests of stored commodities. The number of fumigants approved for use against stored-product pests is limited and decreasing. You can protect the effectiveness of fumigants by doing the following:

- Use IPM
- Use fumigants only when necessary—use non-chemical management strategies whenever possible
- Rotate fumigants whenever possible—for example, sulfuryl fluoride might be used at intervals in a management program that relies mainly on phosphine
- Ensure that the proper dosage rate is applied by following the label recommendations—do not "under apply," "over apply," or decrease exposure times
- Monitor for success—assure that fumigant concentrations stay at the correct concentration for the manufacturer's recommended time

PEST IDENTIFICATION

The first line of defense against insects and other **arthropods** is correct identification. Several characteristics are important for pest identification, including special characteristics of the mouth, legs, and antennae, and the **life cycle** of the pest. **Insects** are six-legged, have one pair of antennae, and have a head, **thorax**, and **abdomen**. **Mites** are tiny, soft-bodied, and are related to spiders. Adult mites have eight legs, no antennae, and two body parts.

The small size and overall similarity of many stored commodity pests make their precise identification difficult. The Plant and Insect Diagnostic Clinic at Iowa State University can aid in insect and mite identification. Samples can be sent to 327 Bessey Hall, Ames, IA 50011 or images emailed to insects@iastate.edu.

PEST BIOLOGY

Almost all insects and mites change in shape, form, and size during their life. This change is known as **metamorphosis**. Stored commodity pests have either complete or gradual metamorphosis.

Most stored commodity insects undergo **complete metamorphosis** and have four life stages: egg, **larva**, **pupa**, and adult (see Figure 6). Eggs hatch into larvae, which become pupae before finally developing into adults. The eggs and pupae are "immobile" phases; most often the larvae and adults will be seen because they are actively moving.

Figure 6. Cigarette beetles develop by complete metamorphosis. From left to right; pupa, adult, and larva.

Grain mites and psocids develop by **gradual metamorphosis** and have three life stages: egg, nymph, and adult. **Nymphs** look like adults except that they are smaller and cannot reproduce.

It is important to understand that the biology of the pest can influence the effectiveness and timing of a fumigant application. These include the:

- Pest's stage of growth. Adults are usually easiest to kill. Immature insects generally require higher dosages or longer exposure periods than adults. The eggs and pupae, depending upon the fumigant, are the most difficult life stages to kill while the young larvae and adults are relatively susceptible.
- Activity level of the pest. Active adults are easier to kill because they have a higher metabolism, allowing them to process the fumigant faster.
- Size of the infestation. Smaller infestations are easier to control. Large masses of pests may generate dust, damaged grain, webbing, and cast skins that interfere with fumigant **penetration**.

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

Fumigants exert their effects on pests only during the time in which the gas is present in the pests' environment. After the fumigant diffuses out of the product, no residual chemical protection is left behind and the product is again susceptible to reinfestation.

COMMON PESTS OF STORED COMMODITIES

Following are descriptions of stored commodity pests found in Iowa, based on the feeding habits of the pest. Each section includes a description of the pest, its life cycle, and the damage it causes.

INTERNAL FEEDERS

Stored commodity pests are known as primary or internal feeders if they develop inside kernels of grain, feed on the inner endosperm, and produce holes in the kernel through which adults exit. Larval and pupal life stages take place inside the kernel, and the insect can survive only when whole kernels are present.

LESSER GRAIN BORER

Figure 7. Lesser grain borer.

Identification: Adult lesser grain borers are 1/8 inch long and shiny dark brown or black. They have a slender cylindrical form (see Figure 7). The body surface is somewhat roughened and its head turns down under its thorax. Lines of small pits occur on the wing covers. The last three segments of the antennae are enlarged on one side. Larvae are C-shaped and white with dark heads, though they are rarely seen since feeding takes place inside the kernel.

Life Cycle: Borers go through complete metamorphosis.

Damage: Larvae and adults attack cereal and coarse grains, especially whole corn and wheat kernels. The damaged kernels are surrounded by powder from the chewed-up grain heads. Lesser grain borers also leave exit holes in the grain kernels.

RICE, MAIZE, AND GRANARY WEEVILS

Identification: Adult weevils are brown to reddish brown, have elongated snouts, and are ⅛ inch long (see Figure 8). They have slender, hard-shelled bodies that appear pitted or scarred with tiny holes. The rice weevil has four faint yellowish spots on the back of the abdomen. The maize weevil is slightly larger than the rice weevil and has more distinct colored spots on its front wings. The granary weevil is uniformly colored with no spots and cannot fly. Weevil larvae are small, white, and legless. They spend their entire lifetime within the kernel, hollowing out the kernel as they burrow.

Life Cycle: Weevils go through complete metamorphosis.

Damage: Feeding by weevil larvae leaves only a hollowed out shell of the kernel. Newly emerging adults leave large exit holes. Adults and larvae feed on both broken and unbroken grain kernels. They also infest grain products such as macaroni.

Figure 8. Rice weevil adult.

SECONDARY FEEDERS

Insects known as secondary or external feeders develop and feed outside the grain kernels or feed within cracked or damaged kernels.

CADELLE BEETLE

Identification: Adults are ⅓ to ½ inch long, flattened, and shiny black (see Figure 9). They have brown antennae and legs. The body narrows between the front of the thorax and the hardened wing covers, giving the appearance of a distinct "waist." Cadelle larvae are about ¾ inch long and have creamy white bodies with distinct black heads. There are two dark plates on the upper part of the segment just behind the head. A distinct plate with two hornlike projections is present on the rear of the larvae.

Life Cycle: Cadelle beetles go through complete metamorphosis.

Damage: Cadelle beetles infest flour, meal, and grain. Both larvae and adults feed on grain, attacking the germ of the kernel, and can live for long periods without food.

Figure 9. Cadelle beetle larva and adult.

DRUGSTORE AND CIGARETTE BEETLES

Identification: These beetles are small, cylindrical, and reddish brown (see Figure 10). Adults are less than ⅛ inch in length and have heads that are tucked down so that they cannot be seen from above. Adults can fly and are attracted to windows or other sources of light. When fully grown, larvae are C-shaped and about 3/16 inch long. Cigarette beetle larvae are creamy white and covered with long, yellowish-brown hairs. They have a brown head and legs (see Figure 6). Drugstore beetle larvae are similar but do not have a fuzzy appearance.

Life Cycle: Beetles go through complete metamorphosis.

Damage: Adults and larvae feed on dry stored food products, seeds, grains and dried plant material. They can cut holes to penetrate most paper packaging.

Figure 10. Drugstore beetle adult.

Figure 11. Indian meal moth larva.

INDIAN MEAL MOTH

Identification: Indian meal moth adults are about ½ inch long and have a tan-to-gray wing base with a coppery reddish tip. Adults are often seen flying weakly indoors or resting on walls. Indian meal moth larvae are dirty white sometimes with a greenish or pinkish tint and are about ½ inch long when fully grown (see Figure 11). The caterpillars are distinguished from beetle larvae by their prolegs (legs found on the abdomen).

Life Cycle: Moths go through complete metamorphosis.

Damage: Larvae feed on grain products, seeds, nuts, a variety of dried fruits, and other commodities, feeding on the germ. The larvae deposit fine, silk webbing as they move along the surface of the grain, preventing proper aeration. Adult Indian meal moths do not feed and therefore cause no damage.

Figure 12. Red flour beetle adult.

RED AND CONFUSED FLOUR BEETLES

Identification: Red and confused flour beetle adults are shiny reddish brown, flat beetles about ⅛ inch long (see Figure 12). The antennae of the confused flour beetle gradually expand toward the end, while red flour beetle antennae abruptly expand at the end to form a club of three segments. The red flour beetle will fly under certain conditions. The confused flour beetle does not fly. Larvae are about 3/16 inch long and off-white.

Life Cycle: Flour beetles go through complete metamorphosis.

Damage: Larvae and adult flour beetles cause damage by feeding on flour or other material such as grain dust and the broken surfaces of grain kernels.

Figure 13. Sawtoothed grain beetle adult.

SAWTOOTHED AND MERCHANT GRAIN BEETLES

Identification: Sawtoothed grain beetles are slender, flat, dark brown beetles about ⅛ inch long (see Figure 13). Their name comes from the six tiny saw-like "teeth" on each side of the thorax. Larvae are small and off-white. Merchant grain beetles are slightly larger and darker brown than the sawtoothed grain beetle. Merchant grain beetles occasionally fly, but sawtoothed grain beetles cannot.

Life Cycle: Beetles go through complete metamorphosis.

Damage: Larvae and adults feed on nearly all foods of plant origin, including grain products such as flour, meal, cereal, and macaroni. They damage grains by infesting slightly damaged pieces and often penetrate improperly sealed packaged foods.

Figure 14. Warehouse beetle adult.

WAREHOUSE AND CABINET BEETLES

Identification: Adults are typically ⅛ to 3/16-inch long, oval in shape, and brownish-black with yellowish wavy patterns on their back (see Figure 14). Larvae are up to ¼ inch long, yellowish to dark brown, and hairy.

Life Cycle: Beetles go through complete metamorphosis.

Damage: Adults and larvae prefer high protein sources and feed on broken kernels. Cast skins left by adult insects and molting larvae are an indication of past or current infestations.

MOLD FEEDERS

Mold feeders feed on molds or fungi growing on grain stored at excessive moisture levels. Mold feeders do not directly damage the kernel. The presence of mold feeders indicates a moisture problem and poorly conditioned grain.

FLAT GRAIN BEETLE

Identification: Flat grain beetles are very small, flattened, reddish-brown beetles about 1/16 inch long (see Figure 15). They have long antennae that are two-thirds the length of their body. Larvae have a pair of black, spine-like "tail horns" at the end of their body.

Life Cycle: Beetles go through complete metamorphosis.

Damage: Larvae and adults are general feeders and prefer grain that has been damaged or is in poor condition. The larvae prefer to feed on the germ of the whole kernels.

Figure 15. Flat grain beetle adult.

GRAIN MITE

Identification: Grain mites are very tiny and have a white oval body with numerous long hairs on their legs and back (see Figure 16).

Life Cycle: Mites develop by gradual metamorphosis.

Damage: Grain mites infest grain with high moisture content and feed on grain-rotting fungi. They also feed on flour, cereals, animal feeds, dried fruits, and other vegetable materials. An abundance or grain mites often indicates a more important problem of mold-related deterioration of the grain.

Figure 16. Grain mite adults. Magnified about 100x.

PSOCIDS

Identification: Adults are very small, light brown, and somewhat flattened insects (see Figure 17). They are usually wingless and have long thin antennae that are almost as long as the body. Nymphs look similar to adults but are smaller.

Figure 17. Psocids.

Life Cycle: Psocids go through gradual metamorphosis.

Damage: Psocids infest flour, other powdery food product, and grain in storage, handling, and processing facilities. They often infest grain that is high in moisture content, feeding in groups on damaged grain and molds growing in the grain.

Chapter 3
Methods of Fumigation

LEARNING OBJECTIVES

After studying this chapter, you should be able to
- Explain the differences between commodity and post harvest, chamber, and tarp fumigation
- Explain the differences between railcar, truck, and ship fumigation
- Define quarantine and preshipment fumigation

All methods by which fumigation may be accomplished have one factor in common—some means to contain an adequate concentration of fumigant for the time necessary to obtain pest kill. Fumigation may be used in several types of situations, including bins, structures, bulk storage facilities, specially designed chambers, rail cars, trucks, and other shipping containers.

Figure 18. Sealing the surface of the grain using plastic (polyethylene) tarps.

COMMODITY AND POST HARVEST FUMIGATION

Commodity and post harvest areas (e.g., grain bins and warehouses) may be fumigated to reduce stored pest infestations. Structures can be fumigated by putting a **tarpaulin (tarp)** over the entire structure or by a tape-and-seal fumigation (see Figure 18). In a tape-and-seal fumigation the fumigant is introduced into a structure that has been enclosed using plastic and/or tape to **seal** around doors, windows, vents, and other openings (see Chapter 7).

CHAMBER FUMIGATION

Fumigation chambers are well-sealed structures that may be located outside main buildings. Some chambers are specially built for fumigation, while others are modified rooms or buildings. Chamber fumigation can be used for many materials because environmental conditions can be carefully controlled and monitored. These types of fumigations also can drastically reduce the amount of fumigant needed. Vacuum fumigations are the best chamber type fumigations because the air is removed and the fumigant is introduced more easily and efficiently.

Figure 19. A sealed structure covered with vinyl-coated fabric tarps and weighted down with sand snakes.

TARP FUMIGATION

Tarp fumigation treats single items or entire structures. It works by placing a gas-tight material over the commodity or structure to be fumigated (see Figure 19). Fumigation tarps must be made of a highly resistant material such as vinyl coated nylon, or polyethylene sheeting of at least 4 mil (4 thousandths of an inch) thickness. All seams are sealed to create a gas-tight enclosure. Low edges of the tarp are weighted down with soil, sand, or **snakes**. Tarp fumigation may be done in the open, on loading docks, or in areas of buildings that allow safe aeration when the tarp is removed.

VEHICLE AND VESSEL FUMIGATION

Items shipped in rail cars, truck trailers, ships, and barges are often fumigated after they are loaded into the vehicle. This prevents pests from being transported to other locations and protects shipped products from pest damage during transport.

RAIL CAR AND TRUCK FUMIGATION

Railcars and truck trailers must be well constructed and in good repair. If not, they must be made airtight, or the entire vehicle tarped so that the fumigant can be retained for the required fumigation period. Fumigation of rail cars and truck trailers must comply with the regulations of state and local highway departments and departments of transportation as well as fumigant label instructions. In some cases, for some fumigants (e.g., phosphine), loaded rail cars can be fumigated **in transit** (while being transferred from one place to another) and within the same premises. However, regulations prohibit truck trailers from being moved on public highways until fumigation and aeration have been completed.

Refrigerated trailers are preferable to other trailers as they are tighter and lack a wood floor that fumigant will leak through. In cool weather, thermostats can be turned up to achieve more desirable temperature conditions.

SHIPS AND BARGES

The fumigation of products or commodities on board a vessel depends on the type of infestation as well as the structure of the vessel. In most cases, a ship's cargo can be fumigated:

- In warehouse or storage silos before loading
- In freight containers before loading
- In the hold of a ship with fumigation and aeration complete before sailing

Ships also may be fumigated in transit in the hold of the ship prior to sailing or in freight containers before loading. In these situations, the fumigation continues during the voyage and is not finished until aeration and, where applicable, removal of spent solid fumigant formulations is completed.

QUARANTINE FUMIGATION

Quarantine fumigation is the fumigation of specific commodities entering the United States to prevent the movement of agricultural pests into or within the country. Agricultural inspectors inspect incoming containers and determine which commodities must be fumigated before they can be delivered to the market. The presence of an **actionable pest** requires that the entire container be fumigated.

Commodities being exported from the United States or to other states also may come under preshipment/quarantine requirements of the destination. **Preshipment** is the term used to describe goods that are held for a maximum of 21 days after fumigation before export. An example of a preshipment use of methyl bromide is the application to wheat immediately before shipment because of official **phytosanitary** requirements of the destination country.

Chapter 4
Laws and Regulations

LEARNING OBJECTIVES

After studying this chapter, you should be able to
- Define label
- Define Fumigation Management Plan
- Explain what should be included in a Fumigation Management Plan
- Describe what happens if you do not prepare a Fumigation Management Plan
- Identify how long Fumigation Management Plans must be maintained
- Identify how long commercial/private applicator records must be maintained
- List the record requirements for commercial/private applicator records
- Differentiate between residue and tolerance

Before any fumigation begins, you must be familiar with and comply with all applicable federal, state, and local regulations. The success of a fumigation is not only dependent on your ability to do your job but also upon carefully following all rules, regulations, and procedures required by governmental agencies.

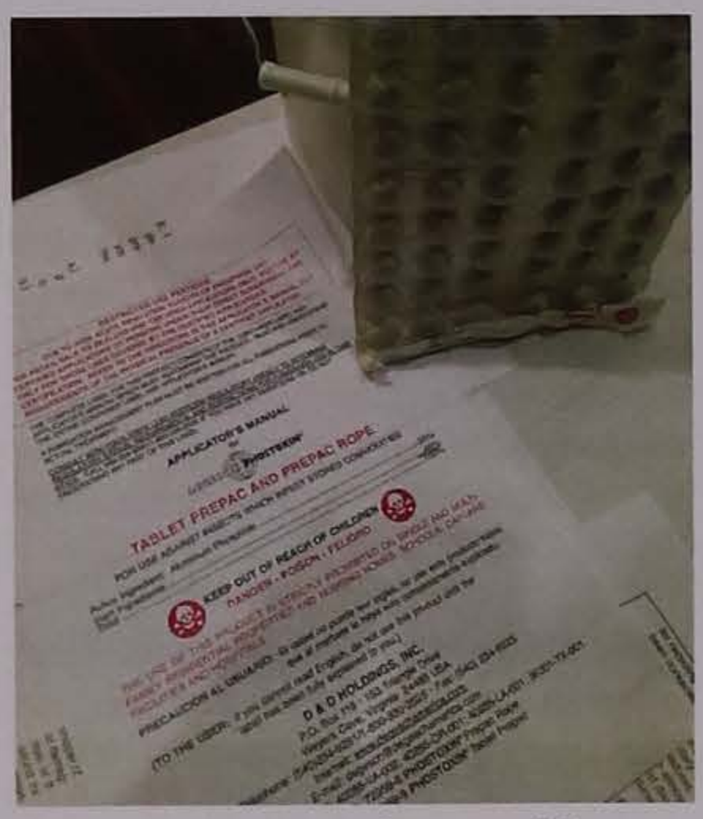


Figure 20. Applicator's manual for solid phosphine.

Always read and follow the directions on the fumigant label. Labels change over time. Directions given on fumigant labels always take the place of directions found in this and other training manuals.

THE FUMIGANT LABEL

The **Environmental Protection Agency (EPA)** regulates the use of fumigants through instructions on the fumigant label. The **label** includes all the information printed on and attached to the fumigant container, referred to on the label, and accompanying literature. The label provides basic information about the fumigant, first aid instructions, precautionary statements, and storage and disposal information. The **applicator's manual** describes, in detail, the sites and commodities that can be fumigated and pests that can be controlled, as well as application rates and safety procedures to follow during fumigation (see Figure 20). The applicator's manual is part of the label. The label is a legally binding document and must be followed exactly. Failure to follow label instructions violates state and federal laws. Always have a copy of all labeling readily available at the fumigation site.

FUMIGATION MANAGEMENT PLAN

Labels for most fumigant products require that you prepare and follow a **Fumigation Management Plan (FMP)** for each structure to be fumigated. An FMP is an organized, written record of all the steps that should be taken before, during, and after fumigation. The FMP should reflect an understanding of the chemical properties and safety issues involved to help ensure a safe, legal, and effective fumigation. Each plan must fully characterize the area to be fumigated and include all appropriate monitoring, notification, and clearing (aeration) requirements. The FMP should document who, what, where, how, and why, including:
- Who should be told about the fumigation? Who will conduct the fumigation?
- What commodity will be fumigated? What type of structure will be fumigated?
- Where can fumigant gas escape?

- How will the structure or commodity be sealed?
- Why was the fumigation necessary?

FMPs are enforced by state and federal governments. If you do not prepare an FMP, you are subject to criminal and/or civil penalties. When developing an FMP, refer to the applicator's manual for specific requirements for the fumigant you are using. You are responsible for working with the owners and/or responsible employees of the site to be fumigated to ensure that the FMP is completed, kept up to date, available for review, and followed. If you need assistance writing an FMP, please contact the fumigant manufacturer or distributor.

The FMP must be kept on site during all fumigation activities. It must be made available to local, state, and federal enforcement personnel and emergency responders. The FMP and related documentation, including monitoring records, must be maintained for a minimum of two years.

RECORDS OF FUMIGANT APPLICATIONS

COMMERCIAL APPLICATOR RECORD KEEPING REQUIREMENTS

The Pesticide Act of Iowa requires commercial applicators to keep an application record for every pesticide application, including fumigants. These records must be made available to IDALS upon request. You must keep the following records at your facility for three years:

- Company name and license number
- Customer's name and address
- Specific site of RUP application including address
- Date of treatment
- Trade name of pesticide used
- Application rate and quantity used
- Temperature and direction and velocity of the wind at the time of application (if working outdoors)
- Use of restricted use pesticides (site and pest)
- Time pesticide application begins and ends

Most of the items that are recorded for commercial and private applicator records are also required in FMPs. However, be aware that simply completing the FMP may not meet legal record keeping requirements.

PRIVATE APPLICATOR RECORD KEEPING REQUIREMENTS

In accordance with the 1990 Farm Bill, private applicators are required by federal law to keep records of all fumigant applications because they are RUPs. The information must be recorded no later than 14 days following the pesticide application and must be maintained for two years after the application. Records must include the following required information:

- Brand or product name of the pesticide
- EPA registration number
- Location of application
- Crop, stored product, or site treated
- Month, day, and year applied
- Size of area treated
- Total amount applied
- Name and certification number of applicator

Sulfuryl fluoride products registered for non-commodity fumigation do not have tolerances for food (see "Residue tolerances" in the Appendix).

FUMIGANT RESIDUES

Fumigants may leave trace or no **residues** on commodities. The EPA determines the amount of residue that may safely remain in or on agricultural products, called a tolerance. The **tolerance**, or tolerated residue, is the amount of the pesticide's **active ingredient** or its breakdown residues that is considered safe to consume and is legally permitted in the commodity. If residues are found above that tolerance level, the commodity will be condemned or subject to seizure by the government, and violators may be prosecuted. A fumigant may have different tolerances on different products. Consult the label or the fumigant manufacturer for tolerance levels specific to the products you use and commodities you treat.

Chapter 5
Safe Use of Fumigants

LEARNING OBJECTIVES

After studying this chapter, you should be able to
- Give examples of accidental fumigant exposure
- List the general symptoms of overexposure to fumigants
- Explain why alcohol should not be consumed before or after a fumigant application
- List the symptoms of phosphine, sulfuryl fluoride, and methyl bromide poisoning
- Describe what should be done if someone is exposed to a fumigant
- Describe what to do if a fumigant canister leaks
- Identify the precautions to take when transporting fumigants
- List the precautions to take when storing fumigants
- Explain why placards are used when transporting and storing fumigants
- List the resources that tell you how to dispose of fumigant wastes

Safety when fumigating must be a top priority. It is important to treat fumigants with respect and to protect yourself and others from accidental **exposure**. The most important thing you can do to ensure personal and public safety is to read and understand the fumigant label.

HOW FUMIGANTS ENTER YOUR BODY

As a fumigant applicator, you may be exposed to fumigants in several ways. Fumigants can enter your body through your lungs (**respiratory exposure**), eyes (**ocular exposure**), mouth (**oral exposure**), and skin (**dermal exposure**). Of these four, respiratory exposure is the most common and dangerous. The risk of inhaling pesticides is greatest:
- When opening and releasing the fumigant
- During application
- During aeration of fumigation enclosure
- When disposing of spent solid fumigants (e.g., phosphine)

RECOGNIZING SYMPTOMS OF FUMIGANT POISONING

Fumigants are highly toxic. Watch for behaviors that could signal overexposure in yourself and others before, during, and after the fumigation process. General symptoms of overexposure to fumigants can include:
- Nausea
- Headache
- Coughing
- Difficulty breathing
- Dizziness
- Fatigue

Make sure that you are in good physical condition if you are actively taking part in a fumigation procedure. You do not want to make the use of fumigants dangerous to yourself or to the public.
- Have a physical examination at least once a year or more often if health conditions require them.
- Do NOT participate in a fumigation if suffering from colds or other respiratory problems that make breathing difficult
- Do NOT participate in a fumigation while undergoing continuing medical treatments unless authorized to do so by medical personnel.

As standard practice, no alcoholic beverages should be consumed for 24 hours before and 24 hours after a fumigation application. Alcohol tends to increase sensitivity to fumigants and also can interfere with proper diagnosis of fumigant poisoning.

Figure 21. Severe phosphine poisoning resulting in unconsciousness.

PHOSPHINE

Early symptoms of phosphine poisoning can be severe, but these symptoms are reversible if exposure stops. Breath and vomit have a distinct odor of garlic. Phosphine does not accumulate in body tissues.

- Slight or mild poisoning symptoms include fatigue, buzzing in the ears, nausea, pressure in the chest, and uneasiness.
- Moderate poisoning symptoms include vomiting, diarrhea, dizziness, strong chest pains, back pains, a feeling of coldness, and difficulty breathing.
- Severe poisoning rapidly results in extreme difficulty in breathing, bluish coloration of skin, agitation, unconsciousness, and death (see Figure 21). Death may be immediate or can follow several days of swelling and fluid accumulation in the lungs, paralysis of the central respiratory system, and/or swelling of the brain.

Cylinder forms of phosphine that use carbon dioxide as a propellant can be potentially dangerous due to high concentrations of carbon dioxide in confined areas. Carbon dioxide may displace oxygen in the air and result in dizziness, disorientation, suffocation, and, under certain circumstances, death.

SULFURYL FLUORIDE

Symptoms of sulfuryl fluoride poisoning include depression, slowed gait, slurred speech, nausea, vomiting, stomach pain, drunkenness, itching, numbness, twitching, and seizures. Inhalation of high concentrations may cause respiratory tract irritation or respiratory failure. Skin contact normally poses no hazard, but contact with liquid sulfuryl fluoride can cause pain and frostbite due to rapid vaporization. Repeated or prolonged exposure to high concentrations may cause injury to lungs and kidneys, weakness, weight loss, anemia, bone brittleness, stiff joints, and general ill health. Sulfuryl fluoride does not accumulate in body tissues.

Chloropicrin is applied as a warning agent prior to release of sulfuryl fluoride products, registered for non-commodity fumigation, into structures. Use of chloropicrin as a **warning agent** is incorporated into the labeling for these sulfuryl fluoride products. See "Chloropicrin" in the Appendix for safe use information.

Figure 22. Severe skin burns due to methyl bromide.

METHYL BROMIDE

Early symptoms of methyl bromide overexposure are dizziness, headaches, nausea and vomiting, weakness, and collapse. Fluid in the lungs and heart irregularities may develop two to 48 hours after exposure. Repeated exposures to low doses result in an accumulation of methyl bromide in body tissues. Such exposures can cause symptoms such as blurred vision, staggering walk, and mental imbalances. If trapped inside tight clothing next to the skin, methyl bromide can cause severe skin burns (see Figure 22).

FIRST AID FOR FUMIGANT POISONING

If you have been exposed to a fumigant and/or if you begin to feel ill, get to fresh air and remain calm. Get to a doctor right away. Do not go alone. Have someone take you to the doctor. Be sure to take the label with you and give it to the doctor.

If symptoms of fumigant poisoning develop in any person in or around a facility during a fumigation or up to several days after a fumigation, immediately take the person to a local medical center (see Figure 23). Also, a person who has been over-exposed to a fumigant (e.g., entered a fumigated space without respiratory protection) should be taken to a medical facility immediately for evaluation, even if the person does not show symptoms of poisoning. The onset of poisoning symptoms can be delayed (e.g., acute symptoms for sulfuryl fluoride are delayed up to 24 hours; methyl bromide up to 48 hours). Call the Poison Control Center, 1-800-222-1222, or the emergency number listed on the product label for medical assistance relating to fumigation poisoning treatment.

Figure 23. Seek medical attention if fumigation poisoning symptoms develop during a fumigation or up to several days after a fumigation.

Before rescuing or aiding a person overcome by a fumigant, call for professional assistance and put on the appropriate personal protective equipment before entering the area (see Chapter 6). The fumigant that harmed the injured person could also injure you. When assisting during fumigant introduction, avoid getting liquid and solid fumigants on your skin, and do not inhale vapors. Follow fumigant label directions if skin and clothing have been exposed to liquid or solid fumigant.

FUMIGANT SPILLS, LEAKS, AND FIRES

Fumigant labels, applicator manuals, and **Safety Data Sheets (SDS)**, formerly Material Safety Data Sheets (MSDS), provide both general and detailed instructions on responding to pesticide spills, leaks, and fires. For example, the label will tell you:

- When you need to wear a respirator
- Whether the material can be salvaged
- What actions to take to minimize the risks to others

Make sure emergency responders have a copy of the label and SDS.

If a leak occurs, evacuate the immediate area. Put on appropriate PPE and then, if possible, move the leaking or damaged cylinder or canister outdoors or to an isolated area. Tighten the cover on a canister or the valve of a cylinder using an adjustable wrench.

If there is a fire, burning fumigants may produce toxic gases. Firefighters must recognize the need to evacuate structures and have the proper respiratory equipment for protection.

TRANSPORTING FUMIGANTS

All fumigants are classified as **hazardous materials** by the Department of Transportation (DOT) and as a result have extensive regulations regarding their transportation. These regulations include vehicle placarding, driver licensing, vehicle safety kits, inspections and maintenance logs, and fumigant documentation.

Vehicles carrying fumigants will need to display a **placard** providing information about the fumigant (see Figure 24). Refer to DOT regulations to determine the placarding requirements for transporting each fumigant. Contact the fumigant manufacturer or distributor for more information on placarding for transportation.

Figure 24. Sulfuryl fluoride DOT placard.

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

An exception to DOT regulations may be obtained from the supplier (e.g., Degesch America, Inc.) for transporting small quantities of some fumigants. All requirements of the special permit must be met.

When transporting fumigants, use common sense and take the following precautions:

- Hazardous materials must be secured within the vehicle so they do not move during transport
- Fumigants should always be transported in a separate air space from vehicle occupants
- Be sure you have the required driver's license with any appropriate endorsements for the specific fumigant you plan to transport
- Cylinders must be transported with the **valve cover** and safety **bonnet** attached
- Do not remove protective valve covers until just before use

Always follow federal and state DOT regulations when transporting fumigants and/or their containers. Contact the Iowa DOT at 515-239-1101 for more information.

FUMIGANT STORAGE

When storing fumigants, it is recommended to take the following precautions:

- Store all containers of fumigant in a locked, well-vented enclosure
- Store cylinders secured in place (to prevent from falling over) with safety caps and protective bonnets securely in place
- Store fumigants in areas separate from food and feed
- Never put fumigants in other containers unless the fumigant label allows (e.g., phosphine in smaller dosing cylinders)
- Keep an updated and accurate inventory of all fumigants in storage

Fumigants can escape from faulty valves or damaged or corroded containers. Leaks can cause dangerous concentrations to build up in closed storerooms. Check valves and containers regularly for leaks using gas detection equipment (see Chapter 6). Before entering any storage area, run an exhaust fan to remove vapors that may have built up inside.

Make sure that all storage areas are properly placarded as pesticide storage. The applicator's manual and/or SDS specify what must be on the placards for fumigant storage areas. National Fire Protection Association (NFPA) placards act as an immediate warning system for emergency service personnel, helping them identify the kinds of material present and the dangers they pose (see Figure 25).

Figure 25. Aluminum phosophide NFPA placard.

FUMIGANT WASTE DISPOSAL

Improper disposal of fumigant wastes can create serious hazards for people and the environment. These wastes include partially spent solid fumigant, excess fumigants, fumigant containers, and unrinsed empty containers. Keep all fumigant wastes out of the reach of children.

Consult the label for information about how to dispose of unwanted fumigant. You also can seek guidance from your county or regional disposal agencies. Partially spent aluminum and magnesium phosphide fumigant, called greendust, will continue to give off gas and may create a significant hazard if not properly

deactivated (see Figure 26). Special procedures are needed to dispose of greendust. They are discussed in detail in the applicator's manual.

The label will tell you how to handle empty containers. In addition, you can ask the supplier about disposing or recycling empty fumigant containers. Never handle fumigant containers or residues in a manner that contaminates water supplies.

Most fumigant containers are returned to the distributor or manufacturer. Cleaning fumigant containers before refilling is the responsibility of the refiller. Even partly filled cylinders are returnable under certain circumstances (check with the manufacturer or distributor).

Figure 26. Dry deactivaction drum for aluminum and magnesium phosphide deactivation.

Chapter 6
Safety Equipment

LEARNING OBJECTIVES

After studying this chapter, you should be able to
- Define personal protective equipment
- Identify when eye protection is required when using fumigants
- Explain why gloves are not always required when using fumigants
- State the specific fumigant gas concentrations requiring respiratory protection for phosphine, sulfuryl fluoride, and methyl bromide
- Describe the differences between full-face canister respirators and self-contained breathing apparatus
- Describe how to properly use a full-face canister respirator
- Identify what type of respirator must be on hand during every fumigation
- Identify when someone needs a more current medical evaluation
- Differentiate between a fit test and a fit check
- Explain why gas detection devices should be calibrated
- Describe the differences between high concentration monitoring devices, low concentration gas detectors, and dual purpose devices
- List the considerations when selecting gas detection equipment

If you apply sulfuryl fluoride for non-commodity fumigations, see "Chloropicrin" in the Appendix for additional requirements.

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE) is the name given to clothing and devices that protect you from contact with fumigants. The label information for each product lists the minimum PPE required for using that fumigant. PPE requirements vary with the fumigant. You are legally required to follow all PPE instructions that appear on the fumigant label.

PPE is effective only if it fits correctly and is used properly. Directions for keeping it clean and maintaining it properly are on the fumigant label and in the manufacturer use instructions.

Figure 27. Wearing a full-face shield when introducing a fumigant.

PROTECTIVE CLOTHING

Some fumigants packaged in cylinders require you to wear long-sleeved shirts and pants during fumigant introduction. Other products direct you to wear short sleeves and loose-fitting clothing. Read the label information carefully.

EYEWEAR

With the exception of aluminum and magnesium phosphides, fumigant labels require eye protection, such as goggles or full-face shield, to be worn during fumigant introduction (see Figure 27). When introducing fumigants using an introduction hose connected to a pressurized cylinder, eye protection can prevent potential injury if the hose accidentally bursts or disconnects. Read the label information to be sure you use the right kind of eyewear, if required.

GLOVES

The need for gloves also varies. For example, some fumigants require you to wear gloves because of possible skin irritation. Other fumigants, particularly liquid products, do not require gloves. Some may even prohibit you from wearing gloves. Some fumigant gases, such as methyl bromide, can cause serious injury to the skin if clothing or jewelry holds the gas tight against the skin. This is the reason that gloves are often not recommended for fumigant application. Always consult the label to determine what precautions you should take.

RESPIRATORS

The most important PPE for fumigators is the respirator. A respirator is a personal protective device that is worn on the face, covers at least the nose and mouth, and is used to reduce the wearer's risk of inhaling hazardous gases. Respirators provide clean air to workers during fumigation and aeration. Respiratory protection is required when concentration levels of fumigants are unknown or above specified levels.

FUMIGANT EXPOSURE LIMITS

Fumigant labels and the SDS list the maximum fumigant concentrations in which applicators can work without respiratory protection, called exposure limits. Gas concentrations greater than specified levels indicate that exposed workers must use respiratory protection equipment. These gas concentrations are known as **Permissible Exposure Limits (PELs)** or **Threshold Limit Values (TLVs)**. These numbers represent the maximum concentration of a chemical considered safe for most people when exposed 8 hours a day, 40 hours a week, also known as the **Time-Weighted Average (TWA)**. The goal is to keep your exposure to chemicals below these limits to prevent the development of adverse health effects (see Table 2).

Table 2. Fumigant concentration requiring respiratory protection:

Fumigant	Gas Concentration (PEL)	Respiratory equipment required
Phosphine	Less than 0.3 ppm	None required
	0.3 – 15 ppm	NIOSH* approved full face canister respirator – hydrogen phosphide canister combination
	Greater than 15 ppm or when concentration is unknown	NIOSH approved self-contained breathing apparatus (SCBA)
Sulfuryl Fluoride	1 ppm or less	None required
	Greater than 1 ppm or when concentration is unknown	NIOSH approved self-contained breathing apparatus (SCBA)
Methyl Bromide	5 ppm or less	None required
	Greater than 5 ppm or when concentration is unknown	NIOSH approved self-contained breathing apparatus (SCBA)

*The National Institute for Occupational Safety and Health (NIOSH) tests and certifies (or approves) respiratory protective devices.

Label and SDS information may provide other designations. For example, if you see "STEL," it means the chemical has a 15 minute exposure limit called a **Short Term Exposure Limit**. You may also see "IDLH," which means Immediately Dangerous to Life and Health. Concentrations above this level could cause death or irreversible health effects.

RESPIRATOR TYPES

There are two basic types of respirators that are suitable for fumigation: full-face canister systems and self-contained breathing apparatus. Other respirators such as dust/mist filtering and half-mask cartridge respirators do not provide adequate protection from fumigants.

Full-Face Canister Respirator

Full-face canisters are normally designed to cover the eyes as well as the nose and mouth (see Figure 28). Full-face canisters do not supply an independent source of air. They contain a **filter** that purifies the air by removing the fumigant as air is pulled through the canister.

Figure 28. Full face canister respirator.

The effective life of an individual canister varies according to the fumigant concentration, humidity, and respiratory rate of the applicator. Maximum limits are stated on each canister or on the instructional information that accompanies each canister. The expiration date of the canister is the date the canister can no longer be used, regardless of whether or not it was ever unsealed. An expired canister should be crushed before it is discarded so that no one will mistakenly reuse it.

To properly use a full-face canister, do the following:

1. Determine the level of fumigant in the atmosphere you are entering. Make sure the concentration does not exceed the level the canister is designed to purify.
2. Read the canister label to match the canister with the fumigant to be used and be sure the canister matches the respirator used.
3. When beginning to use the canister, remove the seals only when attaching the canister to the respirator. Be sure to remove both the top and bottom seal.
4. Log the date and time when the seals were removed. This begins the life of the canister. Always dispose of any canister that has been unsealed for eight hours or more.
5. Canisters and cartridges should be replaced whenever they are damaged, soiled, or cause noticeably increased breathing resistance. Do not rely on odor or taste.
6. Most manufacturers provide information on their website to help in determining the appropriate change out schedule for their product.

Self-Contained Breathing Apparatus (SCBA)

A **self-contained breathing apparatus (SCBA)** provides clean air for breathing from an independent air supply. SCBA's consist of a full-facepiece and an independent air supply that is carried by the wearer (see Figure 29). The breathable air is typically compressed air in a tank. The gas is continually fed into the facepiece each time you breathe.

Figure 29. Self-contained breathing apparatus (SCBA).

A SCBA is required when entering an area where the concentration of the fumigant is unknown or greater than:

- 1 ppm when using sulfuryl fluoride
- 5 ppm when using methyl bromide
- 15 ppm when using phospine (see Table 2).

The amount of time you can use an SCBA before the supply of breathing air runs out depends on several variables:

- Your work rate
- Your physical condition and size
- Holding capacity and percent air fill of the SCBA tank when put into use
- Condition of the SCBA regulator

Before using an SCBA, you should be adequately trained in how to store, inspect, maintain, and fit test the SCBA respirator to be used. You should determine that it is in good working order, has an adequate air supply for the job at hand, fits properly, and provides an adequate seal around the face. You should also participate in periodic training exercises.

Two SCBAs must be on hand during each fumigation in case you need to make an emergency entrance into a fumigation enclosure. The second SCBA is for potential use by another trained person who must be on site if you enter the fumigation enclosure.

MEDICAL EVALUATION

Before wearing a respirator, you must be medically evaluated to ensure that your health and lung capacity are suitable for this task. After a preliminary screening, a medical practitioner may determine that a physical exam is required. For example, if you have a heart condition, a medical evaluation is necessary before respirator fit testing. You must be reexamined by a healthcare professional if your health status, respirator style, or use conditions change. Some people do not medically qualify to wear respirators.

RESPIRATOR FIT AND CARE

After being cleared to wear a respirator, you must be checked to determine whether your respirator provides an acceptable fit and trained on how to use each specific respirator you will wear. **Fit testing** is required for each respirator and is repeated annually. Follow-up fit testing is required under certain circumstances:

- The facepiece style has changed
- Your face has changed physically (e.g., weight change or dental work), affecting fit
- The fit is unacceptable
- You request a fit
- Company policy calls for a fit

You should have your own mask to ensure proper fit. You may share tanks and straps.

Conduct a **fit check** before each use. This safety test, also called a user seal check, helps you make sure that the respirator forms a complete seal around your face. To do this, first put the respirator on and tighten the straps. Cover the exhalation valve and gently exhale. If you can do this without feeling a rush of air, you have a good seal. Next, cover the intake portion of the cartridge with your hands and inhale gently. If you have a good seal, you should not be able to pull any air through the seal against your face.

Be sure to clean your respirator according to manufacturer instructions, inspect it regularly, and store it properly. When not being used, keep all respirators in a sealed bag and away from other pesticides and/or contaminants.

Figure 30. Fumiscope®, a thermal conductivity analyzer, has been used for many years to detect both methyl bromide and sulfuryl fluroride at high concentrations.

GAS DETECTION DEVICES

To ensure adequate protection, the concentration of the fumigants used must be measured. **Gas detectors** read samples of air that are combined with toxic gases and provide a part per million (ppm) count of gas in that sample. All detection devices must be used and maintained according to the manufacturer's instructions and recommendations. Many types of detection devices require periodic calibration to ensure an accurate measurement. Calibration should be performed according to manufacturer recommendations and fumigant label requirements. Some manufacturers will require that the unit be sent to them or to an authorized distributor for calibration.

Different equipment is required depending on need for low concentration safety monitoring or high concentration efficacy monitoring. Sensors for high concentration monitoring do not have the sensitivity to serve for safety monitoring at low levels. For example, low concentration electronic phosphine instruments typically operate in a range of 0-5 or 0-20 ppm with a sensitivity of 0.1 ppm or less. High concentration sensors with a sensitivity of only 1.0 ppm are inadequate for detection at the critical aeration "safe" level of 0.3 or less.

HIGH CONCENTRATION MONITORING DEVICES

High concentration **monitoring** devices detect high fumigant gas concentrations that should be present from the start to the end of a fumigation inside the fumigated enclosure. Thermal conductivity analyzers (TCAs), such as the Fumiscope® (Key Chemical and Equipment Company), are used to measure high concentrations of sulfuryl fluoride and methyl bromide during the fumigation (see Figure 30). Air samples are collected through gas reading lines that typically consist of ¼ inch tubing placed at critical spots inside the fumigated enclosure prior to introducing the gas. Lines are extended to a convenient spot outside the fumigation enclosure, gas is introduced, and readings are taken periodically. You get measurements of the gas concentration at each reading line inlet for each period a reading is made. Fumiscopes must be calibrated at least once a year by the manufacturer or a distributor.

Figure 31. Detecting gas levels outside a grain bin with a low concentration detector.

LOW CONCENTRATION GAS DETECTORS

Low concentration gas detectors measure fumigant concentrations at the PEL. These devices (also called **clearance** detectors) are used to test the air space in a fumigated enclosure to confirm the fumigant has aerated to concentrations at or below the PEL. The low concentration gas detector also can be used to periodi-

cally test, per label directions, nearby air space outside of the fumigated enclosure during fumigation and aeration to ensure that workers and **bystanders** are not over-exposed to the fumigant (see Figure 31).

Following are examples of low concentration gas detectors:

- The Dräger Pac 7000® is a commonly used personal safety detection device for phosphine with a low range sensor (0-20 ppm).
- The Interscan® gas analyzer is a clearance device to detect low concentrations (0-50 ppm) of sulfuryl fluoride for re-entry into the treated area. It must be calibrated within 30 days of use.
- Infrared (IR) analyzers use infrared technology to detect low concentrations of fumigants (0-200 ppm) to allow safe re-entry and final clearance of fumigated spaces. IR analyzers must be calibrated at least once a year by the manufacturer or a distributor. Examples include the SF-ExplorIR® and Miran SapphIRe® analyzer for use with sulfuryl fluoride.

DUAL PURPOSE DEVICES

Dual purpose devices detect both high and low fumigant concentrations that should or should not be present. When using dual purpose devices loaded with both high and low concentrations simultaneously, exposing a sensitive low concentration sensor to high concentrations will "burn out" the low concentration sensor prematurely.

Following are examples of dual purpose devices:

- The Dräger X-am 5000/5600® can measure up to five gases at both high and low fumigant levels.
- The ATI PortaSens II® can be used at low ranges (0-10 ppm) and high ranges (0-2000 ppm) and should be calibrated every 6 months. Once a year is sufficient for calibration if it is used less frequently.
- The Dräger Pac III® can be used either at low range (0-20 ppm) or high range (0-1000 ppm) as personal safety detection devices.
- Both the Dräger Accuro® pump and colorimetric tubes and the Matheson-Kitagawa® pump and precision detector tubes are available for reading high and low gas levels (see Figure 32). Tubes and pumps are fumigant- and pump-specific and can be used for monitoring for leaks, but are more suitable for final clearing. **Detector tubes** are glass vials filled with a chemical reagent that reacts to specific fumigants. To use, a sample of air is drawn through the tube with a bellows-type hand pump. If the targeted fumigant is present, the indicator in the tube changes color. The length of the color change is an indication of the concentration of the fumigant present. No calibration is required but the tubes do have expiration dates.

Figure 32. Colorimetric detector tubes and pump.

SELECTION OF GAS DETECTION DEVICES

Information about gas detection equipment is available from fumigant manufacturers and distributors. Safety equipment catalogs also provide valuable information and help in choosing the appropriate equipment. Consider the following when selecting detection equipment:

- Label requirements
- Detection limitations
- Simplicity of operation
- Reliability
- Performance requirements and features
- Support and service
- Options and accessories
- Cost
- Accuracy

Chapter 7
Planning and Preparation

LEARNING OBJECTIVES

After studying this chapter, you should be able to
- List the factors to consider when selecting a fumigant
- Explain how to select a fumigant labeled for the intended use
- Discuss why the type of structure affects fumigant confinement
- List the factors to consider when determining fumigant dosage rate
- Calculate the volume of rectangular structures, buildings, and grain bins
- Explain why safety procedures should be reviewed before a fumigation
- Explain how to prevent exposure to bystanders and nontarget animals
- Describe how the quality of sealing can affect the amount of fumigant needed
- Explain how sealing can affect the length of time necessary to kill the target pest
- List which type of sealing is best for a structure or commodity (type of structure, ground material)
- Describe the materials needed in tarp, tape-and-seal, and permanent sealing
- Describe why smoke may be used prior to sealing grain bins
- Identify where placards must be placed at a treatment site
- Explain why safety equipment should be checked prior to a fumigation

SELECT A FUMIGANT

Additional preparation steps are required for sulfuryl fluoride products registered for non-commodity fumigation (see "Preparation" in the Appendix).

Fumigant selection should be based on the target pest, the commodity to be fumigated, and the type of structure. Consider all factors that will control the pest and allow you to do the job as efficiently as possible. Consider such factors as:
- **Toxicity** to the target pest
- Ability to penetrate
- Corrosiveness, flammability, and potential for explosion
- Warning properties and detection methods
- Effect on seed germination and finished product
- Residue tolerances
- Availability
- Ease of application
- Cost

Read and review the container label to make certain the fumigant you select is labeled for the intended use. For example, although a fumigant may be labeled for use on stored grain, it may not be registered for use on all grains or in empty storage structures. Do not use fumigants on commodities or sites that are not listed on the label.

INSPECT THE FUMIGATION SITE AND COMMODITY

Before fumigating, become fully acquainted with the site and commodity to be fumigated. Inspect the structure and/or area to determine its suitability for fumigation. If you plan to treat a commodity within a structure, learn about the structure. Consider the condition of the structure and the type of construction. What does it consist of—wood, brick, concrete? 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.

Find out how the commodity is stored and its condition. Do not attempt fumigating grain unless the grain temperature is 40°F or higher. Take necessary precautions to ensure grain storage is safe to enter. When entering grain bins, confined space entry permits may be required by OSHA regulations and should be considered when planning a fumigation. Before applying fumigants, level the grain surface and break up any caking on the surface of the grain.

Monitor the pest(s) you plan to control to determine the pest's life stage and where the populations are highest. If possible, get a previous treatment history of the commodity.

Depending on the fumigant, certain material should be removed or protected before fumigation (see Chapter 1). Read the label to determine what materials could be harmed.

CALCULATE FUMIGANT DOSAGE

To achieve the target dosage, you are challenged with the task of distributing and maintaining a concentration of fumigant over the **exposure period**, the time required for the fumigant to kill target pests. Because of the multitude of factors, no two fumigations are identical. To specify a single dosage rate for all conditions would rarely be correct — usually it would be either too much or not enough for expected pest control.

All fumigant labels provide information on the recommended dosages required to effectively treat stored commodities. For some fumigants, such as sulfuryl fluoride, specialized calculators or computer-based programs are used as part of the label to determine dosage. Using less fumigant than is recommended can result in a gas concentration too low to be effective. Using more fumigant than recommended is illegal, adds cost, and may not increase pest control.

When determining the amount of fumigant to apply, consider the following:
- Target pest
- Type of structure and its size
- Temperature
- Humidity
- How well the structure can be sealed
- Label restrictions
- Fumigant exposure period

Dosage depends on the total volume of the space being treated and not on the amount of commodity it contains, since the gas fills the whole space, regardless of the amount of grain inside. An exception would be if you placed a tarp over the top of the grain to keep the gas within the commodity. Then you would calculate only the total volume of the space of the grain under the tarp (see Example 4).

CALCULATE VOLUME OF STRUCTURE

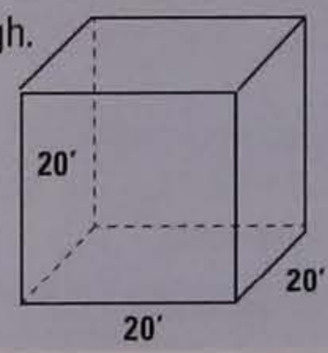
RECTANGULAR STRUCTURES

To determine the volume of a rectangular structure, multiply the length by the width and then multiply the result by the height. Use this calculation for truck trailers, railcars, 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.

Volume of a rectangle = Length x Width x Height

EXAMPLE 1: A structure is 20 feet long, 20 feet wide, and 20 feet high. What is the volume?

Volume of rectangle = Length x Width x Height
= 20 feet x 20 feet x 20 feet
= 8,000 cubic feet



EXAMPLE 2: What is the volume of a stack that is 10 feet 6 inches high, 42 feet 3 inches long, and 10 feet 9 inches wide?

Volume of rectangle = Length x Width x Height
= 42.25 feet x 10.75 feet x 10.5 feet
= 4,769 cubic feet

BUILDINGS

Calculating the volume of a warehouse, grain storage building, or similar structure with a pitched roof is usually more involved. To determine the total volume, you must add the volume of the rectangle to the volume of the roof.

$$\text{Volume of a roof or triangle} = \frac{\text{Length x Width x Height}}{2}$$

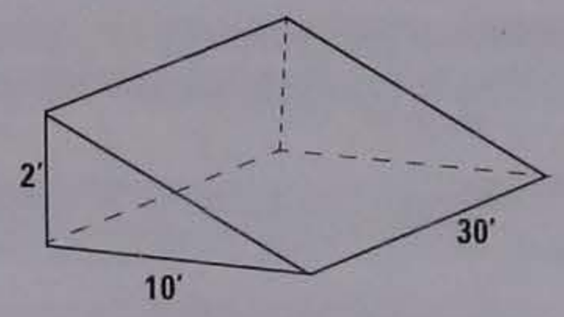
EXAMPLE 3: The volume of a roof is 30 feet long, 10 feet high, and 2 feet tall. The structure is 20 feet long, 20 feet wide, and 20 feet high. What is the total volume of the roof and structure?

Volume of roof = $\frac{\text{Length x Width x Height}}{2}$

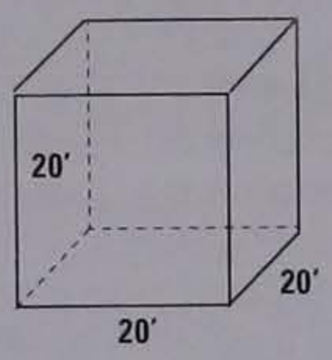
= $\frac{\text{30 feet x 10 feet x 2 feet}}{2}$

= $\frac{\text{600 cubic feet}}{2}$

= 300 cubic feet



Volume of structure = Length x Width x Height
= 20 feet x 20 feet x 20 feet
= 8,000 cubic feet



Total Volume = 300 cubic feet + 8,000 cubic feet
= 8,300 cubic feet

GRAIN BINS

Grain bins are usually cylindrical, with cone-shaped caps. To calculate the volume of a grain bin, you must know how to figure the volume of a cone and a cylinder.

Volume of a cylinder = 3.14 x r^2 x h

Where r = radius (½ of the diameter of the circular base of the bin),

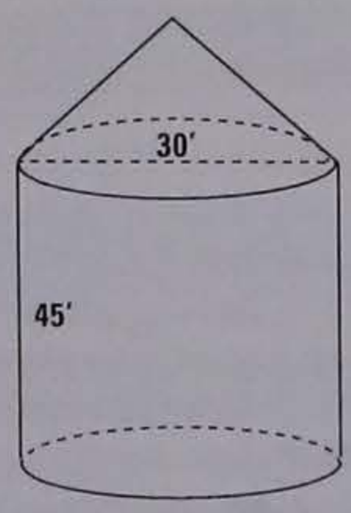
h = height of the cylindrical part of the bin, and

3.14 is a constant often called "pi" and represented as π

Volume of a cone = $\frac{\text{3.14 x } r^2 \text{ x h}}{3}$

EXAMPLE 4: The height of a tarped grain mass in a bin is 45 feet. The radius of the bin is 15 feet. What is the total volume of the tarped grain mass?

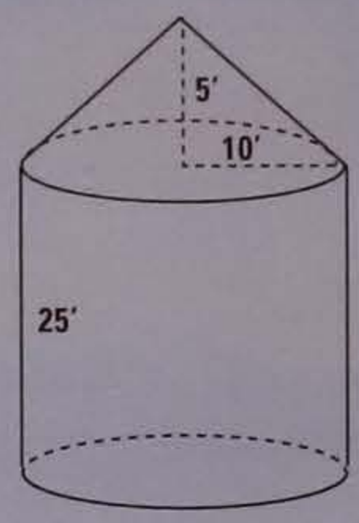
Volume of cylinder = 3.14 x r^2 x h
= 3.14 x (15 feet)^2 x 45
= 31,792.5 cubic feet



EXAMPLE 5: The height of the cylindrical part of a 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. What is the total volume of a bin?

Volume of cylinder = $3.14 \times r^2 \times h$
$= 3.14 \times (10 \text{ feet})^2 \times 25 \text{ feet}$
$= 7{,}850$ cubic feet

Volume of cone = $\frac{3.14 \times r^2 \times h}{3}$
$= \frac{3.14 \times (10 \text{ feet})^2 \times 5 \text{ feet}}{3}$
$= \frac{1{,}570 \text{ cubic feet}}{3}$
$= 523.3$ cubic feet



Total Volume = 523.3 cubic feet + 7,850 cubic feet
= 8,373.3 cubic feet

DEVELOP A MONITORING PLAN

Consult with company officials to develop an appropriate monitoring plan ensuring that nearby workers and bystanders are not exposed to fumigant levels above the allowed limits during application, fumigation, and aeration. This plan must also demonstrate that nearby residents will not be exposed to fumigant concentrations above the allowable limits. The monitoring plan must also be documented in the FMP.

REVIEW SAFETY PROCEDURES

Prior to each fumigation, review any existing FMP, SDS, and other relevant safety procedures with company officials and appropriate employees. Identify the safety measures and emergency procedures required by the label.

If possible, rehearse the fumigation process and emergency evacuation. Rehearsals provide the opportunity to detect problems in emergency plans, and to correct them. It also allows the workers to become familiar with procedures to follow and actions to take in an emergency.

NOTIFY AUTHORITIES

There may be state regulatory requirements in addition to those in the applicator's manual.

Check to see what the local requirements are for notification procedures at the fumigation site. If required by fumigant labeling, notify appropriate agencies (e.g., fire department, police department) of the fumigation ahead of time. Information to provide to these agencies can include the following:

- The names and telephone numbers of all appropriate personnel in charge
- SDS for the fumigant used and a copy of the label
- The FMP

ALERT PERSONNEL

Inform all employees of the fumigation schedule and potential hazards to life and property. Provide them with the required safety measures and emergency procedures. Before releasing the fumigant, make a final check to clear all personnel and **nontarget** animals from the space to be fumigated.

SEAL THE SITE OR COMMODITY

Sealing is done to make the site or commodity as gas-tight as practical before introducing a fumigant. Sealing enclosures may include the use of wood, plastic, fiberglass, steel, or concrete. You can seal a structure or commodity in one of two ways:

1. Place a gas-tight tarp over the item or structure
2. Tape-and-seal all potential openings within a structure with plastic and tape (see Figure 33)

Proper sealing of commodities and structures is necessary to confine the fumigant in sufficiently toxic concentrations for the required length of time to kill insect pests. 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)
- 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)

TARP SEALING

To seal an item or entire structure, cover it with a gas-proof tarp of at least 4 mil thickness (6 mil is ideal) polyethylene sheeting. Cover all sharp edges with protective material, such as padding, to keep them from tearing the tarp. Seal tarp seams by rolling the edges of two tarps together and securing the roll with **clamp**s (see Figure 34). Mend or seal holes in the tarp with durable tape. To get a good seal, it may be necessary to place a section of the tarp material beneath as well as over the commodity. Use loose sand, sand snakes, or water snakes to establish a good **ground seal** (see Figure 35).

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.

Structures made of wood and other permeable materials and those with large holes and cracks are most suitable for sealing an entire structure. **Stacks**, containers, and commodities may be fumigated using a tarp alone.

TAPE-AND-SEAL

Structures that are well-built are most suitable for **tape-and-seal** fumigation. In a tape-and-seal fumigation, spray adhesive and tape are used to adhere plastic sheeting to windows, doorways, vents, and other openings of a structure with an otherwise impermeable exterior structure (e.g., concrete or steel) (see Figure 36). In grain bins, you should also seal unloading augers, roof exhaust vents, and eave gaps (openings where the roof meets the sidewalls) (see Figure 37).

When determining what needs to be sealed in a structure, imagine turning it upside down and filling it with water. The areas where the water would leak out are the areas that you need to seal.

Figure 33. Tape-and-seal fumigation.

Figure 34. Fumigation tarp clamped for a tight seal.

Figure 35. Snakes can be filled with sand or water.

Figure 36. Spray adhesive and tape used in a tape-and-seal fumigation.

Figure 37. Tape sealing to prevent leaks in a grain bin fumigation.

Follow these guidelines when sealing:
- Make sure you have a clean, firm, and dry surface to seal to
- For grain bins, seal outside whenever possible to minimize the need to enter the confined space containing grain
- Seal with the elements in mind—windy conditions may require additional sealing
- Perform all sealing with "containing" a gas in mind

PERMANENT SEALING

In any one of these types of sealing, your job will be made easier by permanently sealing cracks and unused openings. In warehouses and processing plants, expanding foam sealants and silicone caulking may be used with preapproval from management at the fumigation site. Foam sealants and caulking are used to cover cracks and unused openings around windows, doors, and equipment or electrical conduits through walls, ceilings, or junctions penetrating walls to outside or non-fumigated areas.

One method of finding holes or leaks in a grain bin is to use smoke. Prior to filling the bin, a smoke canister is released within the bin. Points where smoke escapes can be marked with paint or other marking substances and later sealed with a caulking compound or sealant.

In bins, the following areas may be permanently sealed:
- Exterior under-roof vents
- Roof deck-to-wall gaps
- Clearance openings around centrifugal direct drive motor shafts
- Bolts missing from bolt holes
- Gaps between flanges on aeration fans connected to transition ducts
- Aeration duct entrance through the bin wall or concrete foundation at the base

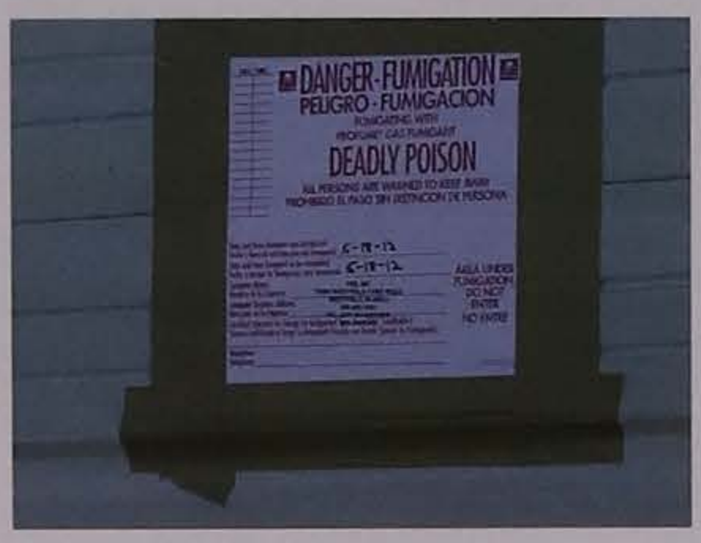


Figure 38. Warning placard.

PLACARD AREAS TO BE FUMIGATED

Before fumigating, areas to be fumigated must always be clearly posted to direct others to stay away. Warning placards inform the public during fumigation and aeration (see Figure 38). Individual fumigants include detailed instructions for the posting of warning placards on fumigated structures. The label specifies the wording and content that must appear on warning placards. Placards must be placed on exterior sides of the treatment area and at all entrances. Read the fumigant labeling for additional requirements on placarding.

CHECK SAFETY EQUIPMENT

Confirm that the required safety equipment is in place and the necessary personnel is available to complete a safe and effective fumigation. Check and adjust all safety and application equipment. Be sure the components can withstand the contact with the fumigant.

It is recommended to arrange for standby equipment and/or replacement parts for application equipment, PPE, and gas detectors. Outline an alternate plan of action. 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.

Chapter 8
Application

LEARNING OBJECTIVES

After studying this chapter, you should be able to
- Explain why fumigators should always work in pairs
- Explain how fumigation sites can be secured
- Describe the differences between cylinderized and pellet/tablet fumigant release
- Explain how fires and explosions can occur when using solid fumigants
- Explain why measuring gas concentrations inside a fumigation enclosure is important
- State fumigant concentrations requiring leak repair for phosphine, sulfuryl fluoride, and methyl bromide
- List the factors that affect the length of the exposure period
- Define equilibrium, aeration, and clearance
- Explain why aeration is important
- Identify the fumigant concentration clearance requirements for phosphine, sulfuryl fluoride, and methyl bromide

Fumigants are valuable tools as long as they are used properly. Read and follow all instructions on the label to ensure a safe and effective fumigation.

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. This person can assist you immediately if you become injured while working around these products. Fumigant labeling requires two persons trained in fumigant use to be present when there is the greatest potential for worker exposure: during fumigant introduction, reentry into the fumigated structure before aeration, initiation of aeration, and during reentry when testing for clearance.

SECURE THE FUMIGATION SITE

All entrances to structures should be locked during fumigation and access allowed only to authorized persons, and even then only in an emergency. If there is a fence surrounding the structure, the best practice is to lock the gate or otherwise secure the site (e.g., blocking entrances) during the fumigation process. Depending on fumigant labeling requirements, the use of **secondary locks** to further guard against unauthorized entry may be required. Use of a security guard may be prudent under extremely sensitive conditions, such as fumigating a building in the middle of a town. Always make sure to inform other people who regularly use the building about the fumigation.

Sulfuryl fluoride products registered for non-commodity fumigation have specific requirements for securing the structure (see "Secure the fumigation site" in the Appendix).

Do not enter the area where fumigant gas is being discharged, except in extreme emergencies.

RELEASE FUMIGANT

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

Figure 39. Releasing cylinderized gas through the introduction hose.

Sulfuryl fluoride products registered for non-commodity fumigation have specific requirements for introduction into the structure to prevent damage to delicate textiles, furnishings, floor and wall coverings, and other contents (see "Fumigant introduction" in the Appendix).

CYLINDERIZED FUMIGANTS

Gas fumigants come packaged under pressure in large steel gas cylinders or small metal cans. When using fumigant from a large cylinder, weigh the cylinder on a hanging or platform scale during introduction to measure and apply the required amount of fumigant. Weighing the cylinder is not necessary if the total contents of a full cylinder will be applied.

Gas is injected into the treatment area through one or more introduction hoses or **shooting tubes**, with the applicator and fumigant cylinder located outside the fumigated space (see Figure 39). Make sure that the hose discharges away from you. Releasing fumigant too fast may cause rapid cooling of the fumigation site, resulting in poor fumigant distribution and/or condensation of water vapor, depending upon the fumigant. The rate of introduction of the fumigant is controlled by the length and inside diameter of the introduction hose. The longer the hose and more narrow the inside diameter, the slower the introduction rate. The rate of introduction for sulfuryl fluoride should not be reduced by partially closing the cylinder valve, which can result in frosting of the valve and introduction hose. Slow release may prevent the fumigant from reaching the effective concentration quickly enough to control the target pests.

Fans or blowers are used to aid in fumigant distribution. Some grain storage structures have built-in aeration or recirculation systems. These devices regulate the temperature and moisture content of the grain. The use of fans or recirculation systems should be continued until the desired concentration of fumigant is achieved uniformly throughout the fumigated space.

PELLET OR TABLET FUMIGANTS

Figure 40. Releasing aluminum phosphide tablets.

Keep all phosphide containers tightly closed until it is time to apply the fumigant. Then open the containers in the open air or near an exhaust fan. To open the container, invert it several times, point it away from your face and body, and slowly loosen the cap (see Figure 40). Do not open the containers in a flammable atmosphere.

The applicator's manual provides directions on how to fumigate farm bins, flat storages, rail cars and other transport vehicles, vertical storages, mills, food processing plants and warehouses, tarped commodities, barges, small sealable structures, beehives, and in-transit **ship holds**. This includes where and how to place the fumigant.

Too much aluminum phosphide in any one spot can lead to fires and explosions. Tablets or pellets should never be stacked on top of each other or piled because doing so interferes with the proper release of the phosphine gas and can create a fire hazard. Never place aluminum phosphide on a wet surface or in standing water since it will evolve the gas too fast and could possibly ignite or explode. Once tablets or pellets have been exposed to air, do not reseal them since they may ignite or explode spontaneously.

MONITOR FUMIGANT

Measuring gas concentrations inside a fumigation enclosure using high concentration gas monitors allows you to:

- Check if the correct quantity of gas has been introduced into the fumigation enclosure
- Determine when the gas inside the fumigation enclosure is evenly distributed, and when to start timing the exposure period
- Make dosage corrections to ensure that the fumigation will be successful
- Determine if and when the target endpoint (accumulated dosage of gas – concentration x time) has been reached

After the gas has been introduced to a structure, use a low concentration gas detector to check for fumigant leaks around the exterior perimeter of the fumigated enclosure (see Chapter 6). Seals should be checked with the detector to ensure significant amounts of gas are not leaking. Leaks must be repaired to minimize loss of fumigant and reduce risk of exposure to bystanders and/or occupants of nearby buildings (see Table 3).

Monitoring is very important. You would not drive your car on a trip if it did not have a functioning gas gauge. Likewise, you should not fumigate if you do not have an effective monitoring tool to show the gas concentration level.

Table 3. Fumigant concentration outside fumigation enclosure requiring leak repair:

Fumigant	Gas Concentration (PEL)
Phosphine	Above 0.3 ppm
Sulfuryl Fluoride	Above 1.0 ppm
Methyl Bromide	Above 5.0 ppm

DETERMINE EXPOSURE PERIOD

The exposure period does not start until monitoring shows that the concentration of fumigant gas inside the fumigation enclosure has reached the target concentration throughout the enclosure, often called **equilibrium** (see Figure 41). Equilibrium within grain storage is commonly not achieved due to convection currents. Any area of the fumigated enclosure that does not reach the target concentration for the required exposure time can result in poor pest control.

The length of the exposure period differs depending on the:

- Fumigant being used
- Dosage of fumigant applied
- Life stage and species of the target pest
- Temperature of the commodity and space being fumigated
- Tightness of seal in the fumigated enclosure

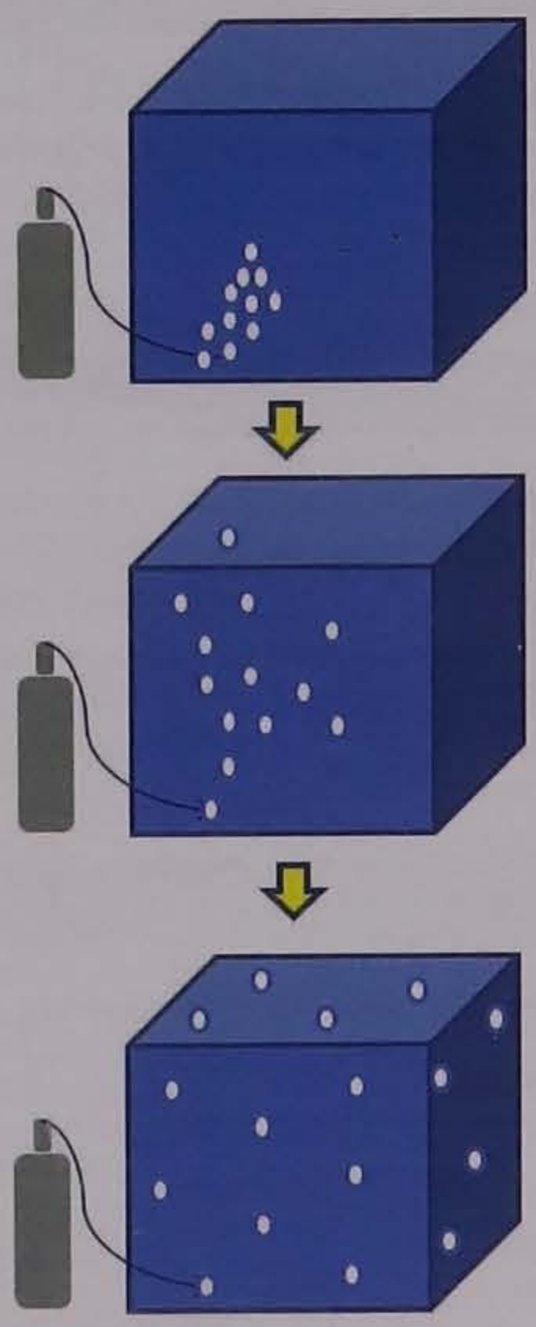


Figure 41. Equilibrium is reached when fumigant molecules are evenly spaced within the confined area.

Sulfuryl fluoride products registered for non-commodity fumigation have specific procedures required for aeration and clearance testing prior to reoccupancy (see "Fumigant aeration and clearance testing" in the Appendix).

AERATE FUMIGANT

Aeration, the process by which fumigated air is replaced with fresh air, must follow all fumigations. Proper aeration is important for your safety and the safety of your clients. Procedures for aeration vary with the fumigant, the area, and the product(s) being fumigated.

Common ways to aerate include the use of fans or other ventilation equipment or passive aeration in open air. Wear the label-recommended respiratory protection when beginning the aeration. Direct air being exhausted from the fumigation enclosure away from work areas, sensitive plants, and neighboring property.

During aeration, check the air outside and inside the fumigation enclosure. Measure gas concentrations with a low concentration gas detector. Read and follow the label information for aeration procedures specific to each fumigant product that you use.

CLEAR STRUCTURE

At the end of the aeration process, you must use low concentration gas detector equipment to confirm that the gas concentrations are at or below the PEL in the commodity or structure (see Table 4).

Table 4. Fumigant concentration requirements for clearance:

Fumigant	Gas Concentration (PEL)
Phosphine	0.3 ppm or below
Sulfuryl Fluoride	1.0 ppm or below
Methyl Bromide	5.0 ppm or below

Warning placards can then be removed. Once authorities have been notified that fumigation aeration is completed, personnel are allowed to enter or re-enter the fumigated area.

Appendix—Sulfuryl Fluoride Products Registered for Non-Commodity Fumigation

STRUCTURAL PESTS FOR FUMIGATION

Refer to labeling, which include the manuals, for sulfuryl fluoride products. Fumigation is typically conducted for structure-infesting pests which are cryptic and can infest areas inaccessible for localized treatments. Examples of these pests can include drywood termites, wood-boring beetles, and bed bugs. Structural fumigation is also conducted for extensive infestations of pests for which other treatments have failed and/or rapid elimination is required for human safety, prevention of damage to structures and contents, or quarantine requirements. Examples of these pests can include rodents, spiders, cockroaches, carpet beetles, and clothes moths.

RESIDUE TOLERANCES

Sulfuryl fluoride products registered for non-commodity fumigation do not have residue tolerances. See "Preparation – items to remove or seal" below for commodity preparation.

CHLOROPICRIN

Chloropicrin is applied as a warning agent prior to release of sulfuryl fluoride products registered for non-commodity fumigation. Refer to the product labeling for specific structures, such as passenger railcars and permanent and temporary fumigation chambers, when application of chloropicrin may not be required if other conditions are met (such as use guards and/or secondary locking and barricading).

APPLICATION

Chloropicrin is introduced into the fumigated space five to ten minutes prior to release of sulfuryl fluoride. Chloropicrin is poured onto wicking material in an evaporation container placed in the air stream of a fan. The evaporation container should not be made of magnesium, aluminum, or their alloys as chloropicrin can be severely corrosive to such metals. Follow label directions for the dosage rate for chloropicrin, maximum amount of chloropicrin to apply per evaporation container, and the minimum number of chloropicrin release sites based on the volume of the space to be fumigated. When applying chloropicrin at multiple chloropicrin introduction points within a structure, start at the point farthest from the exit and work toward the exit.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The PEL for chloropicrin is 0.1 ppm. Due to the intrinsic warning characteristics of chloropicrin, most persons can detect chloropicrin at concentrations near the 0.1 ppm PEL.

Appendix—Sulfuryl Fluoride Products Registered for Non-Commodity Fumigation

PERSONAL PROTECTIVE EQUIPMENT (PPE)

All persons applying chloropicrin must wear long-sleeved shirt and long pants (or the equivalent), chemical-resistant gloves, and protective eyewear or face shield. Goggles are not permitted to be worn as eye protection. Either a positive pressure self-contained breathing apparatus or combination air-supplied/SCBA must be worn when applying chloropicrin to more than two chloropicrin introduction points within a single fumigated structure. Follow manufacturer's instructions for cleaning and maintaining PPE. Follow sulfuryl fluoride labeling directions for cleaning of washables.

LOW CONCENTRATION DETECTOR

A low concentration detector is not required when using chloropicrin as a warning agent due to intrinsic warning qualities of chloropicrin. In addition, the specific aeration procedures required for structures fumigated with sulfuryl fluoride products (registered for non-commodity fumigation) also effectively aerate chloropicrin. The commonly available low concentration detectors for chloropicrin (such as colorimetric tubes) typically do not detect chloropicrin below 0.1 ppm.

RECOGNIZING SYMPTOMS OF OVEREXPOSURE

Chloropicrin is a warning agent which, at very low airborne concentrations, causes irritation of the eyes and respiratory tract, tearing, and has a very disagreeable pungent odor. Overexposure by inhalation can cause blue lips and fingernails, nausea and/or vomiting, diarrhea, and abdominal pain. Onset of symptoms can be delayed. Death can result due to lung injury and/or infection. Overexposure can result in methemoglobinemia, which impairs the blood's ability to transport oxygen. Adverse effects have been reported on the heart, kidney, and liver. Exposure to the liquid during application can cause severe chemical burns to skin and eyes.

FIRST AID FOR CHLOROPICRIN POISONING

Specific first aid directions are provided in the manuals for sulfuryl fluoride products registered for non-commodity fumigation. First aid for inhalation overexposure to chloropicrin is the same as for fumigants. Skin and eyes exposed to liquid (or overexposed to gaseous) chloropicrin should be rinsed with water for at least 15 minutes. If chloropicrin (liquid) is swallowed, vomiting should not be induced unless you are told to do so by a poison control center or doctor. This can cause additional burning to the digestive and respiratory tracts. Instead, have person sip a glass of water if able to swallow. Medical treatment should be obtained for any overexposure.

CHLOROPICRIN SPILLS, LEAKS, AND FIRES

Emergency directions for spills, leaks, and fires are similar to those for fumigants, and are provided in the manuals for sulfuryl fluoride products registered for non-commodity fumigation. One exception is spill control for chloropicrin, which is packaged and applied as a liquid. Spills can be permitted to evaporate, or spilled liquid can be absorbed onto vermiculite, dry sand, earth, or similar absorbent material. The absorbent material should be thoroughly aerated outdoors prior to disposing on site or at an approved disposal facility.

TRANSPORTING CHLOROPICRIN

Chloropicrin is classified as a hazardous material by the Department of Transportation (DOT) and has extensive regulations, similar to fumigants, regarding transportation.

Appendix—Sulfuryl Fluoride Products Registered for Non-Commodity Fumigation

CHLOROPICRIN STORAGE

Chloropicrin has similar storage requirements as fumigants.

CHLOROPICRIN WASTE DISPOSAL

If the chloropicrin container is disposable and is non-returnable to the supplier, it is recommended to aerate the empty container opened, with the cap removed, within the fumigated space during fumigation. The location should be close to a fan, such as at a chloropicrin introduction site. After the empty container has aerated inside of the fumigated space, replace the cap and dispose the container in a sanitary landfill or by other approved state and local procedures.

PREPARATION

OCCUPANT NOTIFICATION

Prior to the fumigator and customer entering into a fumigation agreement, the Fact Sheet for sulfuryl fluoride must be provided to an adult occupant of the structure to be fumigated. For multi-unit structures, the Fact Sheet must be provided to an adult occupant of each currently-occupied unit. The Fact Sheet is available from the registrant/distributor for the sulfuryl fluoride product you are using.

ITEMS TO REMOVE OR SEAL

- *All persons, domestic animals, pets, and desirable growing plants* are removed from the structure prior to fumigation. Check sulfuryl fluoride product labeling for instructions regarding handling of fish tanks, and to how to exclude feral or stray animals from being in the space to be fumigated (e.g. crawl space, between the tarp and the building).
- When fumigating a single unit or room within a larger, *multi-unit structure*, such as in strip malls, townhouses, apartments, and condominiums, all units of the entire structure must be vacated and treated as if fumigated, including occupant notification, posting, securing, and aeration. However, chloropicrin is only applied in the fumigated space where sulfuryl fluoride is introduced.
- A *connected structure* is defined as any structure connected with the structure to be fumigated by construction elements (e.g., pipes, conduits, ducts, etc.) which may allow passage of fumigant between the structures. Check sulfuryl fluoride product labeling for requirements for connected structures. If labeling requires the connected structure to be vacated, that structure should be treated as if fumigated, including occupant notification, preparation, posting, securing, and aeration. However, chloropicrin is only applied in the fumigated space where sulfuryl fluoride is introduced.
- *Food, feed, drugs (including tobacco products), and medicinals* (including those items in refrigerators and freezers) can remain in the structure if they are in plastic, glass, or metal bottles, cans, or jars with the original manufacturer's air-tight seal intact or are double bagged in nylon polymer bags specified by the product label. Otherwise, these items must be removed from the structure BEFORE the fumigation is conducted. Check if the sulfuryl fluoride product labeling lists specific opened items (such as dental hygiene products, cosmetics, externally applied lotions and ointments, ice and water) that do not need to be removed or sealed in nylon polymer bags prior to fumigation.
- *Mattresses* (except waterbeds) and pillows completely enveloped in waterproof covers will need to be removed prior to fumigation if the waterproof cover cannot be removed. Check the labeling for sulfuryl fluoride product to determine if these items can be fumigated if the waterproof covers can be opened or contains built-in vents designed to permit air passage.
- Check the labeling for sulfuryl fluoride products for additional items, such as basic solutions and chlorine generating equipment, which should be removed or excluded from the fumigated space.

Appendix—Sulfuryl Fluoride Products Registered for Non-Commodity Fumigation

OPERABLE OPENINGS

Operable internal doors, internal openings to attics and sub areas, storage chests, cabinets, drawers, closets, and appliances (such as washers, dishwashers, dryers, microwave or conventional ovens) are opened prior to fumigation. Refrigerators and freezers containing sealed food items must have doors opened during aeration until the concentration of sulfuryl fluoride in them is 1 ppm or less. For tarped structures, operable windows must be opened following sulfuryl fluoride product labeling requirements.

HEAT SOURCES

All flames, including pilot lights of water heaters, gas refrigerators, ranges, ovens, broilers, dryers, gas fireplaces, etc., and glowing heating, such as those in heaters, must be turned off prior to fumigation. Check sulfuryl fluoride product labeling for guidance on shutting off and turning on natural gas or propane service.

TARPAULIN FUMIGATION

To minimize escape of gas through the soil and to avoid injury to nearby plants, dry soil between the foundation and tarp is watered prior to fumigation.

SECURE THE FUMIGATION SITE

Exterior doors and entrances must be secured by a method which is demonstratively effective in preventing entry by normal means by anyone other than the certified applicator in charge of the fumigation or persons in his/her direct supervision. Check sulfuryl fluoride product labeling to determine if a secondary locking device is required for every entrance, or if an existing locking device, such as a pin or bar for sliding glass doors or interior bolt, can be used if this lock cannot be opened from the exterior of the structure.

CALCULATE THE FUMIGANT DOSAGE

A specific calculation device is required for each sulfuryl fluoride product to determine the required fumigant dosage. The calculation devices used to calculate the dosage of sulfuryl fluoride products for non-commodity fumigation are different from the device used to calculate the dosage for commodity fumigation. Check with the registrant/distributor for the sulfuryl fluoride product you are using to ensure you have the required calculation device.

Appendix—Sulfuryl Fluoride Products Registered for Non-Commodity Fumigation

FUMIGANT INTRODUCTION

The sulfuryl fluoride release point(s) should be into the largest, open space(s) where fumigant will not be applied directly to any surface. Multiple release sites may be necessary if the structure is large, multi-story, or compartmentalized, or if a high dose rate of sulfuryl fluoride is applied.

The fumigant should be released through a suitable leak-proof hose with a minimum burst pressure of 500 pounds per square inch. The fumigant is directed into the air stream from at least one fan having a capacity of at least 1,000 cubic feet per minute for each pound of sulfuryl fluoride released per minute. Damage to structure contents can occur if insufficient fan capacity is used for the rate of sulfuryl fluoride released. It is recommended that protective sheeting, such as polyethylene plastic or tarping material, be placed under the introduction hose and fan to protect floor surfaces during application. Check sulfuryl fluoride product labeling for additional guidance.

FUMIGANT AERATION AND CLEARANCE TESTING

Specific minimums for active aeration time and fan capacity are required for aerating structures sulfuryl fluoride products labeled for non-commodity fumigation. After the required step-by-step aeration process required by labeling has been completed, the concentration of sulfuryl fluoride is tested, with an approved low concentration gas detector, in the breathing zone of each room to confirm the gas concentration is 1 ppm or less before permitting re-entry. Check sulfuryl fluoride product labeling for site specific aeration procedures, including sites such as passenger railcars and fumigation chambers.

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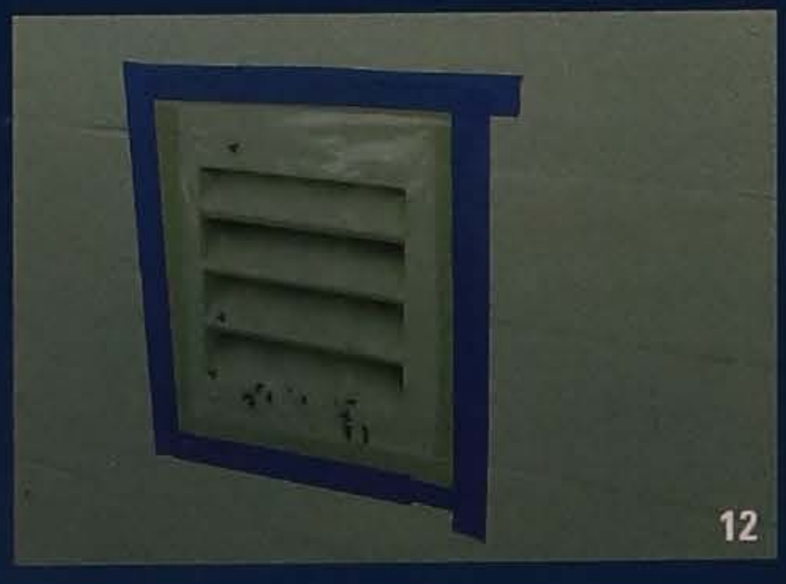

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