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Fumigation

Categories 1b - Agricultural Fumigation and 7b– Structural Fumigation

Category 1-B Agricultural Fumigation covers the use of pesticide gases in enclosed areas used for the production, storage, or transportation of agricultural commodities or to the contents of any structure used for the production, storage, or transportation of agricultural commodities.

(Photo: Kentucky Pest News)

Fumigators must be familiar with the general considerations of pesticide use:

- the laws and regulations governing pesticide registration and application
- safety
- environmental effects of pesticides
- pest biology and pest recognition
- labels and labeling.

Soil Fumigant Training for Certified Applicators

Updated soil fumigant product labels require that certified applicators successfully complete an EPA-approved training program that covers the new soil fumigant provisions. A training manual is available at: http://www.ctaginfo.org/pdf-documents/Fumigation_low.pdf

The EPA-approved training program for certified applicators using methyl bromide, chloropicrin, chloropicrin and 1,3-dichloropropene, dazomet, metam sodium, and metam potassium is available at http://www.fumiganttraining.com/

The EPA-approved training program for certified applicators using dimethyl disulfide (DMDS) – can be found at http://paladin.trainingmine.com/

This training must be completed every three years. Kentucky does not have additional certified applicator training options or requirement for soil fumigators.

Introduction

Fumigants are gases or chemicals that become gases soon after release. They can kill many kinds of pests when applied at a high enough concentration for a sufficient time. Fumigant molecules are much smaller than spray droplets or mists so they can penetrate even seemingly solid items like brick, concrete, and wood. **The effectiveness of a fumigant is lost if it is not confined to the treatment area for a sufficient time and these products do not provide residual protection.** New pests can attack as soon as a treated commodity or structure has been aerated.

Fumigation is one of the quickest and most effective ways to eliminate pests in stored commodities, shipping containers, or structures. In addition, the process is used in quarantine situations to prevent pests from being moved from one location to another.

Fumigants are some of the most toxic pesticides in the world. Many are fast acting, odorless, and invisible. Small amounts can kill people and non-target animals. Some are highly flammable; others are corrosive. **Skill and training are critical for safe use of this group of pesticides.**

Laws and Regulations

The Environmental Protection Agency (EPA), the Kentucky Department of Agriculture (KDA), and the Occupational Safety and Health Administration (OSHA) regulate the use of fumigants. Fumigators must follow their directives as well as all instructions on the fumigant label. There are fines or penalties for misusing a fumigant or for failing to properly use and maintain protective equipment.

This section **contains only selected portions from the KDA pesticide regulations covering fumigation.** The complete official regulations are available online at: http://www.kyagr.com/consumer/documents/ES_UnofficialPesticideRegulations.pdf

Fumigation Crew

At least two (2) individuals are required for the release of any fumigant.

Fumigators must work in pairs (fumigationzone.com)

Notification

Each fire and police department that has jurisdiction over the location where a fumigation is to be performed must be notified in writing at least three (3) hours prior to the time stated in the notice for the release of the fumigant.

The **fumigation notice** must include:

1. Location of the structure or enclosed space, its character and use

2. The fumigant to be used

3. The date and time of fumigant release and approximate exposure period

4. The name and day and night telephone numbers of the operator in charge

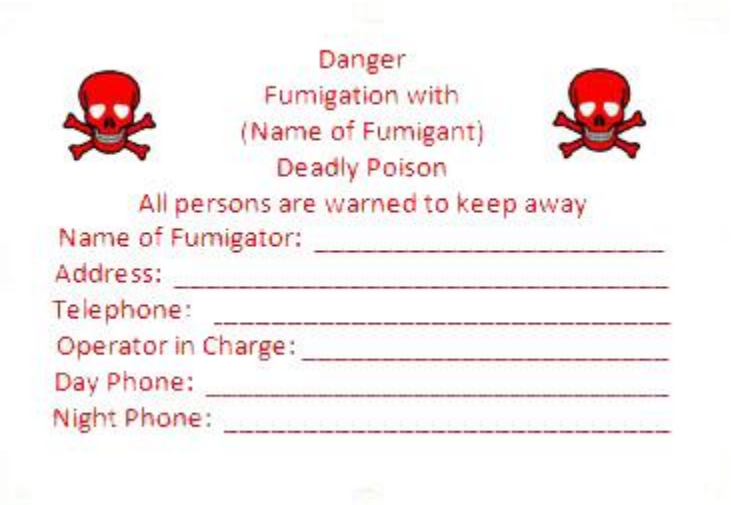
If trucks, railcars, or other common carriers are in-transit during the fumigation operation, the carrier and the receiver must be notified that fumigation has taken place.

The operator in charge must carefully inspect all parts of the structure to be fumigated and structures or enclosed spaces physically joined to or in contact with it. The operator must verify that no humans or domestic animals remain in the structure and that all necessary precautions have been taken to safeguard the lives and health of all persons.

Notice of Warning

The **occupants of the structure or enclosed space to be fumigated must be warned no later than three (3) hours in advance of any fumigation operation.** The notice must be left with a responsible adult person or be attached in a conspicuous manner on the entrance or entrances of the structures or enclosed spaces occupied by human beings.

Before releasing the fumigant, **danger signs must be posted** at the ground level on all doors or entrances as follows:



The signs must be printed in indelible red ink or insoluble paint on a white background. The words "Danger" and "Deadly Poison" must be in block letters two (2) inches high and all other letters shall be in proportion.

Guard Required

During the fumigation period, and until the structure has been ventilated and declared safe, at least one (1) capable, alert guard, must be on duty at the structure or enclosed space being fumigated. One (1) guard is sufficient for each fumigation operation unless the operator-in-charge judges that the conditions and circumstances necessitate additional guards.

(image: Formfonts.com)

The guard will keep unauthorized people from entering during the exposure period and while the structure or enclosed space is being ventilated. Unless specified, the guard requirement does not apply if a warning agent is used. Spot fumigation does not require a guard unless the operator-in-charge determines it is necessary.

The following procedures are **not considered fumigation operations** if non-restricted use pesticides are used according to label directions:

(a) aerosol dispersions; and

(b) any equipment or device that produces a fog, smoke, or mist.

Fog, smoke, mist, or aerosol application of a non-restricted use pesticide is not considered to be a fumigation.

(*photo: Fumigation Services*)

Commercial structural pest control or fumigation licenses must be renewed by June 30 of each year and are subject to all the terms and conditions of other licenses issued under KDA Pesticide Regulations.

According to federal and state law, a pesticide label is a legal document; using a pesticide in a manner that is inconsistent with label directions is illegal. **Fumigants can only be used on sites or commodities listed on the label, labeling, or the applicator manual.** Product label directions list the factors that affect the fumigant's efficiency on a particular commodity. Anyone who violates the Federal Insecticide, Fungicide, and Act may face civil penalties up to $5,000 for each offense. Criminal penalties may be as much as $25,000, one year in prison, or both. It is unlawful to transfer a fumigant from its original container to another unmarked container.

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Deciding to Fumigate

Advantages of Fumigation

Proper use by highly trained, licensed fumigators is essential.

Fumigants can:

1) quickly eradicate arthropod and/or rodent infestations in commodities and structures.

2) penetrate cracks, crevices, and some packaging materials that may limit the effectiveness of insecticide sprays and dusts to control pests.

3) leave no unsightly, odorous, or hazardous residues if the site is aerated properly.

The ideal fumigant should not change or harm the treated commodity in any way, nor should it leave any residue that could be hazardous during processing or harmful to the consumer.

Tolerance level is the amount of pesticide residue that may legally remain in or on agricultural products after treatment and aeration. Follow the label to be sure fumigant residues never exceed those levels.

Disadvantages of Fumigation

Fumigants:

1) are highly toxic to most living things, including humans. Breathing even small amounts of some fumigants can be fatal. There must be a quick response to problems and emergencies such as spills, leaks, or equipment failures.

2) require special protective equipment: self-contained breathing apparatus (SCBA) and gas detectors.

3) require tightly sealed areas. Leaks can allow fumigant concentration to drop below lethal levels before the required exposure period has elapsed.

4) some products are corrosive or flammable.

5) often require warm temperatures to be effective. This may be a problem in the winter.

Fumigation is time-consuming and expensive. The process usually requires more labor than other pest-control methods. Structural fumigation is disruptive because it requires that tenants / occupants leave. The special hazards and conditions of fumigation necessitate strict legal restrictions and regulation.

Safety Considerations

Fumigants are Restricted-Use pesticides because of their high acute toxicity, primarily by inhalation. They belong to Toxicity Category I (signal words Danger-Poison plus skull and cross bones). Their labels contain information on correct use, safe storage, and correct disposal of residues and empty containers. Labels also give antidotes and first-aid treatment in case of exposure.

People who handle fumigants must be thoroughly familiar with application procedures, safety equipment, first-aid treatment, and disposal procedures. **At least two people** must be present when using fumigants and both must have the proper respiratory equipment.

The quantity of a fumigant to be applied in a sealed building, vacuum chamber, railcar, or to packed commodities under a tarpaulin is determined by the volume (cubic feet) of the space. In most cases, there is no allowance for the space occupied by the commodity. Label instructions for each fumigant determines the basis for applying the fumigant.

Fumigant Characteristics to Consider

- What is the product's volatility and penetrating power?
- Is the product corrosive, flammable, or potentially explosive?
- What are its warning capabilities and detection methods?
- Are there potential effects on seed germination or quality of the commodities or processed products?
- What is the decomposition time and resulting residues, if any?
- What is the disposal procedure for spent materials or empty containers?
- How can seasonal or forecast weather affect the operation?

Factors That Affect Fumigation

Sealing the Structure

Proper sealing is most important step in a fumigation. The more tightly sealed the structure, the more efficient the fumigation. Wood and cement blocks are porous, so even well-sealed structures will not hold fumigant gases as well as those made of metal, plastic, masonry, or concrete. Increased dosages and exposure times can compensate for the loss of gas through porous building materials.

Inspect the structure to be fumigated to determine if it can be made sufficiently tight. This includes windows, doors, vents, chimneys, open pipes and structural flaws. Turn off all ventilation, supply air, air conditioning, and any other air moving systems that could negatively affect the fumigation. Seal cracks, holes and openings.

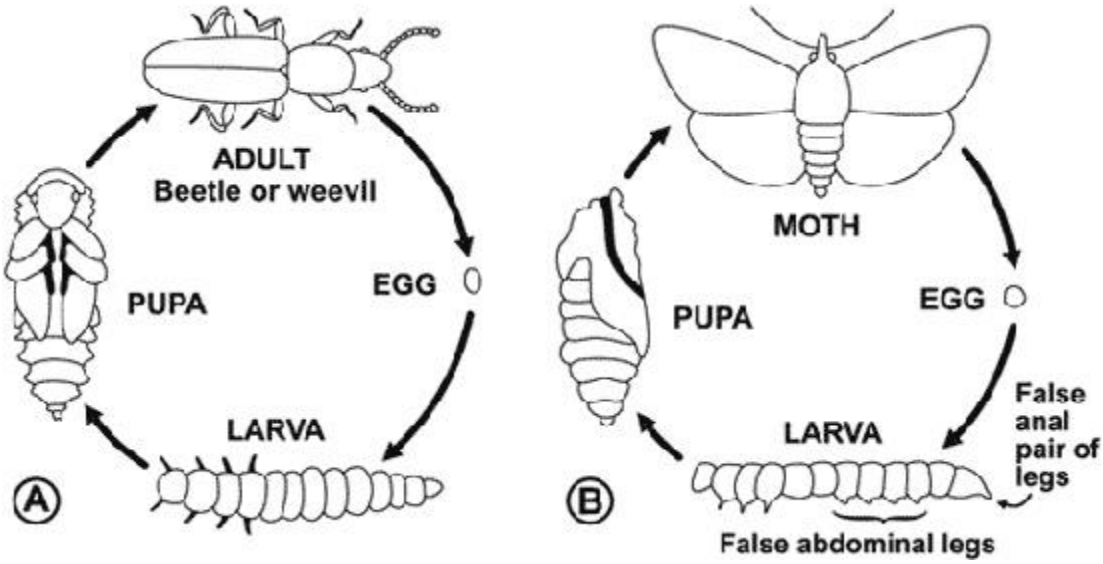
Sealing opening
(photo: Oklahoma State University)

Sealing techniques can include polyethylene sheeting, adhesive tapes and adhesive sprays. Expandable foam or caulking material can work well on structural flaws. Proper sealing will insure sufficient gas levels inside the fumigated structure and will reduce the chance of unwanted exposures outside of the fumigated area.

Sealing seams with silicone caulk
(photo: factsheets.okstate.edu)

Target Pest Species

<u>Susceptibility</u> to fumigants depends on the pest species, its type and stage of development, and its behavior. Fumigant gases usually enter an insect through breathing openings called spiracles. The life stages of the insect that are least active metabolically (e.g., eggs, pupae) are the most difficult to kill by fumigation.



Stored grain insect life cycles (Canada Grain Commission)

• **Insects that develop outside grain kernels (secondary pests) are usually more susceptible to fumigants** than primary pests that develop inside grain kernels.

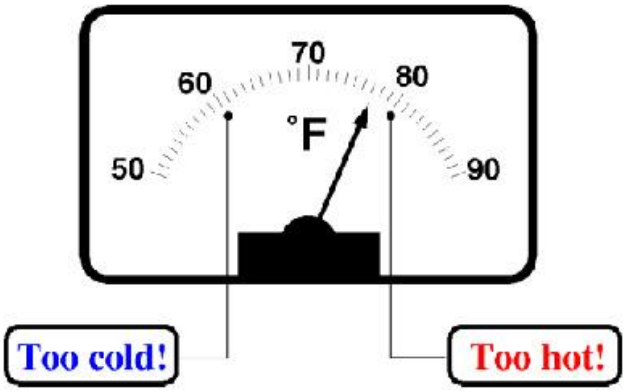
• **Heavy infestations are more difficult to control.** Masses of insects generate large amounts of dust, damaged grain, webbing and cast skins that interfere with fumigant penetration and increase sorption.

• **Resistance is the ability of an organism to tolerate a pesticide.** Some insects may be sensitive, weakly resistant, or strongly resistant to a specific insecticide. Frequent fumigation at dosages too low to kill all insects promotes problems with resistance.

Fumigant labels give dosages needed for different species of insects and different life stages of those species. For this reason, a fumigator must be familiar with pest biology.

Temperature

Temperature has a major impact on fumigant performance. **Poor pest control may result if the fumigation is done outside of the optimal range (60°F to 80°F).** Fumigants vaporize and diffuse more slowly at low temperatures. In addition, insect activity and metabolism are slower. This combination reduces killing action, especially when temperatures are below 40°F. Cooler temperatures require higher label rates and longer exposures. In contrast, fumigants vaporize faster and dissipate more quickly at high temperatures.



Optimal temperature range for fumigation (photo: Formilab.ch)

Moisture

Moisture affects fumigant penetration. **Commodities/structures with higher moisture content require higher doses of fumigant.** However, phosphine tablets and pellets need humidity to generate gas. If the air is too dry or the moisture content of the commodity is too low, these "moisture-activated" fumigants may not react completely. This can result in reduced pest control and increased applicator exposure during cleanup.

Air Movement

Some air movement is essential for effective fumigation. The gas must spread evenly and quickly throughout the commodity or space being treated. It must enter small crevices, cracks or spaces so that a lethal concentration contacts every pest. This even distribution is called equilibrium.

Fumigants also spread faster when their initial concentration is high and the penetration distance is short.

Stratification can occur when the fumigant fails to mix with air. Fans, ducts, or blowers may be necessary to prevent this. Fans are usually sufficient to stir the air in open areas but tightly packed commodities in confined areas may require blowers or ducts to circulate the fumigant.

Structure Construction

Fumigant labels list a range of dosages for specific situations. **The most important factor is the tightness of the structure.** The ability of a building to hold a fumigant directly affects the amount needed to sustain a lethal concentration throughout. Higher dosages are needed for "loose" structures. Lower doses may be adequate for tightly constructed structures such as railcars or fumigation chambers. **It is often better to seal loosely built structures than to use a higher fumigant dose.**

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Example Fumigants

Phosphine Gas
(Aluminum Phosphide, Magnesium Phosphide)

Phosphine is a mobile gas that can disperse to all parts of a storage structure or enclosure. This highly toxic gas kills animals and humans by disrupting respiration and metabolism. In addition, phosphine gas will corrode certain metals and may ignite spontaneously at concentrations above its lower flammable limit of 1.8% volume/volume (18,000 ppm).

Aluminum phosphide and magnesium phosphide are space, commodity, and rodent burrow fumigants. Formulations include pellets, tablets, prepacs, prepac ropes, bags, and plates. These solids react with moisture in the air to produce phosphine gas. The process starts slowly, gradually accelerates, and then slows as the product is spent.

Phostoxin pellets (photo: ecvv.com)

The odor of this colorless gas has been described as similar to garlic or decaying fish. Formulations that include ammonium carbonate release carbon dioxide and ammonia. Carbon dioxide reduces the fire hazard, while ammonia is a warning agent. Phosphine is slightly (1.2 times) heavier than air so it will not move evenly through solid storage, such as a grain bin. One or more fans are need to mix the fumigant with air.

Magnesium phosphide also reacts faster with water to release phosphine gas but the process is faster than with aluminum phosphide. Consequently, magnesium phosphide products are formulated into strips or blankets that can be placed very quickly. This application method **usually is not used to fumigate stored grain**. However, magnesium-phosphide products **effectively fumigate warehouses and processing plants.** Since magnesium phosphide is more reactive, it can be used to fumigate under cooler and/or drier conditions.

Magtoxin® sheeted stacks (photo: apolimantikiltf.gr)

A phosphine fumigation period must be long enough to provide adequate pest control and to allow for more or less complete reaction of the product with moisture in the air. Applicator and worker exposure is minimized if little or no unreacted phosphide remains.

The minimum length of the fumigation period varies with formulation and exposure conditions (see table below). Generally, insects are more difficult to control and the rate of phosphine gas production is reduced at lower temperatures and humidity.

Temperature (°F)	**Minimum exposure periods for aluminum phosphine (days)**	
	Pellets	**Tablets**
40	Do not fumigate	Do not fumigate
41-53	8	10
54-59	4	5
60-68	3	4
Above 68	2	3

The fumigant dose is based on the total volume of the space being treated, not on the amount of commodity present. Lengthening the fumigation period will not increase insect control if the structure is not carefully sealed or if gas distribution is poor. Exposure periods in the table may not be adequate to control all stored products pests under all conditions, nor will they always provide for total reaction.

Some structures must be completely covered with tarpaulins for fumigation; **those that cannot be properly sealed by any means should not be fumigated.** Apply additional fumigant if phosphine concentrations drop below an effective level. Follow the requirements for the minimum number of workers and use proper respiratory protection if re-entry into the treated structure is required.

After decomposition, aluminum phosphide leaves a gray-white powder composed almost entirely of aluminum hydroxide and other inert ingredients. There is no problem with fumigant added directly to a commodity such as grain. However, spent powder must be retrieved for disposal after a space fumigation. If properly exposed, the spent fumigant will normally contain only a small amount of unreacted aluminum phosphide and may be disposed of without hazard.

Spent fumigant powder (photo: Degesch America, Inc.)

Low humidity, cool temperatures, shortened exposure periods, or cases where more fumigant is added during the fumigation may result in partially spent material. This residue must be deactivated prior to disposal. Improper disposal of excess pesticide is a violation of Federal Law.

Personal Protection - Phosphine

Applicators should wear **dry cotton gloves** if contact with tablets, pellets, or dust is likely. The **gloves should remain dry during use**. Wash hands thoroughly after handling the product. Aerate potentially contaminated used gloves and other clothing in a well-ventilated area prior to laundering.

Wear dry cotton gloves if contact with product is likely
(photo: Degesch America, Inc.)

Respiratory protection is required when the concentration of phosphine in the air is unknown or if it exceeds the Permissible Exposure Limit (> 0.3 ppm). A NIOSH/MSHA approved full-face gas mask with a phosphine canister may be used at levels up to 15 ppm. An approved self-contained breathing apparatus (SCBA) must be worn if the concentration is above 15 ppm or if the phosphine concentration is unknown.

Full-face respirator (photo: ULINE) and SCBA (photo: Scott Safety)

Certified applicators must be present and are responsible for all workers

A **Certified Applicator must be physically present, responsible for, and maintain visual and/or voice contact with all fumigation workers during:**

1) the **opening of the product containers and application.** The applicator does not need to be physically present once the application is complete and the structure has been secured.

2) **during the initial opening of the fumigated structure for aeration**. The applicator does not need to be physically present once the aeration process is secured and monitoring has established that aeration can be completed safely. A trained person can complete the process and remove the placards.

3) Persons with documented training in the handling of phosphine products must be **responsible for receiving, aerating, and removing placards from vehicles that have been fumigated in transit**.

Gas Detection

Gas detection devices
(photo: Gas Detection Warehouse)

Several **gas detection devices** can measure phosphine gas concentrations. Glass detection tubes used with the appropriate hand-operated air sampling pumps are widely used. These inexpensive devices are simple to use and provide accurate relatively rapid results. In addition, electronic devices are available for both low level and high phosphine gas readings.

Placarding of Fumigated Areas

Placards must be placed at all entrances to the fumigated structure. They must be able to withstand adverse weather conditions and must have the following wording:

☑ The signal words **DANGER/PELIGRO** and the **SKULL AND CROSSBONES** symbol in red.

☑ "**Structure and/or commodity under fumigation, DO NOT ENTER/NO ENTRE**".

☑ "**This sign may only be removed by a certified applicator or a person with documented training after the structure and/or commodity is completely aerated (contains 0.3 ppm or less of phosphine gas)**".

If an incompletely aerated commodity is transferred to a new storage structure, the new structure must also be placarded if it contains > 0.3 ppm phosphine. Worker exposure during the transfer must not exceed allowable limits.

☑ The date the fumigation begins.

☑ Name and EPA registration number of fumigant used.

☑ Name, address and telephone number of the Fumigation Company and/or applicator.

☑ A 24-hour emergency response telephone number.

Leakage from Fumigated Sites

Phosphine gas is highly mobile. Given enough time, it may penetrate seemingly gas-tight materials. Check adjacent enclosed areas that may be occupied to ensure that significant leakage has not occurred. **Sealing the fumigated site and/or increasing airflow in the occupied areas must be sufficient to bring down the phosphine concentration to a safe level (< 0.3 ppm).**

Aeration and Re-entry

Aerate the fumigated structure before allowing anyone to enter. Be sure that gas leaving the treated commodity does not produce areas with unacceptable levels of phosphine. Do not allow anyone to re-enter treated areas until the level of phosphine reaches 0.3 ppm or below unless they are protected by an approved respirator.

Bin aeration fan (photo: Feed&Grain.com)

Sulfuryl Fluoride

Sulfuryl fluoride (Vikane) is **used to fumigate closed structures and their contents for drywood and Formosan termites, wood-infesting beetles, bed bugs, carpet beetles, clothes moths, cockroaches, and rodents.** It breaks down in the insect's body to release fluoride, which interferes with the insect's ability to maintain energy. Without energy, the insect dies in a few days. Insect eggs are less susceptible to sulfuryl fluoride than other life stages.

Sulfuryl fluoride is a respiratory irritant that also affects the central nervous system of mammals and humans. It is non-flammable, non-corrosive, and does not react with materials to produce odors or residues. Although the gas is only slightly toxic by inhalation, it poses **an acute hazard because it is odorless and colorless.** For this reason, occupants must leave the structure before the fumigation begins and stay out until the gas is removed.

Sulfuryl fluoride gas is introduced into enclosed structures to fill all air spaces and to penetrate cracks, crevices, and pores in wood. It penetrates materials quickly and dissipates rapidly during ventilation. To be effective, the fumigant must be contained for a sufficient time; therefore, **workers must place a tent around the structure during the fumigation**. Sulfuryl fluoride is heavier (1.35 times) than air.

The **warning agent chloropicrin (tear gas) must be released into the structure/ area to be fumigated at least 5 to 10 minutes before introduction of the fumigant.**

Protective Clothing

Wear **splash resistant goggles or full-face shield** when handling the liquid fumigant during introduction or when working around any lines containing the fumigant under pressure. Do not wear gloves or rubber boots. Do not reuse clothing or shoes contaminated with the liquid fumigant until thoroughly aerated. **Wear loose fitting or well-ventilated long-sleeve shirt, long pants, shoes and socks.**

Respiratory Protection

Special monitoring equipment is needed to use sulfuryl fluoride. No respiratory protection is required if the gas concentration in the fumigated area, as measured by a suitable detection device, does not exceed 5 parts per million. **If the minimum allowed concentration is greater than 5 ppm or is unknown, all persons in the fumigated area must wear a NIOSH or MSHA approved positive pressure self-contained breathing apparatus (SCBA) or combination air-supplied/SCBA.** The SCBA must be on site and operational before fumigation.

Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) makes up about 0.0004% in the air that we breathe. It is 1.5 times heavier than air. **When used as a fumigant, its concentration must be increased to about 40%-60% of the air volume.**

CO_2 tank
(photo: GrowersHouse.com)

Structures fumigated with CO_2 must be airtight and there must be a way for displaced air to escape. Consequently, CO_2 **usually is used in a facility designed for closed-loop fumigation**. It has exchangers designed to remove air and introduce the fumigant, which is recirculated through the structure.

Fumigating with CO_2 is generally safer than with other chemicals. However, **a breathing apparatus is needed for re-entry into a structure during fumigation and for anyone who reenters a structure that contains levels of CO_2 higher than 5% of the air volume. A SCBA (self-contained breathing apparatus) must be worn** because canister gas masks do not work for CO_2.

Even though CO_2 does not leave a residue, there are **concerns that it will change the flavor of products** made from some fumigated vegetables, malting barley, or other porous grains.

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Fumigation Operations

Structural Fumigation

Structural fumigation
(photo: sanjoaquinpestcontrol.com)

Structural fumigation is a pest control method that involves filling the airspace within a structure with a toxic gas. The structure is covered with tarp or tent to keep the gas inside. The gas penetrates cracks, crevices, and pores in the wood to eliminate pests, such as wood-destroying organisms and bed bugs. Fans are used to help the gas escape into the atmosphere. After the tarp is removed, leftover residues are not expected to remain on surfaces.

The primary active ingredient in fumigants intended for residential dwellings is sulfuryl fluoride. Only certified applicators can use sulfuryl fluoride products because the U.S. EPA classifies them as Restricted Use Pesticides (RUP). Certified applicators have been trained in the proper handling of the fumigant and fumigation-related equipment and procedures.

Some **basic steps in structural fumigation**

• The structure must be sealed with a tarp to trap gas inside during fumigation.

• The structure must be secured and warning signs posted to prevent people from entering the structure during fumigation.

• Because sulfuryl fluoride is a colorless, odorless, and highly toxic gas, chloropicrin (a highly irritating substance) is commonly used as a warning agent to clear people from the structure.

• The tarp is removed and the structure is aerated after fumigation.

• Applicators conduct air monitoring procedures to **make sure sulfuryl fluoride levels do not exceed the EPA established limit of 1 part per million (ppm).**

• Occupants are not allowed to reenter until the applicator checks are complete.

Tarpaulin Fumigation

Tarpaulin fumigation (image: fao.org)

Tarpaulins provide the flexibility to fumigate a range of items from a wood borer-infested museum piece to an entire structure. **Tarps should be at least 4 mils (0.004 inches) thick and made of gas-impervious polyethylene, vinyl or neoprene-coated nylon, or an equivalent material.** Multiple tarps can be joined by overlapping the adjoining edges by at least 12 inches and fastening them with clamps spaced not more than 12 inches apart.

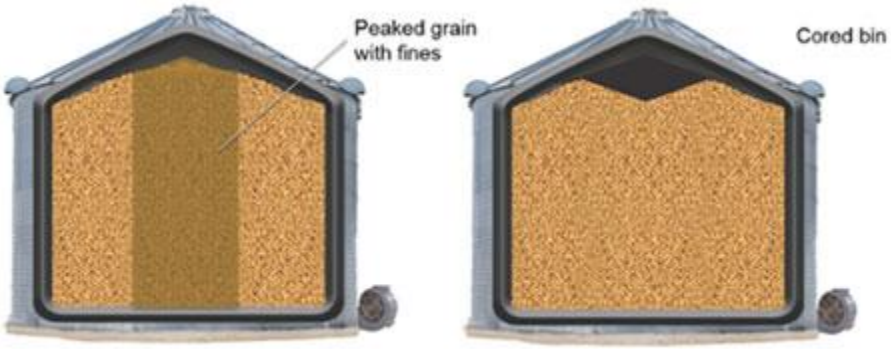
Fumigation on impermeable surface
(photo: pestcontrolcape.co)

Fumigate on an impermeable surface. Concrete paving without cracks or joints is best. **If an impermeable floor is not available, place a tarp on the surface, then stack the commodity on top.**

Tarps should be large enough to allow an 18-inch lip of material around the base of the enclosure. Be sure that the ends overlap. Seal lips against the floor by piling sand on the exposed tarp. Use "sand or water snakes" around the entire lip. They should be at least 3-inches in diameter and made of canvas or polyethylene tubing. As a final precaution, check tarps tor pinholes, leaks, and tears before use. Pad sharp corners with burlap a soft material to prevent tears. Use care when walking on tarps or using heavy equipment near them.

Grain and Bulk Commodities

<u>Grain fumigation</u> can be affected by type and condition of the grain: size, shape and permeability of the kernels, and the amount of dockage (fines, dust, etc.) in the grain.



Fines increase potential problems with some stored grain pests and can reduce effectiveness of fumigation. (Photo: info.intellifarms.com)

<u>Sorptive capacity</u> of stored grain refers to **<u>adsorption</u>** (the adhesion of the fumigant gas molecules to the external surface of the grain), plus **<u>absorption</u>** (gas molecules held in the kernel). **Other factors being constant, the sorptive capacity of a grain increases with a decrease in kernel size and a corresponding increase in surface area.** Permeability of seed coat is also a factor. Increased sorptive capacity means less gas fumigant in the surrounding air. As a result, recommended dosages are generally higher for smaller grains such as wheat, rye, or sorghum than they are for corn.

Phosphine gas is an extremely effective fumigant for grain and other commodities, either in bulk or packaged. When fumigating grain, the phosphine gas dosage rate depends on the type of storage, the pests to be controlled, and commodity temperature. As with all fumigations, seal the structure as tight as possible. In some cases, you may have to cover the entire structure with polyethylene or gas-proof tarpaulins.

Phosphine gas has remarkable penetrating and distributing power, therefore, you may not need special recirculating equipment. Simply apply the fumigant directly into the grain mass or the stream of grain as it is conveyed into the silo (elevator). Place the tablets or pellets into the stream of grain by hand or with a dispenser. If the bulk commodity is already stored in a silo, bulk bin, flat storage, etc., insert the fumigant tablets or pellets into the mass with a probe. Fumigant manufacturers also supply these probes.

The recirculation method gives the best results when using phosphine in a grain bin or elevator. This method requires blowers, which are usually located outside at the bottom of the silo or storage building. Ducts connected to the blowers go from the inside bottom to the top of the bin so the air will go down through the grain and recirculate to the top. Recirculation allows gas to penetrate areas that are resistant to natural gravity movement of the gas, thus providing better insect control.

Seal the grain storage facility as air tight as possible before fumigating and ensure that the recirculation system is operating properly. After establishing airflow throughout the grain mass, turn the fans and place the phosphine on top of the grain. Recirculate air until the fumigant is thoroughly distributed. Then, turn off the recirculation system and allow at least a 4-day exposure time.

Aerate the grain by disconnecting the return air duct and operating the ventilation system until exhaust air is free of fumigant traces, as indicated by a gas detector tube or audible alarm. Phosphine can be left in the grain for long periods without adverse effects and this will improve the control. However, aeration is needed if grain is moved soon after fumigation. **DO NOT USE detectors that depend on flame around grain elevators.** Also, **check the grain surface for possible pockets of gas that may not have aerated.** The fumigant label will state the exposure time and aeration procedures. The residual dust from the aluminum phosphide pellets or tablets will be removed automatically by the usual handling of the grain. No additional measure is required to render the bulk commodity marketable.

There is a **fundamental difference between phosphine fumigation of bulk and packaged commodities**. Tablets or pellets are added directly to bulk products. However, neither tablets, pellets, bags, or plates, nor their residues come in direct contact with the goods in packaged commodities.

Chamber Fumigation

(Photo: dir.indiamart.co)


(Photo: dir.indiamart.com)

A **fumigation chamber** is an example of a tight seal. Little gas escapes from a well-constructed chamber.

Compare that to placing a gas-tight tarp over commodities or structures. Tarps can provide a poor-to-excellent seal depending on:

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

Vacuum Chambers

The penetration rate of gas into the material to be fumigated is often an important factor, and is related to the material's sorptive capacity. The **product's penetration rate is greatly increased if fumigation is done in an airtight chamber from which the air has been removed**. This is vacuum fumigation. You can remove the fumigant quite completely from by drawing a second vacuum after the proper period of exposure to the gas and then breaking this vacuum with air. This process is known as "air-washing". **Do NOT use phosphine for vacuum fumigations**.

Vacuum fumigation is an advantage when speed is an important factor. The **vacuum usually reduces the time necessary to kill insects protected by plant materials (e.g., in baled cotton) to a small fraction of that required under natural atmospheric conditions.** However, if the amount of plant material is great, the amount of fumigant needed increases greatly because of increased sorption. Another advantage of vacuum fumigation is that **applicators are not exposed to the gas**.

Vehicle Fumigation

Railcars are the most frequently fumigated vehicles in Kentucky.
(photo: tdc.ca)

Stationary (Static) fumigation is approved for boxcars, hopper cars with covered tops that can be closed and secured, containers, and trucks with permanently enclosed tops. The carrier must remain sealed and stationary for the minimum retention period for an effective kill:

Phosphine & CO_2 - 24 hours

CO_2 - 96 hours

In-transit fumigation is approved for hatch or trough type hopper cars that have covered tops that can be closed and secured. Boxcars are not approved. **Trucks, trailers, containers, and vans are not approved while traveling on public roads**; however, these carriers are acceptable if they have permanently enclosed tops, sides, and bottoms, and are transported by rail. Aeration of these carriers is prohibited while enroute.

Railcar fumigation procedure:

☑ **Place cars on a seldom-used track or siding so that they will not have to be moved while under fumigation. Rail cars can only be fumigated with phosphine.**

☑ **Carefully seal all car openings. Pay particular attention to the space around doors, the eaves, and the floor.**

☑ **Post warning signs conforming to the fumigant label on both doors and on each hatch on top of the cars before applying the fumigant.**

☑ **After fumigation, open all doors and vents to allow as much air circulation as possible. Thirty (30) minutes is usually required to aerate a car after fumigation but this must be determined using a gas detector. Keep all persons out of the area during fumigation and aeration and until the gas detector shows that no fumigant is present. Only then is it safe to enter the car without wearing respiratory protection.**

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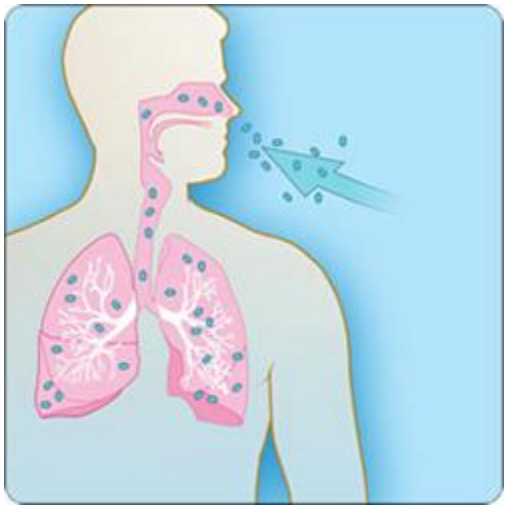
Fumigation Safety

Inhalation is the most dangerous and common route of exposure to fumigants. Most are highly toxic so breathing even small amounts can cause serious illness or death. Exposure also can occur thorough your eyes, mouth, or skin. The label will list the personal protective equipment (PPE) that the manufacturer requires. Know what to do in case of an exposure.



Inhalation is the most common route of exposure to fumigants (levitt-safety.com)

Mild inhalation exposure can cause a feeling of sickness, ringing in the ears, fatigue, nausea and tightness in the chest. Exposure to fresh air will usually relieve these symptoms.

Moderate inhalation exposure can cause weakness, vomiting, chest pain, diarrhea, difficulty breathing and pain just above the stomach.

Symptoms of **severe inhalation** exposure may occur within a few hours to several days after exposure. Severe poisoning may result in fluid in the lungs. This can lead to dizziness, blue or purple skin color, unconsciousness, and even death.

Do not attempt to rescue someone in an enclosed area if you are not wearing the proper respiratory protection.

A **fumigant exposure limit** is the highest level of fumigant that you may be exposed to without being required to use any controls to reduce your exposure. You also can reduce your risk of inhalation overexposure by monitoring fumigant concentrations during treatment and aeration. Be sure your exposure stays below established exposure limits.

The three most common terms used to express the exposure limit of a fumigant are the:

• **Threshold limit value - Time weighted average (TLV-TWA)** refers to the average concentration of a fumigant to which most workers may be repeatedly exposed for 8 hours a day, 40 hours a week without adverse effects. Concentrations at or below the TWA represent conditions that you may be exposed to on a daily basis. These levels are considered safe. Concentrations above the TWA may lead to "overexposure" to a fumigant, which can cause discomfort, sickness or even death.

• **Threshold limit value - Short term exposure limit (TLV-STEL)** is the concentration of fumigant to which most workers can be exposed continuously for a short period without suffering from:

- Irritation
- Chronic or irreversible tissue damage
- Narcosis (drunkenness) that may increase the chance of accident or injury

Exposure to concentrations at the STEL should not be longer than 15 minutes and should not occur more than four times per day.

• The **permissible exposure limit (PEL)** designates the maximum exposure permitted as an 8-hour TWA. Refer to the fumigant label information to find out what the different exposure limits are for each product you use.

Personal Protective Equipment

Personal protective equipment (PPE) is clothing and devices that minimize your exposure to a pesticide. The label lists the minimum required PPE. Federal and state laws require pesticide users to follow all instructions on the product label, including wearing the appropriate PPE.

Respirators

The main types of respirators are:

1) atmosphere-supplying respirators and

2) air-purifying respirators.

They must be approved by NIOSH (National Institute of Safety and Health). The specific type of required may vary depending on applicator health, type of fumigant used, and working conditions. Atmosphere-supplying respirators use canisters to supply breathable air or draw air from outside the fumigation area.

Atmosphere-Supplying Respirators

The two main types of atmosphere-supplying respirators are the self-contained breathing apparatus (SCBA) and the supplied-air respirator (SAR).

SCBA (photo: scottsafety.com)

Self-contained breathing apparatus (SCBA) consists of a full-face mask attached to a tank of compressed air. The face piece must fit snugly to keep out contaminated air. There is an alarm to warn when the air supply is low. Movement is not restricted with this system. However, the weight and bulk of an SCBA often makes strenuous work difficult.

Supplied air – air line respirator (PK Safety)

Supplied-air respirators have a full-face mask that delivers air from a compressed air tank or an outside air pump. The air tank or pump is located outside the fumigation area.

Air-Purifying Respirators

Air-purifying respirators combine a face piece with a specific filter media. Outside air is drawn into the mask through a filter media. The filter absorbs impurities in the air.

Air purifying respirator (Fastenol.com)

Fit testing respirators (photo: IrwinsSaferty.org)

Respirators should be fit-tested and approved by a licensed health care professional. In addition, be sure that all parts and replacement parts meet manufacturer specifications.

How long a canister will last depends on several things:

- The type of canister
- The size of the canister
- The type and concentration of gas in the surrounding air
- The length of exposure
- The rate of breathing
- Whether there is more than one gas present
- The temperature and humidity at the time of use.

Other Protection Equipment

Fumigant labels also may require other types of PPE, including protective clothing and gloves. Requirements vary so read the label information carefully. Labels recommend loose-fitting clothes, long-sleeved shirts, long pants and socks for skin protection. Others do not specify.

The need for gloves also varies. Applicators must wear gloves because of possible skin irritation some solid fumigants. Labels of liquid products do not require gloves and may prohibit wearing them. Learn which items are required for the product you plan to use.

Whenever possible, provide two-way radio communication between workers applying fumigants and those outside. Also, keep on hand:

- An **emergency air-supplying respirator**, especially if canister-type respirators are being used
- **Antidotes** where applicable
- A **safety harness or rescue belt**
- **Basic first aid** equipment

First Aid for Fumigant Poisoning

Human exposure can occur even when you take all of the proper precautions. Unusual behavior by you or your fumigation partner could be a sign of exposure. Know what to do. The label information is your best source of information. First aid procedures on it usually are specific to the product. If you suspect fumigant exposure, remain calm, get to fresh air, and call for help immediately. Take a product label and Safety Data Sheet with you to the emergency room.

CPR (photo: aacc.edu)

If you are with someone suffering from inhalation exposure, carry him or her to fresh air immediately. Then:

☑ **Call for help – 911.**

☑ **Loosen all tight clothing.**

☑ **Give artificial respiration if breathing has stopped or is irregular.**

☑ **Keep the victim as quiet as possible.**

☑ **Prevent chilling by wrapping the victim in blankets. Do not to overheat the victim.**

☑ **If the victim is convulsing, protect his or her head from striking the floor or wall.**

☑ **Begin CPR if the victim does not have a pulse. Keep the victim's chin up so that the air passage remains free. Do not put anything in the mouth of an unconscious person.**

☑ **Get medical attention right away or take the victim to a doctor or emergency facility.**

Liquid and solid pesticides are most often the cause of skin exposure. However, some fumigant gases can injure the skin. Clothing or jewelry can hold the gas against the skin, causing burns or blisters. Fumigants absorbed through the skin can enter the bloodstream, causing systemic effects. Most fumigant labels suggest that you remove all jewelry and wear loose-fitting clothes. Some labels prohibit the use of gloves. Always consult the label to determine what precautions you should take.

If skin exposure does occur, take the following steps:

- ☑ **Get to fresh air.**
- ☑ **Remove contaminated items (clothing, jewelry, gloves, shoes, bandages, etc.) immediately.**
- ☑ **Drench the skin with water.**
- ☑ **Wash the skin, hair and fingernails with soap and water.**
- ☑ **Rinse thoroughly and wash again.**
- ☑ **Dry and wrap the affected skin in a blanket.**
- ☑ **If exposure causes a burn, cover the area loosely with a clean, soft cloth. Avoid using ointments, powders and other medications.**
- ☑ **Do not wear contaminated clothes again until you wash and air them for several days.**

Protecting the Public and the Environment

Reading the label is the most important thing you can do to ensure personal and public safety. Labels may include both an abbreviated sticker label and an extended label booklet. It may list specific sites that you should avoid or application methods that are not permitted. There will be storage and specific safety precautions.

Monitoring for the Fumigant

There is always a risk that fumigant gas will escape from a treatment area. Monitoring for these leaks is critical. Be sure to take air samples when treating commodities that are next to work areas. Use appropriate gas detectors to verify that fumigants are not leaking. This is particularly important during indoor treatments.

(photo: vikingfumigation.com)

Transporting a fumigant is dangerous. Leaks and spills caused by accidents can be beyond your control.

You can prevent many accidents by taking the following precautions and using common sense.

☑ Do not carry fumigants with people in a closed vehicle and do not take fumigants through tunnels without permission from the Kentucky Department of Transportation (KDOT).

☑ Have the required driver's license with appropriate endorsements for the specific fumigant you plan to transport.

☑ Read the label information and/or the Safety Data Sheet (SDS) to determine the signage requirements for transporting each fumigant that you use. You can also contact the fumigant manufacturer for more information on placarding for transportation.

☑ Be sure cylinders are upright, secured, and protected from rear-end collision.

☑ Do not remove protective valve covers until just before use.

☑ Follow federal and state department of transportation regulations.

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

Storing fumigants is hazardous; when possible, buy only what you need. Store fumigants on sturdy shelves in an area apart from feed or seed. **A separate building that is well-ventilated or has a mechanical exhaust system is best.** Be sure that all fumigant storage areas are locked and posted as pesticide storage sites. Warning signs should indicate the presence of fumigants.

(image: amazon.com)

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

Do not risk contamination of water supplies. Dispose of all empty containers, residues and rinsates according to state waste management procedures. Keep all pesticides and their empty containers out of the reach of children.

Proper aeration is important for the safety of you, your crew, and your clients. Poor aeration is one of the most common problems associated with fumigation. When treating raw agricultural products, be sure the rate of air exchange during the aeration phase will adequately remove the fumigant. If necessary, use fans or other ventilation equipment.

Preparation and planning will help to prevent public and environmental exposure. How well have you sealed an area? Have you inspected all equipment thoroughly? Are you applying the fumigant at or below the label rate? Have you set aside enough time to aerate the site or item completely? Have you set up fences and posted warning signs to keep people, livestock and pets out of the treatment area?

Spilled aluminum or magnesium phosphide may generate high levels of phosphine gas so all personnel must wear SCBAs during the cleanup. **DO NOT USE WATER AT ANY TIME** to clean up these spills; water speeds up the production of phosphine gas, which could result in the release of toxic gas or produce a fire hazard.

If aluminum flasks have been damaged enough to leak, repair them temporarily with aluminum tape, or transfer the undamaged product to a sound metal container and label it.

Pre-Fumigation and Fumigation Application Procedures

- ☑ **READ AND FOLLOW THE LABEL DIRECTIONS.**
- ☑ **Post areas to be treated immediately before fumigation. Use bilingual placarding if workers or neighbors do not read English.**
- ☑ **Apply fumigant from the outside where appropriate.**
- ☑ **Only allow entry into fumigation area in extreme emergencies, and only with mandatory respiratory protection.**
- ☑ **When fumigating, consider prevailing wind and other factors that may affect the fumigation.**
- ☑ **Post warning signs.**
- ☑ **Provide guards where required. This is necessary unless the fumigated area is completely locked or enclosed by a locked fence.**

Post-Application Operations

- ☑ **Provide guards where required and/or necessary.**
- ☑ **Allow adequate aeration time for the structure / commodity.**
- ☑ **Turn on all ventilating or aerating fans where appropriate.**
- ☑ **Before re-entry, use a suitable gas detector to determine fumigant concentration so appropriate precautions may betaken. Most fumigants do not provide adequate odor warning.**
- ☑ **Check for gas concentrations in areas that aerate slowly.**
- ☑ **Remove warning signs when aeration is complete.**
- ☑ **Dispose of empty containers and used canisters.**
- ☑ **Return unused chemicals in properly and clearly labeled containers to storage area.**

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Structural Pests

Powderpost Beetles

Powderpost beetle is a term used to describe several species of small (1/8-3/4 inches long), wood-boring insects that reduce wood to a fine, flour-like powder. The larvae create narrow, meandering tunnels as they feed on the wood. Infestations are discovered after noticing small, round "shotholes" in the wood surface. These are exit holes where adult beetles have chewed out of the wood after completing their development.

Powderpost beetle exit holes and accumulated sawdust
(Photo: townandcountrysolutions.com)

Newly-emerged adults mate and lay eggs on or below the surface of unfinished wood. Tiny larvae hatch from the eggs and bore into the wood. Life cycle from egg to adult can take from 1 to 5 years, depending on the beetle species and wood condition.

The two most common and destructive families of powderpost beetles in Kentucky are the Lyctidae and Anobiidae. Lyctid powderpost beetles only attack products manufactured from hardwoods , e.g., oak, ash, walnut and hickory. Consequently, infestations usually occur in wood paneling, molding, window and doorframes, plywood, hardwood floors, and furniture. Rafters, joists, studs and other structural framing of homes are not normally attacked by lyctid beetles because they are almost always constructed from pine or other softwoods.

Damage By Common Wood-Boring Beetles

Insect Type	Wood Type	Age Of Wood*	Shape & Size Of Holes		Reinfestation*
Anobiid Beetles	Soft & Hard	New & Old	Round	1/16" • 1/8"	Yes
Bostrichid Beetles	Soft & Hard	New	Round	3/32" • 9/32"	Rarely
Lyctid Beetles	Hard	New & Old	Round	1/32" • 1/16"	Yes
Old House Borer	Soft	New & Old	Oval	1/4" • 3/8"	Yes

*New wood is freshly cut or unseasoned lumber. Old wood is seasoned or dried lumber.
*Many other wood-boring beetles can initially infest new wood in homes, but their damage is limited and they do not rein-

Controlling wood-boring beetles in houses (aces.edu)

Lyctid Powderpost Beetles

Lyctid powderpost beetle (image: epestsupply.com)

Lyctids rarely infest wood older than five years. Thus, infestations generally are encountered in new homes or newly-manufactured articles. In almost all cases, infestation results from wood that contained eggs or larvae at the time it was placed in the home. Typically, the infested article was constructed from wood which was improperly dried or stored.

Anobiid Powderpost Beetles

Anobiid powderpost beetle (image: epestsupply.com)

Anobiid powderpost beetles may attack both hardwoods and softwoods so infestations may be found in all the same places as Lyctid beetles, as well as in structural timbers (beams, sills, joists, studs, subflooring, etc). Maple, beech, poplar and pine are especially susceptible to attack. Anobiids prefer to infest damp wood; therefore, infestations usually begin in moist, poorly-ventilated areas such as crawl spaces, basements, garages and utility sheds. Under favorable conditions of moisture and temperature, infestations may spread upwards into walls and upper levels of the structure, including furniture. Infestations may occur because of using infested lumber, or from beetles flying in from outdoors or being carried in on firewood. Infestations develop slowly, but wood can be reinfested.

Powderpost beetles sometimes die on their own accord. Therefore, it is important to be able to determine whether the infestation is active or inactive. Active infestations will usually have powder the color of fresh-cut wood sifting from the exit holes. In contrast to old, abandoned holes, new holes will not have taken on the weathered appearance of the surrounding wood. Powder streaming from recently opened holes may accumulate in small piles beneath the exit holes. If these piles of powder are covered with a film of dust or debris, the damage is old. Careful observation may be required to distinguish new powder from frass dislodged from old larval galleries by vibrations.

Fresh powderpost beetle activity (image: volvoab.com)

One final means of confirming that an infestation is active is to mark or seal any existing exit holes, sweep or vacuum up all powder, and check the wood later for new holes and powder. Since most ppb emergence occurs from April-July, it might be worthwhile to **wait until the following spring/summer to determine if new holes and fresh powder are present** (this is especially true when attempting to make a determination during the fall or winter).

Stored Grain and Product Pests

Arthropods that infest stored agricultural products can be divided into primary and secondary pests based on their feeding habits.

Primary Grain Pests

Primary pests deposit eggs on or in whole kernels and the larvae develop in them. Larval feeding destroys sound grain, reducing nutritional value, seed germination, or contaminating the product. These internal feeders also produce fines and damaged kernels that allow infestation by secondary grain pests.

Example primary pests include:

- Rice, granary and maize weevils
- Lesser grain borer

Grain Weevils

Rice weevil life stages (uky.edu)

Weevils are among the most destructive stored product pests. Mouthparts of adults form elongated snouts characteristic of all weevils. Adults can live for four to five months.

Females typically lay 50 to 200 eggs. Females use their strong mandibles to chew small holes into grain kernels. A single egg is placed in each hole. The small, white, legless larvae hatch, feed and develop inside kernels of grain. They can survive in grains for at least 10 weeks at temperatures as low as 41°F.

Wheat, corn, oats, and sorghum are just some of their preferred foods.

Lesser Grain Borer

Lesser grain borer (image: Agebb.missouri.edu)

The adult lesser grain borer is 1/8 inch long cylindrical beetle with a shiny dark brown or black body. The last three segments of the antennae are enlarged on one side. The body surface is rough and the head is hidden from view. Powerful jaws allow the insect to bore into wood as well as grain.

Adult lesser grain borers are strong fliers and long-lived. Females lay up to 500 eggs singly or in clusters in loose grain. Their C-shaped white larvae have dark heads and short legs. **They burrow into and feed inside nearly all types of grain. Infested grain has a characteristic sweet and slightly pungent odor.**

Secondary Grain Pests

Secondary pests feed on damaged or processed grains. The outer layer of the grain or seed must be damaged – cracked, holed, abraded or broken. This may result from physical damage during harvesting, rapid drying or by the feeding of a primary feeder.

Some secondary feeders live in grain storage areas with primary feeders. Secondary beetles are collectively called **"bran bugs" or "bran beetles".** Concentrations of bran beetles may raise the temperature and/or moisture level within stored grain, conditions that favor rapid growth.

Two common secondary feeders of raw agricultural and processed products include the:

- Indian meal moth

- Confused and red flour beetles

Indian Meal Moth

Indian meal moth adult (photo: Pest.Kill.org)

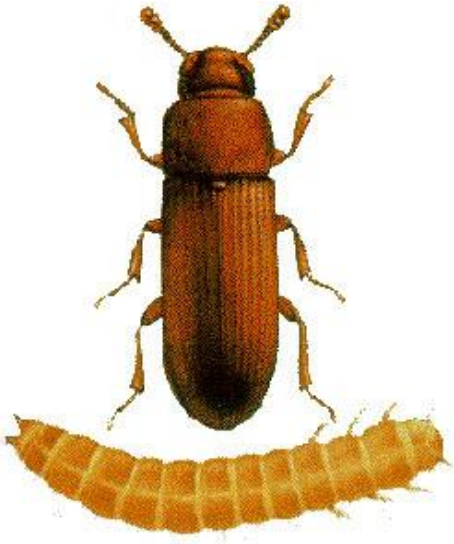
Indian meal moth larvae silk and frass (waste) in infested nuts

The Indian meal moth is **one of the most common pests of grain storage and processing facilities and warehouses.** Adults are distinctive. The outer two-thirds of the front wings are copper brown, the bases are grayish white. The hind wings are pale gray. The head and thorax are reddish brown. Adult Indian meal moths are weak fliers that are usually active for only a few hours in the evening. Usually, they remain close to the infested material.

Female adult Indian meal moths lay eggs singly or in groups directly on food material. The small, pale yellow eggs hatch in about three days. Larvae emerge and feed in the top 4″ to 6″ of the infested commodity. They are usually dirty white but may have a green or pink tint. Full-grown caterpillars are about 1/2 inch long with a brown head. Heavily infested materials are covered with a fine, web-like mesh of silk spun by the caterpillars. Infestations may be discovered when full-grown caterpillars crawl away from their food to spin a cocoon for pupation.

Flour Beetles

Adult confused and red flour beetles are long, flat, shiny, reddish brown insects measuring about 1/7 inch long. Female flour beetles lay several hundred small, whitish eggs directly on the food source. The female covers the eggs with a sticky secretion to which bits of the food adhere. Small, brownish white larvae hatch in five to twelve days. They are full grown in one to four months. A full-grown larva is about 3/16 inch long and tinged with yellow.



Flour beetle adult and larva (image: USDA ARS)

Flour beetle larvae feed on broken kernels, flour, meal and other starchy materials. They are often hard to detect because they cover themselves with bits of the food they infest. They may appear as tiny lumps in the flour. The larvae pupate and transform into adults. Flour beetles do not penetrate whole grain kernels or undamaged grain. Instead, these **secondary feeders cause damage by scraping the surface of foods or eating finely ground material**. Their preferred foods include **grains and grain products, peas, beans, flour, dried fruits, shelled nuts, spices and other commodities.** These beetles may leave a bad odor that affects the taste of infested products.

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General Fumigation Practices

Computing the Job

Dosage recommendations are based on cubic content.

In **square or rectangular** buildings, simply **multiply the interior length by width and height**.

In **irregularly shaped** buildings, **find the cubic content of each unit then add the units together** to find the total. In the case of peaked roofs, the average height between sidewall and top of the roof may be used as the third multiple in calculating the cubic content.

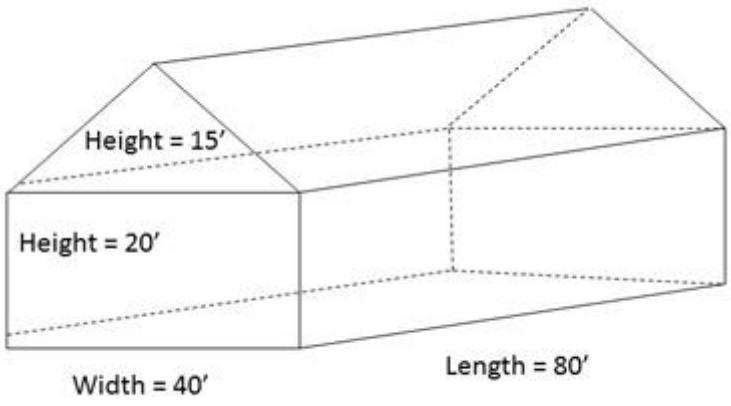
When measuring, **do not deduct for space occupied by machinery, commodities, or furnishings**. Exceptions to this rule apply to fresh fruit and vegetables or canned or bottled materials that cannot be penetrated by the gas.

Follow the recommended checklist for release and aeration procedures at the end of this chapter.

Calculations For Fumigators

Volume calculations are the basis for determining the amount of fumigant needed for enclosed spaces. They are straightforward as long as you break them down into individual steps.

Flat Storage With Triangular Loft



Multiply length x width x height

Example:

L = 80 ft

W = 40 ft

H1 = 20 ft

H2 = 15 ft

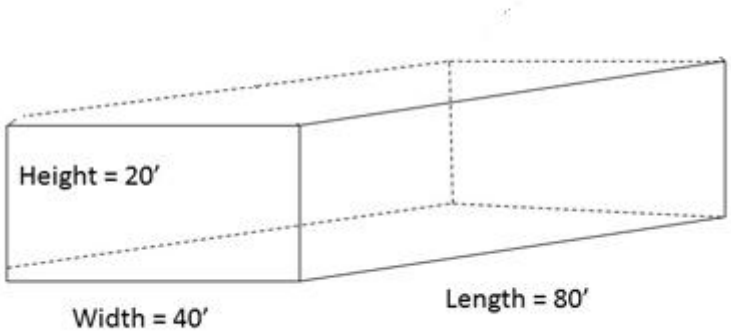
Break the structure into a

1) a **rectangular building** plus

2) a **triangular loft** and calculate the volume of each.

3) **Add the two values** to get the total volume of the structure.

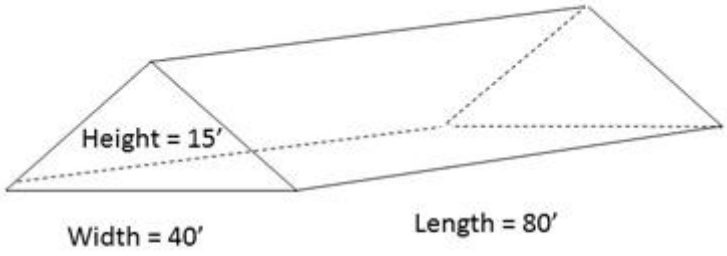
The **formula for the volume of the rectangular structure is L x W x H1**.



The example structure is 80 ft long x 40 ft wide x 20 ft high.

Its volume is 80 ft x 40 ft x 20 ft = 64,000 cubic feet.

Volume of the triangular loft equals the area of the triangle (front surface) x the length of the structure.



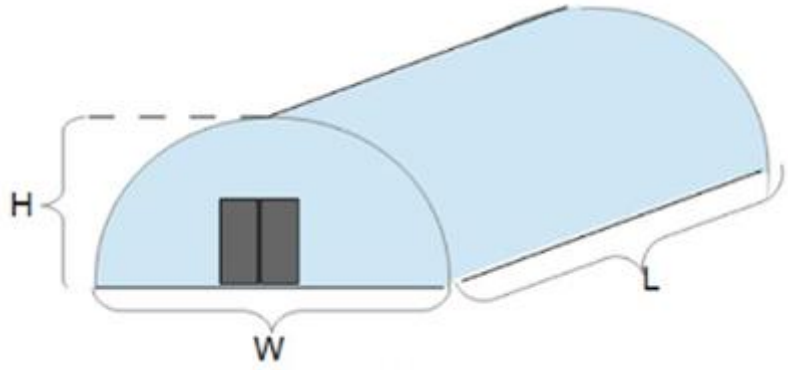
The <u>area</u> of a triangle = (W x H2)/2 = (15 x 40)/2 = 300 sq ft

<u>Volume</u> = area of the triangle (300 sq ft) x 80 ft = 24,000 cu ft

Total volume of building

64,000 cu ft + 24,000 cu ft = 88,000 cu ft

Quonset Hut (Semicircular Ends)



Multiply the area of a half-circle (front surface) x length

Example:

$\pi = 3.14$

H = 12 ft

L = 40 ft

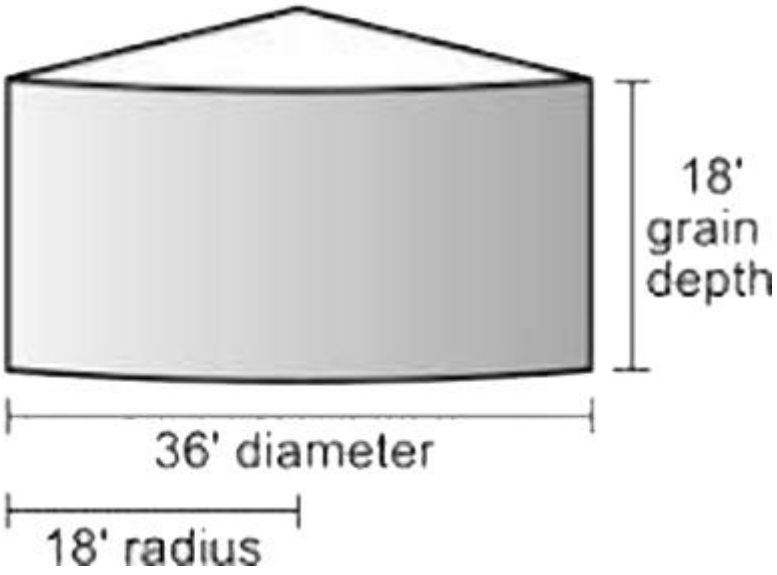
Area of a circle = (πH2)

Area of a circle = 3.14 (122) = 452.2 sq ft

Area of half-circle = 226.1 sq ft

Area of half-circle x Length = 226.1 sq ft x 40 ft = 9,044 cu ft

Cylindrical Storage (Round Bin)



Multiply the area of the base (circle) x the height

Example:

$\pi = 3.14$

H = 18 ft

D = 36 ft

R = 36 ft / 2 = 18 ft

Area of a circle = (πR^2)

Area of a circle = $3.14 \times (18^2) = 1{,}017.4$ sq ft

The formula for the volume of this structure is 1,017.4 sq ft x 18 ft = 18,312.5 cu ft

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Good Practice Checklist For Fumigation

This checklist emphasizes steps related to life safety and fire safety. However, all items do not apply to all fumigants in all situations. This is intended as an outline for a more detailed operating procedure for fumigations.

Planning & Preparation

☑ **Become fully acquainted with site and commodity to be fumigated, including:**

1. General layout of the structure, connecting and adjacent structures, and above- and belowground escape routes.

a. Check equipment to ensure that product flow has ceased and that equipment has been made as tight as practicable to prevent drafts and/or leaks. This applies especially to spot fumigations,

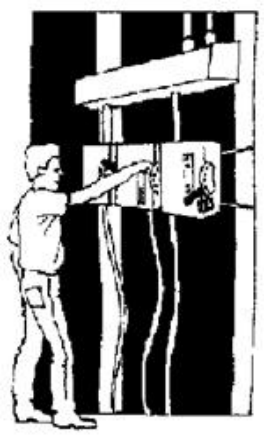
b. Check all spouts, conveyers, conduit heat pipes or other possible openings leading from the area to be fumigated.

2. The number and identification of persons who routinely enter the area to be fumigated and the proximity of other persons and animals.

3. The specific commodity, its condition, and mode of storage.

4. The commodity's treatment history, if available, to be aware of possible food residues.

5. Accessibility of utility service connections.



Locate utility service connections
(Photo: Nasdonline.org)

6. Locate the emergency shut-off stations for electricity, water, and gas.

☑ **Post current emergency telephone numbers, i.e., Fire, Police, Hospital, and Physician.**

☑ **Select an appropriate EPS-registered fumigant.**

1. Make sure the selected chemical or chemicals will not leave illegal residues.

2. Check, mark, and prepare the application points for spot or general fumigation.

3. Determine the dosage rates. Consider the structure's type, size, temperature, and humidity. Determine how well the structure can be sealed, any label restrictions, and the sorption of the fumigant. Fumigators develop good judgment about specific situations with experience.

☑ **Study directions, warnings, antidotes, and precautions on the label and on the manufacturer's instruction manual.**

☑ **Notify local fire and police authorities and other security personnel about the proposed fumigation's location, date and time, the chemicals to be used, type of protective equipment required, and fire hazard rating.**

☑ **Inform local hospital emergency rooms of your fumigation practices and the specific materials used.**

☑ **Provide authorities with pertinent safety literature on the materials to be used.**

☑ **Arrange for standby equipment, replacement parts, and an alternate plan of action.**

☑ **Inform all employees of the operational schedule, potential hazards to life and property, and the required safety measures and emergency procedures.**

☑ **Prepare warning signs for posting treated areas, provide for security of building, and arrange for watchmen when required.**

☑ **Have available first aid equipment and antidotes where applicable.**

☑ **Plan for application from outside the structure where possible.**

☑ **Plan for ventilating the treated space and commodities when the required exposure is finished. Do this before you start treatment.**

☑ **Properly identify areas used for storage of fumigant chemicals and provide the conditions required by the manufacturer's directions**

☑ **Make sure there are no open fires, motors, or light switches that could spark, or hot surfaces, such as heat pipes and electric fixtures, within the space to be fumigated.**

☑ **Provide fans to distribute the fumigant where applicable.**

☑ **Provide gas sampling and/or detection device.**

☑ **Make a final check to clear all personnel and non-target animals from the space to be fumigated.**

Sources

National Pesticide Information Center: http://npic.orst.edu/factsheets/archive/sftech.html

http://www.vdacs.virginia.gov/pdf/bb-heat1.pdf

https://www.degeschamerica.com/wp-content/uploads/2016/04/Phostoxin-Tablet-Pellet-manual.pdf

https://pested.osu.edu/sites/pested/files/imce/6%20Fumigation.pdf

http://www.extension.umn.edu/agriculture/pesticide-safety/pat/pfum/manual.pdf magtoxin

https://www.gipsa.usda.gov/fgis/handbook/FumigationHB/FumigationHandbook_2016-03-09.pdf

General Fumigation: https://www.uaex.edu/farm-ranch/pest-management/docs/training-manuals/AG1161.pdf

Structural Fumigation: http://npic.orst.edu/pest/fumigation.html