UK COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY — COLLEGE OF AGRICULTURE

Categories 1b & 7c

FUMIGATION TRAINING MANUAL

Introduction

The most effective way to reach pests in their most remote hiding places is through fumigation, the use of poisonous gases to kill pests in an enclosed area. To be effective, fumigants must reach target pests as gases. Fumigants are "wide-spectrum" pesticides, killing all species of arthropods and rodents that are likely to be found in a building. They are also volatile pesticides whose vapors enter the insect's body through the body wall or breathing system. Fumigants penetrate to many areas of a building not reached by sprays or dusts, even penetrating to the burrows of wood-infesting insects, as well as to the center of tightly packed commodities, such as tobacco in hogsheads, bales, cases or grain in large silos or bulking bins. A fumigant gas generally does not leave unsightly, odorous, or hazardous residues.

Fumigation also has certain disadvantages. Highly skilled, experienced, and licensed are required since all fumigants are extremely hazardous to use. The application of fumigants is limited to areas, spaces, items, or commodities that can be tightly enclosed. Fumigated structures must be sealed as air tight as possible and their occupants must leave, sometimes for seven days or longer. Some fumigants may damage items in the area being fumigated. Also, fumigation generally costs more than other pest control procedures, and fumigants leave no protective residue so that is possible immediately after treatment.

Fumigants are Restricted-Use pesticides because of their high acute toxicity, primarily by inhalation. They can act as respiratory poisons, anesthetics or narcotics, or enzyme poisons. Because of their gaseous nature and acute inhalation toxicity, fumigant products are labeled as Toxicity Category I and all fumigants will have warnings such as "Danger... .. Keep Out of Reach of Children ... .. Poison," and the skull and symbol. The label contains information on using the product correctly, obtaining practical pest control, storing the product safely, and disposing of the containers and residue of the fumigant correctly. The label also states antidotes and first-aid treatment, in case a human should be poisoned during a fumigation.

Any use of a fumigant in a manner inconsistent with the label may be in violation of the law. If a person violates the Federal Insecticide, Fungicide, and Act he or she may be subjected to civil penalties as much as $5,000 for each offense, or criminal penalties as much as $25,000 or one year in prison, or both. It is unlawful to transfer a fumigant from its original container to another unmarked container.

All fumigants are highly toxic and require trained personnel for application. Anyone handling fumigants should be thoroughly familiar with application procedures, safety equipment, first-aid treatment, and disposal procedures. At least two people should always be present when using fumigants and both should have the proper respiratory equipment for the particular fumigant being used.

The ideal fumigant should not change or impair the treated commodity in any way, nor should it leave any residue which could be hazardous during processing or harmful to the consumer. The EPA has determined the amount of pesticide residue that may safely remain in or on agricultural products as well as processed foods. This is called "tolerance." The EPA has also established exposure limits, which are the levels of fumigant concentration above which it is not safe for people (workers) to be exposed.

The quantity of a fumigant to be applied in sealed buildings, vacuum chambers, rail cars, and to packed commodities under tarpaulins is determined by the volume (cubic feet) of the space. In most cases, no allowances are made for the space occupied by the commodities. In grain silos or bulking bins, the quantity of a fumigant to be applied is calculated per ton or per 1,000 bushels of grain. The dosage rate of fumigants that are applied to the soil for tobacco beds in most cases is based on the size of the bed (such as 9 100 or 12 100) or the number of square feet to be fumigated. Of course, the label of each fumigant determines the basis for applying the fumigant.

If it is ever necessary to enter a structure when it is under fumigation, enter with a partner and the proper respiratory protection. After aeration, do not occupy fumigated premises until the fumigation supervisor has tested the fumigated area with the proper equipment and has announced the premises clear and safe to enter.

A fumigation's effectiveness can easily be checked by placing test cages of live target insects in various parts of the building, area, or commodity to be fumigated. Retrieve test cages after fumigation for a mortality count of the insects. Store all fumigants in locked, well-ventilated buildings.

Because fumigants are pesticides, fumigators should be familiar with the general considerations in pesticide use: the laws and regulations governing pesticide registration and application; safety, environmental effects of pesticides; pest biology and pest recognition; and labels and labeling. The information given here on fumigation should be used in conjunction with the core manual for all categories of pesticide applicators *Applying Pesticides Correctly.*

Kentucky has two categories of commercial fumigators; 1 C, Fumigation Agriculture-related non-residential for applicators controlling pests by fumigation in enclosed spaces *not including residential structures;* and 7C, Fumigation *including residential structures.* As of February 1,1988, all uses of all formulations of methyl bromide are classified as Restricted-Use. Farmers and other landowners who wish to apply methyl bromide as a soil fumigant on their own lands must become certified as private applicators.

Types of Fumigation

The two types of fumigation and their methods currently in use are listed below.

Space Fumigation:
- Chamber and vault fumigation
- Vacuum chamber fumigation
- Vehicle fumigation: railroad car, truck or van
- Tarpaulin fumigation
- Spot fumigation
- Structural fumigation
- Empty building fumigation: warehouse, grain elevator, food processing plant, mill, restaurant
- Shipboard, in transit ship or fumigation
- Farm grain storage fumigation
- Rodent burrow fumigation
- Fumigation of beehives, supers and other beekeeping equipment.

Soil Fumigation:
- Field, nursery, greenhouse and seed or transplant bed soils
- Non-tarp fumigation by injection.

Types & Nature of Fumigants

A number of fumigant active ingredients formerly used have either been canceled entirely or have had their uses strictly limited in the U.S. All space fumigant products, and several soil fumigant products, especially those containing chloropicrin and/or methyl bromide, are now labeled Restricted-Use.

Fumigants are broad spectrum pesticides that can act as respiratory poisons, anesthetics or narcotics, or enzyme poisons. They are chemically simple molecules, but they can exert potent and wide-ranging effects on the target organisms. Because of their gaseous nature and acute inhalation toxicity, fumigant products are labeled as Toxicity Category I with the signal word Danger, or Danger-Poison with the skull and crossbones symbol.

The following section lists and describes the active ingredients that are still available and legal to use.

Methyl bromide is formulated as a liquid and vapor under pressure. It is odorless, non-flammable, and generally not corrosive nor irritating to eyes as a vapor. Because it is highly toxic by inhalation and also odorless, many formulations contain chloropicm as a warning agent on non-food products. Methyl bromide products are used both for space and soil fumigation. If trapped inside tight clothing next to skin, methyl bromide can cause severe skin burns. Do not use it to fumigate materials that contain sulfur (e.g., hair, fur, leather, and rubber goods) because of an undesirable chemical reaction with sulfur. It is a good idea to test a small piece of the material to be fumigated to determine if it might react; that is, to actually conduct a small-scale fumigation on the suspect material.

Chloropicrin is a heavy, colorless, non-flammable chemical with an irritating tear gas odor, Like methyl bromide, it is highly toxic by inhalation. If added to methyi bromide formulations at a concentration of 2% or less, it is considered to be only a warning agent; it at concentrations greater than 2%, it is considered an active ingredient that augments the fumigant activity of the

methyl bromide. It will not be labeled for food use in the future.

Aluminum phosphide and **magnesium phosphide** are space, commodity, and rodent burrow fumigants. The formulations include pellets, tablets, prepacs, prepac ropes, bags, and plates. They are solids that react with moisture to liberate hydrogen phosphide (phosphine), which is a gas highly toxic to insects, humans, rodents, and other animals. It is thus absolutely necessary to keep aluminum phosphide and magnesium phosphide products DRY in storage. Since magnesium phosphide is more reactive than aluminum phosphide, it is generally recommended for fumigation under cooler and/or drier conditions. Phosphine ignites spontaneously in air at concentrations above 1.8% by volume. Some formulations include ammonium carbarnate, which liberates ammonia gas and carbon dioxide to reduce the fire hazard posed by phosphine. Ammonia also serves as a warning agent.

Sullfuryll fluoride is a space fumigant used primarily to control wood-destroying insects. It is a colorless, odorless, non-flammable gas formulated in cylinders under pressure. Special monitoring equipment is needed to use Vikane, the product containing sulfuryl fluoride as its active ingredient. Registration is expected soon to permit sulfuryl fluoride under the name Profume to be used to fumigate flour mills and similar areas.

DDVP, also known as dichlorvos, is a contact and stomach insecticide with some fumigant action and is used to protect stored products. Since it is an orgaophosphate it should be handled with the precautions used with other organophosphate products. It is somewhat corrosive and should be kept dry in storage. DDVP is under Special Review by the Environmental Protection Agency.
Ethylene oxide is a colorless, toxic, flammable liquefied gas that can be used as a fumigant on spices, black walnuts, and copra. It is formulated with carbon dioxide or dichlorodifluoromethane to reduce flammability.

Advantages & Disadvantages of Fumigation

Because fumigants are wide spectrum pesticides, space fumigation, done properly, will kill all species and life stages of insects and rodents that are likely to be found in the structure being fumigated. Soil fumigation will kill soil microorganisms, nematodes, and many weed seeds and seedlings. Fumigants, being gases, penetrate into building's nooks and crannies, including the galleries of insects that infest interior wood, that cannot be reached by pesticide sprays and dusts. Pests are rapidly killed and the fumigant gas does not leave unsightly, odorous, or hazardous residues if the site is properly aerated after fumigation.

Fumigation does have certain disadvantages. Fumigants are broadly toxic and hazardous to use, and thus fumigations must be done by highly skilled and experienced, licensed furnigators. Because space fumigation is done successfully only in enclosed spaces, structures or sites to be fumigated must be tightly sealed. All humans and other non-target organisms must leave the area until the fumigation period is over and aeration has been completed. You should also remove items that may be damaged by the fumigants. Another disadvantage is that fumigation may cost more than other methods of pest control. Also, fumigants leave no protective residue and pests may reinfest the fumigated site immediately after treatment. Corrosion is a real concern when fumigating with the metal phosphides.

When selecting a fumigant, consider the following characteristics as they apply to the site to be fumigated:
- The fumigant's volatility and penetration power
- The fumigants corrosiveness, odor, flammability, or explosive potential
- Warning capabilities and detection methods
- In the case of commodities, the fumigants effect on seed germination and quality of the finished or processed product
- Decomposition time of the fumigant chemical or its residues
- Disposal of spent materials or containers
- Availability of the product of choice, ease of application, and cost.
- Season of year, weather, and climate.

Factors that Modify Fumigant Effectiveness

Fumigants are used in various formulations and dosages according to the nature otthe commodities and pests involved. Factors that modify fumigant effectiveness that must be considered when selecting a formulation include the following:
✓ Pests to be controlled
✓ Temperature
✓ Moisture

✓ Structure area fumigated
✓ Method of application

Pests to be controlled. A pest's susceptibility to umigants depends on the species, its stage of development, and-its habitat. In general, fumigant gases reach the insects' tissues through the respiratory system. Most insects breathe through a series of openings, called spiracles, in the outer skeleton. Once inside the insect's body, oxygen from the air and fumigant gases are diffused through the insect's thin cell membranes. Some primitive insects and mites, close relatives of insects, breathe by taking in air through the cuticle, which covers the whole body.

The life stage of the insect that is least active metabolically (e.g., pupae, hibernating adults) is the most difficult to kill by fumigation. Fumigant labels give dosages needed for different species of insects and different life stages of those species. For this reason, a fumigator should know some pest biology.

Insects that have been fumigated with methyl bromide die slowly. At first, they may be unable to walk or fly normally. They usually come to rest on their backs and eventually are unable to recover from that position; however, they may move their heads, legs, or antennae for as long as several days before they finally die. (Some fumigants may anesthetize insects so that they appear to be dead shortly after fumigation only to revive and resume normal life.) Persons accustomed to seeing a quick kill are sometimes disappointed by observing insects that have been exposed to lethal dosages of slow-acting fumigants. Such insects are doomed to die eventually.

Temperature. Sub-lethal concentrations of the fumigant gas may result if fumigation is done at abnormally high or low temperatures. At low temperatures, the fumigant vaporizes and diffuses slower. Insect activity and metabolism are likewise slower. These factors tend to retard killing action, especially at temperatures below 10° C (50°F); thus, at lowertemperatures, you must use higher dosages and longer exposure time for a successful fumigation.

Conversely, at excessively high temperatures, fumigants vaporize faster and may dissipate too soon for lethal concentrations to be maintained long enough to kill pests, especially if the seal of the fumigation site is not perfect.

In the range of normal fumigating temperatures (60° to 80° F), the fumigant concentration needed to kill a given stage of an insect species decreases with the rise in temperature; this is mainly due to the insects' increased respiration rate, in response to the rise in temperature. Death occurs faster in the higher end of the normal temperature range.

Fumigant labels generally warn not to use the product at temperatures below 40° F (5° C); some soil fumigants also set an upper boundary.

Moisture. Adequate moisture is required for release of the actual toxicant, phosphine, in aluminum phosphide and magnesium phosphide products. At relative humidities below 25%, or gram moisture below 10%, release of phosphine requires more time. Excessive moisture may interfere with fumigant action by reducing fumigant concentration within a commodity, or by retarding aeration during soil fumigation. Do not fumigate extremely dry soils because a certain amount of moisture is needed so that weed seeds will germinate and can be killed while actively growing. Thus, as in the case of temperature, there is an optimum for moisture. Product labels give appropriate information on the effects of moisture.

Air Movement. Fumigate when there is little air movement. Regardless of how well the enclosure to be fumigated is sealed, wind can create problems due to leaks. Leaks in an enclosure are the single most likely cause for fumigation failures.

Structure, Site or Commodity. The most important step in a structural fumigation is the proper sealing of the structure — the more tightly sealed the structure, the more efficient the fumigation. Because wood is porous, wooden structures, even well-sealed ones, will not retain fumigant gases as well as those made of metal, plastic, masonry, or concrete. Cement blocks are also porous and likewise are a problem for efficient fumigation.

Increased dosages and exposure times can compensate for the loss of gas through diffusion into porous building materials. Tarpaulin fumigation using a gasproof sheet or cover is more effective than sealing a building with paper or tape and holding a fumigant within structural walls. Tarpaulin fumigation has the advantage of reaching the exterior wood areas (doors, sills, etc.) which may be infested.

According to federal and state law, a pesticide label is a legal document, and use of a pesticide in a mannerthat is inconsistent with label directions is illegal. Thus, use a

fumigant only on sites or commodities listed on the label, the other parts of the labeling, or the applicator's manual. Product label directions discuss the factors that affect the fumigant's efficiency on a particular commodity.

Ideally, a fumigant should not change the quality of or damage the treated commodity in any way, or leave any hazardous residue during processing of the commodity that could be harmful to the consumer. In fumigation, as in any pesticide treatment of a raw agricultural commodity or packaged food product, the "tolerance" must be considered. The tolerance, or tolerated residue, is the amount of the pesticide's active ingredient that is considered safe to consume and is legally permitted to remain in the commodity. Tolerances are expressed in parts per million, which is the same value as milligrams per kilogram (1,000 grams). On methyl bromide product labeling, the tolerances are given for the raw agricultural commodities for which the chemical has an established tolerance, along with the stored product pests to be controlled, dosages, and exposure times. Follow dosages and exposure times in order not to exceed the legal tolerances in the commodity fumigated.

Grain fumigation can be affected by type and condition of the grain: size, shape and permeability of the kernels, and the amount of dockage (chaff, dust, etc.) in the grain. "Sorptive capacity" of stored grain refers to adsorption, the adhesion of the fumigant gas molecules to the external surface of the grain, plus absorption, the holding of gas molecules within the kernel by capillary action. Other factors being constant, 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; hence, recommended dosages are generally higher for smaller grains such as wheat, rye, or sorghum than they are for corn. A more complete discussion of the factors affecting grain fumigation accompanies this fumigation training manual. Persons planning to fumigate stored food commodities should carefully read this manual.

Methods of Application. Soil fumigants may be applied under a tarpaulin (methyl bromide products) or by chisel injection into the soil (Telone, Vorlex), according to label directions.

Solid space fumigants that release phosphine may be added directly as pellets or tablets to animal feed, feed ingredients, and raw agricultural commodities stored in bulk. Treat commodities not stored in bulk (e.g., bagged) in the same way as processed foods; these should not come in contact with tablets, pellets or residual dust, except for brewer's rice, malt and corn grits for use in the manufacture of beer.

A Good Practice Checklist for Fumigation

The following checklist emphasizes steps related to life safety and fire safety. The steps noted will apply to most fumigation operations but cannot be expected to apply to all fumigants in all types of fumigations. Use the checklist 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 structures, adjacent structures, and escape routes, above and below ground.
   a. Check over equipment to ensure that product flow has ceased and that equipment has been made as tight as practicable to prevent drafts and/or leakage from it. 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. Number and identification of persons who routinely enter the area to be fumigated; proximity of other persons and animals.
3. The specific commodity and its mode of storage and condition.
4. The commodity's treatment history, if available, to be aware of possible food residues.
5. Accessibility of utility service connections.
6. Location of the nearest telephone or other communication facility.
7. Location of the emergency shut-off stations for electricity, water, and gas.

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

Select a fumigant or combination of fumigants, registered by EPA for the work involved.
   1. Make sure the chemical or chemicals selected will not result in residues that may be illegal under Sections 408 and 409 of the Federal Food, Drug and Cosmetic Act.
   2. Check, mark, and prepare the points of application (applies to spot and general fumigation).

3. Determine the dosage rates. Consider the type of structure and its size, temperature, humidity, how well the structure can be sealed, 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 surtaces. such as heal 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

Safety Recommendations

Personnel

Assign at least two persons to each fumigation job.
When a fumigated area must be entered, use a "buddy system" of at least two persons
Make sure that employees actively taking part in a fumigation are in good physical condition. Fumigators:
  — should have a physical examination at least once a year and more often if health conditions require such. Fumigation businesses should maintain up-to-date health records for each employee
  — should abstain from alcoholic beverages and medical or recreational[1] drugs for 24 hours before and 24 hours after a fumigation job
  — should NOT participate in a fumigation if they have colds or other respiratory problems that make breathing difficult.
  — should NOT participate in a fumigation while undergoing continuing medical or dental treatments unless authorized to do so by the physician or dentist in charge.
Instruct all personnel in first aid and other emergency procedures, including personal decontamination
Make sure fumigators understand the use of specific antidotes, first aid procedures, ana symptomatic relief measures.
Instruct employees to report ail accidents immediately to the employer or supervisor. Caution personnel to report all indications of illness or physical discomfort regardless of their apparent minor nature Signs of illness may include but not be restricted to any or all of the following: dizziness, diarrhea, nausea, headaches and lack of coordination
Make sure employees understand the hazards that may be encountered because of carelessness or misuse of fumigants
Teach employees in the selection, operation, and maintenance of all protective equipment and safety procedures required by the fumigant of choice

Protective Equipment

Fumigators must use protective equipment to prevent injury or loss of life if they are likely to be exposed to gas levels above the allowable limits.

It is necessary to follow exactly the label recommendations concerning specific protective equipment and clothing for each fumigant product

Label requirements for protective clothing and equipment are related to threshold concentrations of the fumigants in fumigated spaces: therefore, fumigators need reliable detection devices to ensure health ana safety of personnel, as well as to comply with the law, because the pesticide label is a legal document. For information about specific detection devices, see the section on Use of Safety Devices, Analyzers, and Detectors.

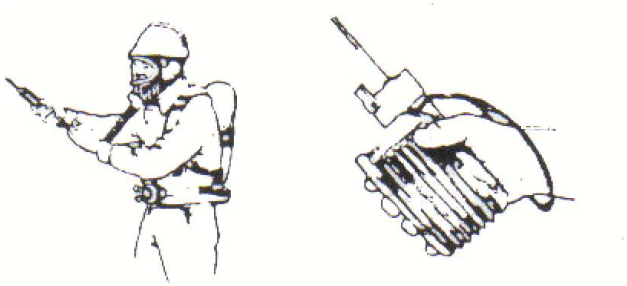
If the fumigant concentration in the fumigated area, as measured by a direct reading detector device, exceeds the threshold concentration specified by the ERA for that fumigant. all persons in the area must wear the protective equipment specified on the label. Such equipment will be either an NIOSH/MSHA approved self-contained breath-ino apparatus (SCBA) or a combination air-supplied/ SCBA respirator. Manufacturer's directions and specifications for SCBA's must be understood and followed Gas mask/canister combinations are also allowed under certain circumstances. Threshold concentrations for some space fumigants that may still be legally used are given below

Fumigant	Threshold Concentration (ppm)
methyl bromide	5.0 (TLV)[a]
chloropicrin	0.1 (TLV)
cyanide	10.0 (TLV)
hydrogen phosphide (Phosphine)	0.3 (TWA/TLV)[b]
sulfuryl flouride	5.0 (TLV)

[a]Threshold Limit Value (at any time during fumigation)
[b]Time Weighted Average over an 8-hour period for applicators

If the concentration of methyl bromide in the area, as measured by a pump ana appropriate detector tubes (e.g.. Draeger, Kitagawa. MSA. and Sensidyne). does not exceed 5 ppm, no respiratory protection is required. It this concentration is exceeded AT ANY TIME, all persons in the fumigation area must wear an NIOSH/MSHA self-contained breathing apparatus (SCBA) or combination air-supplied/SCBA respirator.

Applicators must not be exposed to hydrogen phosphide levels above 0.3 ppm as an 8-hour Time Weighted Average (TWA) during application. With exposure up to 1 5 ppm. or TO ESCAPE FROM levels up to 1500 ppm, an NIOSH/MSHA approved full face gas mask, hydrogen phosphide canister combination may be used. Above 1 5 ppm, or if concentrations are unknown, an NIOSH/MSHA approved SCBA must be used.



Respiratory protection must be available at the site of application in case it is needed when applying aluminum phosphide within a structure; it does not have to be available for outdoor applications. At any time other than during application the allowable limit for hydrogen phosphide exposure is a ceiling of 0.3 ppm.

No respiratory protection is necessary if the chloro-picrin concentration, as measured by a Matheson-Kitagawa detection device, does not exceed 0 1 ppm at any time during the fumigation. If it does, fumigators must wear an NIOSH/MSHA approved air purifying respirator approved for organic vapors, an SCBA, or a combination air-supplied SCBA/respirator

The threshold for sulfuryl fluoride is 5 ppm; persons may be exposed to this level daily for 8 hours without adverse effects. The Short Term Exposure Limit (STEL) is 10 ppm; persons may be exposed to this level continuously for 15 minutes without adverse effects.

Storing, Handling, & Disposing of Fumigants

Store all fumigant products in a locked, dry, well-ventilated place away from heat. Post as a pesticide storage area. Do not risk contamination of water, food, or feed by storing these products in the same area as other pesticides. Do not store fumigants in buildings that animals or humans occupy. Remember that ALL PESTICIDES AND THEIR EMPTY CONTAINERS SHOULD BE KEPT OUT OF REACH OF CHILDREN

Handle methyl bromide cylinders carefully. Do not drop. bump, or drag cylinders or slide them from one place to another. Only transport these cylinders on hand trucks, fork trucks, or similar devices to which the cylinder can be firmly secured. Do not remove the valve protection bonnet and safety cap until immediately before use. and always make sure the cap is in place when the cylinder is not in use. Close empty cylinders securely with safety cap. Make sure the protection

bonnet is in place and return the empty cylinder to the shipper. THESE CYLINDERS MUST NOT BE USED FOR ANY OTHER PURPOSE.

Some aluminum phosphide products are supplied in relatively gas-tight, resealable aluminum flasks, which should not be opened and exposed to atmospheric moisture any longer than is absolutely necessary to remove the products. Tightly reseal partially empty containers and mark them as partially used. Triple-rinse empty flasks and stoppers with water and offer them for recycling or puncture and dispose of the flasks in an approved sanitary landfill or use other local and state approved procedures. Dispose of the rinsate in the same way or by other means given in the labeling.

If properly exposed, the dust remaining after fumigation with hydrogen phosphide products will be gray-white and contain only a small amount of unreacted aluminum or magnesium phosphide. Residual dust from an incompletely exposed product, the so-called "green dust." needs special deactivation and disposal procedures. Small amounts may be disposed of by a "dry" method. Large quantities must be disposed of by a "wet" method, in which the residual dust is deactivated in a detergent or surfactant and water solution. Follow the detailed directions EXACTLY as they are on the product labels.

Triple-rinse liquid soil fumigant containers and dispose of the rinsate in the field just treated. The containers can then be offered for recycling or punctured and disposed of in the same way as other pesticide containers.

Hazardous Materials Management

The Superfund Amendments and Reauthorization Act of 1986 require communities and states to develop plans for managing hazardous materials that are found in their areas. The Environmental Protection Agency has compiled a list of extremely hazardous materials for which records must be kept by the local Emergency Planning Committee and the state Emergency Response Commission. EPA has also set up Threshold Planning Quantities (TPQ's) and Reportable Quantities (RQ's) for each material on the list. The TPQ is the amount which, if held in storage at a facility, must be reported to the local Emergency Response Commission The RQ is the amount which, if accidentally released into the environment through misapplication or spillage, must be reported to the Commission. Among the hazardous materials on the EPA list are numerous pesticide active ingredients.

The fumigants on the list, with TPQ's and RQ's are:

Fumigant	TPQ (lbs)	RS (lbs)
methyl bromide	1,000	1,000
aluminum phosphide/ phosphine	500	500
hydrocyanic acid (cyanide)	100	10
methyl isothiocyanate	500	1
DDVP	1,000	10

Facilities that use or store the TPQ of any of the chemicals on the list of extremely hazardous materials must furnish Material Safety Data Sheets (MSDS's) for those chemicals and file annual inventories with the local Emergency Planning Committee and the state Emergency Response Commission. The MSDS's are provided by the chemical manufacturers

If you do not know how to get in touch with your local Emergency Planning Committee, you can obtain this information from the state committee. In Kentucky, contact: State Emergency Response Commission/DES
Col. James H. (Mike) Molloy, Director
Boone National Guard Center
Frankfort, KY 40601
(502) 564-781 5 or 564-8660

NOTE: pesticide applicators who apply pesticiaes LEGALLY ACCORDING TO LABEL DIRECTIONS do not have to report their normal operations as a release into the environment, even though more than the RQ may be released. Only misapplications and spills must be reported.

Spill & Leak Procedures

Methyl bromide product directions recommend that if a spill or leak occurs, fumigators should evacuate the immediate area of the spill or leak, then use either an NIOSH/MSHA approved SCBA or a combination air-supplied SCBA respirator to go back into the affected area to correct the problem. The spill should be allowed to evaporate and no one should enter the spill area without respiratory protection until the concentration of methyl bromide is less than 5 ppm. Remove leaking containers to an isolated area and cover them with a polyethylene sheeting (tarp) at least 4 mi thick. Place the edges of the tarp in a trench and seal them with soil, tamped down tight.

Contaminated soil, water, and other cleanup debris comprise a toxic/hazardous waste. If the Reportable Quantity of 1,000 pounds of methyl bromide is

exceeded, the spill must be reported to the local Emergency Response Commission.

A spill of aluminum or magnesium phosphide products may generate high levels of phosphine gas, hence all personnel must wear an SCBA for spill cleanup. DO NOT USE WATER AT ANY TIME to clean up these spills; water speeds up the production of phosphine, which could result in a toxic or fire hazard. The RQ for phosphine is 100 pounds.

If aluminum flasks have been damaged enough to leak, temporarily repair them with aluminum tape, or transfer the undamaged product to a sound metal container. If a spill is only a few minutes old. return intact products to the original flasks, or to another sound metal container, stoppered tightly. Remember to properly label the alternate container. If you do not know the age of the spill, or if the product has been contaminated with soil, water, or debris, gather up the spillage and place it in a small open bucket of less than 1 gallon capacity, with no more than 2 or 3 pounds of spillage per bucket. Carry out wet deactivation on site if feasible; if not, carry spillage in an open vehicle to a suitable area and deactivate it there. Small amounts of spillage (up to 18 pounds of product) may be spread out in an open area to be deactivated by atmospheric moisture.

The best way to avoid spills and leaks is to use the product strictly according to label directions.

Application Procedures

Pre-Fumigation & Fumigation Period

Detailed directions for various types of fumigations are given on the recently improved fumigant labels. READ AND FOLLOW THE LABEL DIRECTIONS.
Post areas to be treated immediately before fumigation. Placarding should be bilingual 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 watchmen where required. This is always necessary unless the fumigated area is completely locked or enclosed by a locked fence.

Post-Application Operations

Provide watchmen where required and/or necessary
Allow enough time and use enough fans to ventilate and aerate in accordance with structural limitations.
Turn on all ventilating or aerating fans where appropriate.
Before re-entry, use a suitable gas detector to determine fumigant concentration so that 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 property and clearly labeled containers to storage area.

General Fumigations

Building Types

Virtually all frame or metal buildings can be fumigated if they are in good repair and tight, or if they can be made tight by sealing or tarping. Cement blocks pose a special problem because they are porous. They sometimes can be fumigated if you inerease the dosage and exposure to compensate for the diffusion loss. Additional gas for methyl bromide or sulturyl fluoride can be used after detector readings indicate that a higher concentration is needed. Any time more gas is added, there is gas leaking into areas where it is not wanted. There is no rule of thumb allowing for leakage. Applicators must exercise judgment from their observation of the building's condition. Fumigations must conform with all local, state, and national regulations.

Sealing the Building

The fumiganfs ideal properties of penetration and diffusion also make it difficult to confine and for that reason, a good sealing job is necessary. In fact, properly preparing and sealing the structure is the most important

part of a successful fumigation. Careful sealing also saves time and material. When sealing a building, think in terms of sealing it so tightly that if it were filled with water, none would escape.

Because a fumigant is difficult to confine, high winds, increase fumigant loss and cause the fumigant to drift to the leeward side of the building. If fumigation must be done on a windy day, apply more gas on the windward side to minimize the loss and drift and take gas level readings more often.

The first step in sealing the building is to dose off all external openings to the building. Seal root ventilators and chimneys by wrapping them with a tarpaulin, or plastic sheet, or by stripping the screened openings with a wide commercial masking tape.

Next, close all stairwells and interior doors and replace any broken panes. Tightly wedge and lock all exterior doors and windows and caulk or tape cracks. Check for cracks in the floor, roof, and around the eaves and seal them.

Take special care to seal partitions to adjacent storage or work areas in a building. Clear adjoining buildings sharing a common wall.

If a nearby building is occupied, you must check it frequently with a monitoring device during fumigation to ensure the occupants' safety. Check local regulations for specific requirements.

Appearance, economy and ease of cleanup will probably determine your choice of sealing materials.

Where time and neatness are factors, masking tapes and commercial caulking compounds will probably justify their extra cost

Because fumigant gas can penetrate accumulations of trash and sweepings, necessary cleanups may be postponed until the fumigation is completed. Open all doors and hatches on milling machinery, including elevator boots and repair openings, conveyer lids, settling chamber doors, and dust trunks. This also applies to reels, purifiers, sifters, shorts and bran dusters, feeder gates on rolls and purifiers as well as other openings to allow the gas to enter the equipment Be sure to open "dead" spouts before fumigation because they are particularly difficult to penetrate.

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 irregulars ha ped 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 See appendix.

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 maaterials that cannot be penetrated by the gas.

Follow recommended checklist for release and aeration procedures.

Tarpaulin Fumigations

(excerpted from Pest Control, November 1981)

A fumigation enclosure made from tarps can be used in a wide range of control jobs from the wood borer infested museum piece, to the whole house termite job, to the grain elevator plagued by stored product pests. Tarps give the fumigator flexibility in treating any size or shape structure, at the site of infestation.

Gas-impervious polyethylene, vinyl or neoprene coated nylon, or an equivalent fabric can be used. Tarps should be at least 4gauge in weight (.004 inches or 4mits in thickness). You may use thinner tarps in certain types of fumigations. Heavy oiled-type canvas is not recommended.

If more than one tarp is necessary, overlap them at least 12 inches at the joints, roll the adjoining edges together and fasten with spring clamps not more than 12 inches apart. You can also use wooden laths on each side of the joint and C clamps fastened at 12-inch intervals along their length. However, the spring clamps provide more flexibility at the seams and allow the tarp to better conform to the shape of the object being fumigated. For a semi-permanent chamber using tarns over a frame, you can seal seams with plastic cement.

Conduct the fumigation on a tight floor. Even well dampened firm soil, or asphalt paving may leak excessively. Concrete paving without cracks or joints is best If not available, place a tarp on the surface and then stack the commodity on top. The bottom and top tarps can be joined.

Tarps should be large enough to allow an 18 inch lip of

material around the base of the enclosure. Seal this lip against the floor by piling sand on the exposed tarp. "Sand or water snakes" can also be used around the entire lip, being certain ends overlap rather than just butting together. These snakes should not be less than three inches in diameter and should be made of canvas or polyethylene tubing. You can fill polyethylene tubing with water at the job site, and easily drain it afterward and store it in compact rolls.

Methyl bromide fumigations. Stack articles to be fumigated on pallets or frames to permit free air flow beneath the load. The tarp should be supported about two feet above the load and held out from the sides about one foot. These precautions ensure that the gas will reach every part of the load. In addition, pile multiple stacks of grain to allow air flow between stacks.

A single enclosure should generally not be more than 10 feet high, 25 feet wide, or 50 feet long. If You will need blowers or fans to adequately propel the fumigant to all parts of the load. (Fans are not needed for hydrogen phosphide fumigations).

For loads up to about 3,000 cubic feet, two 18-inch office-type fans will provide the necessary circulation. Place the fans at opposite ends of the enclosure, one high and one low, with both directed at the center of the load. Keep them on during the entire period of gas introduction and for at least 30 minutes afterward. When the gas analyzer shows the fumigant is evenly distributed, (equilibrium) turn off the fans. For large loads, or in space fumigation, a blower having a minimum air moving capacity of 1/5 the cubic contents of the area involved should be positioned to take the air from floor level and discharge it over the top of the load.

Carefully measure the space to be fumigated to determine volume and proper fumigant dosage. In large tarpaulin fumigations, fractional dosages can be evened off to the next higher pound. Use the appropriate gas analyzer to measure for even distribution, and place analyzer tubes so that the tarp will not be sucked over them.

Volatilizers (which turn the liquid fumigant to a gas) are recommended for all methyl bromide fumigations. Thev are also essential at 60 degree For lower, or when dosage is three pounds or more ot this most commonly used fumigant

As a final precaution, check tarps tor pinholes, leaks, and tears before use. Pad sharp corners of the load with burlap or some other soft material to prevent tears. And use care when walking on tarps or using heavy equipment near them.

Tobacco Warehouse Fumigation

Tobacco warehouses are constructed of virtually every type of building material — metal, wood, brick, cement block. Some have closed sides, others are louvered. Some have solid roofs, some have skylights, and others have ridge vents. Tobacco warehouses are in residential, industrial, and commercial areas, or in areas that have very little transit traffic. Such varied conditions can cause problems for the fumigator. Therefore, before fumigation, you should study these conditions carefully to plan the best and safest approach.

The Tobacco or Cigarette Beetle, *Lasioderma serricorne*, and the Warehouse or Stored Tobacco Moth, *Esphestia elutella*, are the two most destructive insects to stored tobacco. These insects have a four-stage life cycle — egg, larva, pupa, and adult. They are known as warm weather pests and usually flourish in Kentucky from May to late October or early November, depending on the temperature.

As explained in the General Fumigation Section, seal the warehouse as air tight as possible In some cases, the whole building will need to be covered and sealed with polyethylene, while in others, only the openings in the building, such as doors, windows, and vents need sealing. A polyethylene cover 2 to 4 mil thick is recommended because it will cling to the building better than will a thicker material.

Tobacco is usually stored in warehouses in barrels (hogsheads), wooden or cardboard cases or boxes, and/or in burlap bales. It is packed very tightly, therefore, to reach the insects in the centers, the fumigant must have great penetrating power. In the past, methyl bromide and hydrogen cyanide were used with little success because they did not penetrate the tightly packed tobacco. Currently, the most widely and successfully used fumigants in tobacco warehouses are the metal phosphides. If the warehouse is sealed properly and the correct dosage is applied for the required exposure time, phosphine gas will penetrate with no mechanical aid to the very center ot the tobacco containers and will kill all life stages of any pests present. Four days are required for penetration of tobacco in hogsheads.

Phosphine is most effective when the temperature of the tobacco is above 65˚ F (above 70˚ F is even better)

When determining when tobacco should be fumigated, consider the number of insects caught in the suction or pheromone traps and the temperature of the atmosphere and the tobacco. All warehouses should use traps to keep track of the insect population and to indicate the severity of the infestation. The suction traps formerly used have largely been replaced by pheromone traps to detect presence of cigarette beetles and tobacco moths.

After the building is sealed, it is a good idea to check it for leaks before beginning fumigation. Check for leaks by using thermal smoke generators against the walls and sealed openings inside the building. A person on the outside can mark the areas where smoke escapes, so they can be resealed. A Dyna-Fog or Tifa Unit is good equipment for this purpose.

Apply the fumigant on the floor through the center of the warehouse. If you use tablets or pellets, they should be put loose on pieces of kraft paper.

As soon as the fumigant is placed in the center of the warehouse, everyone should leave through the escape door, which should then be sealed tightly. Phospnine gives off a warning odor similar to carbide or garlic. Just before phosphine is released from the product, an ammonia-like odor will be released to warn the applicator(s) to leave the area at once. This usually occurs about 10 minutes before phosphine is released. Only actual measurements can accurately tell the concentration. For best results, stored tobacco should be exposed for 96 hours. Hogsheads of tobacco should be aerated for at least three days.

To check the fumiganfs penetration into a container and also to determine if any leaks are occurring during the fumigation, insert a metal tube into a commodity container located as far from the fumigant release as possible. Attach a plastic tube to the metal tube and run it to the outside of the building so a gas reading can be taken safely with either an Auer or Draeger high level phosphine detector tube. Gas concentrations are measured in "parts per million." It is generally agreed that if the phosphine gas concentration is 50-100 ppm at the end of a 96-hour fumigation, there will be a 100% insect mortality rate.

When fumigating only part of the contents of a tobacco warehouse, cover the commodity to be fumigated with polyethylene and secure the bottom to the floor with loose sand, sand snakes, or tape. Also, tightly seal the floor under the commodity. In general, follow the same procedure as suggested under the Tarpaulin Fumigation Section.

All the safety precautions as described under the Good Practice Checklist for Fumigation should be followed for tobacco warehouse fumigation. Using the proper detection equipment, check the building thoroughly after aeration before re-entry.

Phosphine is very corrosive to certain metals, such as copper wiring, brass sprinkler heads, and electronic equipment.

Many pieces of equipment cannot be adequately protected and should be removed before fumigation.

For safety reasons, the person doing the fumigation should be the only one who has a key to the building being fumigated.

The fumiganfs label will list the disposal procedures for the phosphine residue. Follow the procedures exactly as recommended. Also, city, county, and/or state agencies having jurisdiction over the disposal of toxic wastes should be notified before disposal.

Tarpaulin Fumigation

When fumigating packaged commodities, follow the steps listed below:

1. The Stack — Stacks of stored commodities usually can be fumigated where they stand as long as the tarpaulin is large enough to cover the stack completely. If, however, material is being stacked expressly for fumigation (such as when unloading a freight car), stack it in a square five or six feet high. Be sure to allow for a tarpaulin margin of at least two feet around the stack when the cover is laid over it.

The stack should be on a concrete floor or other airtight surface. Where floors are not airtight (such as on a loading dock), cracks should be caulked or otherwise sealed to prevent the fumiganfs escape. Polyethylen, or additional tarpaulin laid on the floor under the material to be fumigated, can provide a satisfactory seal.

2. The Gas Expansion Dome Center — Four or more sacks, cartons, or cases upright on top of the stacked material to form a gas expansion dome. The expansion

dome aids gas distribution for some fumigants. It is not required, however, for a solid fumigant, such as magnesium or aluminum phosphide, which produces phosphine.

3. Tubing and Evaporating Pans — Use copper or polyethylene tubing to inject the gas near the center of the expansion dome. Fasten the outlet of this tubing to an evaporating pan to prevent liquid fumigant from dripping on the commodity being fumigated, or splashing onto the tarpaulin.

4. The Tarpaulin — Use polyethylene or gas proof, impregnated, tarpaulins. Water-proofed canvas tarpaulins are not satisfactory. Before spreading the tarpaulin, sweep around the stack to provide a clean surface for sealing. Unroll or unfold the tarpaulin over the stack, providing a margin on the floor of two or three feet. Run the applicator tubing out from under the tarpaulin at a corner, which should be folded. If phosphine tablets or bags are used, there is no need for any special equipment. The tablets or bags can be put in trays and slid underthe cover. Seal the tarpaulin by weighting it down with a row of bagged material or sand-filled tubes (Canvas or plastic tubing about four inches in diameter may be used for these "sand or water snakes.")

5. Applying the Fumigant — Release the required amount of fumigant from outside the stack based on the cubic measurement of the stack.

6. Removing the Cover — When fumigation is finished, pull the tarpaulin back only partially and leave it for about 30 minutes. This will allow the fumigated material to air out before the cover is removed completely. After aeration, remove the tarpaulin, carefully fold it, and store it for the next use.

Chamber Fumigation

Vacuum Chambers — The penetration rate of gas into the material to be fumigated is often an important factor, and is related to the sorptive capacity of the treated material. The fumigant's penetration rate is greatly increased if fumigation is done in an airtight chamber from which the air has been exhausted. This treatment is called vacuum fumigation. You can remove the fumigant quite completely from the fumigated material 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 advantageous when speed is an important factor, because the vacuum usually reduces the time necessary to effectively 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.

Atmospheric Chambers — You can construct a suitable low-cost fumigation chamber using a gas-tight room with an appropriate door and a minimum of equipment, including applicator, exhaust blower, and a small fan for even gas distribution. (Fans are unnecessary in phosphine fumigations.) Heating may be necessary, preferably by steam pipes, to maintain a temperature of at least 70˚ F during fumigation.

Vehicle Fumigation

(Railroad Cars)

Railroad cars are the vehicles most frequently fumigated in Kentucky. Follow the procedures listed below when fumigating these vehicles.

1. Place cars on seldom used trackage or siding so that they will not have to be moved while under fumigation. In-transit fumigations are not permitted on public highways, and are permitted in rail cars only with phosphine fumigants.

Always apply liquid fumigants from outside the railroad car using a 1/4 inch copper or plastic tubing attached to a can puncturer or to a fumigant cylinder. The tube can enter the car through a hole drilled in the floor near the center ol the car or through some other convenient hole, such as *z* crack in the door or some roof opening. Secure the discharge end of the tube near the ceiling at the center ol the car by fastening the tube to a pole, stick or some other support that can be propped up to hold the end of the tube near the ceiling. Plug the discharge end of the tube anc drill a hole through the opposite walls of the tube aboui one to two inches below the tip to allow the fumigant misi to escape above the commodity load and toward the opposite ends of the car.

If solid fumigants are used, apply them directly on thf floor of the rail car on kraft paper or in trays. You can alsc use prepacs, bags, or plates. If the commodity is in bulk form, put the fumigant into it when it is being

loaded or use the probe method if the car is already loaded. The fumigant label will recommend the exposure and aeratior time as well as the dosage rate.

Carefully seal all car openings. Pay particular attention to the space around doors, the eaves, and the floor. During application and fumigation, tightly seal all openings usec to introduce the gas tube up to and surounding the tube Any holes bored through the car should be as small as possible and carefully sealed following fumigation. Use masking tape or polyethylene as sealing materials.

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 application of a liquid fumigant such as methy bromide with the proper dosage, withdraw the tubing anc seal the hole used for application. Keep the car sealed foi 12 to 18 hours. You can use a halide detector to check sealed areas for leaks. The fumigated car should not b i moved during the exposure period.

At the end of the fumigation period, open all doors anc vents to allow as much air circulation as possible. Thirt minutes is usually required to aerate a car afte fumigation, but this must be determined by the use ofj gas detector. Keep all persons out of the area during fumigation and aeration and until such time as the gas detector shows no fumigant present. Only then is it safe tc enter the car without wearing respiratory protection.

Tobacco Bed Soil Fumigation

Methyl bromide used as a soil fumigant acts as an insecticide, nematicide, and herbicide. Thus it is used

for many types of crops, such as tobacco beds, strawberries, and tomatoes. When using methyl bromide, the soil should be worked thoroughly just before treatment. The soil should be dry enough to work well because the fumigants movement in the soil is directly related to the amount of soil moisture. Do not fumigate when the soil is wet.

Cover the bed with a gas-proof cover and seal the edges with soil. Insert tubing (plastic) at three points in a 1 00-foot bed, one at each end and one at the center. Place an evaporating pan or tray under the cover at the end of each tube. Puncture cans with the applicator and release the labeled dose of methyl bromide gas for a bed into the evaporating pans or trays under the plastic cover.

Leave the plastic cover on the bed for at least 24 hours, and do not seed the bed for 24 hours after the cover has been removed. If methyl bromide is heated to 150 degrees F or warmer, it will be released as a gas and no evaporating pans or trays will be necessary. When using unheated methyl bromide, the soil temperature should be 50 degrees F or warmer.

Some soil fumigants can be mechanically injected into the soil.

Use injection type applicators and set shanks 6" to 8" apart. Inject at a depth of 6" to 8". Immediately after application, drag soil to remove chisel marks, then firm with a smooth roller. If additional water is needed, apply only half inch. If a tarp seal is used, less fumigant may be effective. In soils 70 degrees F or higher, give special attention to sealing the surface of the soil. Tarping gives the best seal. The fumigant should stay in the soil at least four days; seven days is better. Aerate the soil by discing. Repeat discing several times if soil is extremely wet.

Grain Elevators (Silos) &Bulk Bin Fumigation

The recirculation method gives the best results when using phosphine in a grain bin or silo (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 more effectively penetrate areas that are resistant to natural gravitational diffusion, thus providing better insect control.

Before fumigant application, seal the grain storage facility as air tight as possible and ensure that the recirculation system is operating properly. After the air flow has been established throughout the grain mass, turn the fans and place the phosphine on top of the grain. Recirculation should be used until the fumigant is thoroughly distributed. Turn off the recirculation system and allow at least 4 days 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 of time without advedrse effects and this will improve the control. 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.

Phosphine gas is an extremely effective grain fumigant. It also is effective for other commodities, whether they are in bulk form 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). Either place the tablets or pellets into the stream of grain by hand or with a dispenser.

If the bilk 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 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. (This is another advantage of this type of fumigation.) Subsequent to treating, no additional measure is required to render the bulk commodity marketable.

There is a fundamental difference between the fumigation of bulk and packaged commodities with phosphine gas: with bulk products, the tablets or pellets are added directly to the goods; packaged commodities, however, are treated in such a way that neither the tablets, pellets, bags, or plates, nor their residues come in direct contact with the goods.

Characteristics of the "Perfect Fumigant"

The perfect fumigant:

Controls the target pests effectively.
Has low toxicity to non-target organisms.
Has low use hazard.
Is noncorrosive, nonflammable, and nonexplosive.
Does not react with fumigated products.
Has no undesirable odor
Vaporizes readily.
Penetrates rapidly to location of target pests.
Has low sorption on wood and other building materials
Has low solubility in liquids.
Can be monitored easily.
Can be aerated readily.
Is packaged for convenient storage, transport, and disposal.

TABLE 1. Essential Properties of Fumigants In Common Use for Insect Control[1]

Name & Formula	Molecular Weight	Boiling Point *(0˚C at 760 mm. pressure)*	Solubility in Water *(g/100 ml)*	Flammability *(% by volume in air)*
Chloropicrin $CCI_3.NO_2$	164.39	112.0	Insoluble at 20°C	Nonflammable
1 ,3— dichloropropene $C_3H_4CI_2$	110.98	108.0	—	Nonflammable
Dichlorvos (DDVP) CCI_2 = CHO.PO. (OCH_3)	221.0	120˚ C/14 mm	Slight	Nonflammable
Ethylene oxide $CH_2.O.CH_2$	44.05	10.7	Very soluble at 20˚ C	3-80
Hydrocyanic acid gas HCN	27.03	26.0	Very soluble at 20˚ C	6-41
Methyl bromide CH_3Br	94.95	3.6	1.3 at 25°C	Nonflammable
Methyl isothiocyanate C_2H_3NS	73.12	119.0	Slight	Nonflammable
Phosphine PH_3	34.04	-87.4	Very slight	Highly flammable
Sulfuryl fluoride $S0_2F_2$	102.06	-55.2	0.0075 at 25°C	Nonflammable

[1]From Monro Manual of Fumigation for Insect Control

APPENDIX

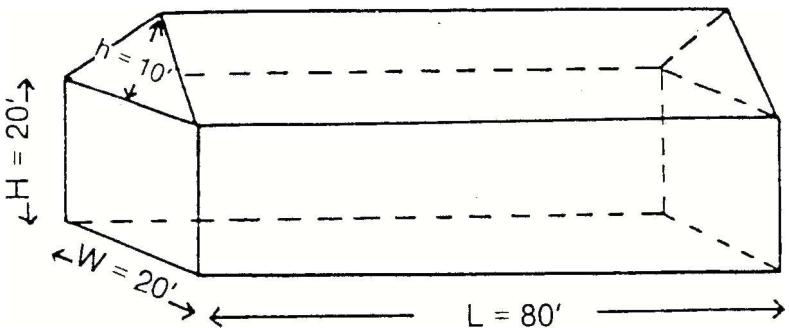
Formulas for Calculating Volume

Flat Storage not including loft

Volume (cu ft) = L x W x H
80′ x 20′x 20′= 32,000 cu ft
32,000 cu ft x 0.8 = 25,600 bushels

Loft:
volume (cu.ft) = $\frac{L \times W \times h}{2}$

$\frac{80' \times 20' \times 10'}{2}$ = 8,000 cu ft or ft^3



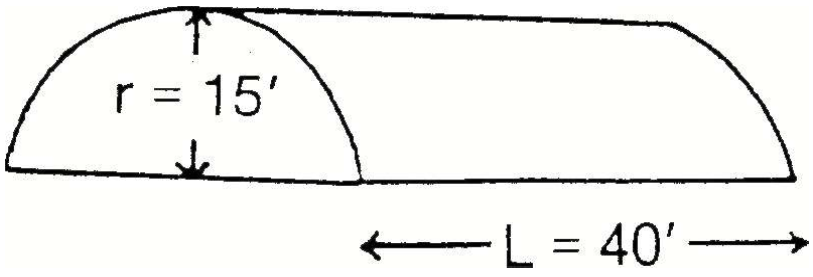
Flat storage plus loft:
Total Volume = 32,000 ft^3 + 8,000 ft^3 = 40,000

Quonset hut (semicircular end)

Volume (cu ft) = $\frac{\pi r^2 \times L}{2}$

π = 3.1416
r = 15′
L = 40′

$\frac{3.1416 \times 15' \times 15' \times 40'}{2}$ = $14,137^3$

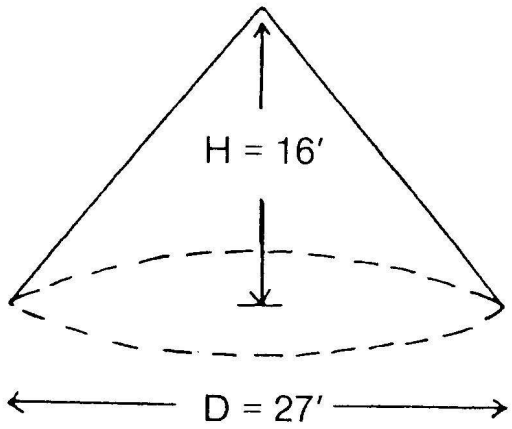


Cone

Volume (cu ft) = $\pi r^2 \times \frac{H}{3}$

π = 3.1416
H = 16 ft
D = 27 ft
r = ½ D = 13.5 ft

3.1416 x 13.5′x 13.5′x 5.33′= 3,051 cu ft



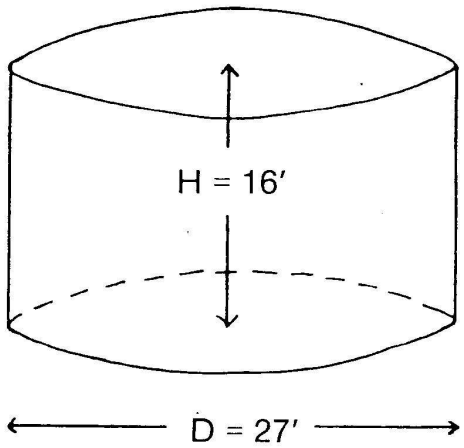
Round Bin (cylinder)

Volume (cu ft) = $\pi r^2 \times H$

π = 3.1416
D = 27 ft
r = ½ D = 13.5
H = 16 ft

3.1416 x 13.5′x 13.5′x 16′= 9,160 cu ft

9,160 cu ft x 0.8 = 7,328 bushels



Where trade names are used, no endorsement is intended, nor criticism implied or similar products not named.

ACKNOWLEDGEMENTS

This manual was prepared by Lorraine D. Rodriguez in response to a need for updated training materials after the Environmental Protection Agency had canceled several fumigants and instituted a Label Improvement Program for those remaining in registration. A number of people sent us updated f umigant labels and/or made constructive comments on the first draft of the manual: Donald G. Shaheen, Vice President of Degesch America, Inc.; L. V. White, Great Lakes Chemical; Kevin Pass, Action Pest Control Co. and David K. Mueller, Fumigation Service and Supply Inc./Insects Limited, Inc. Dave also furnished illustrations used in the manual. We are grateful to all of these persons and also to Freda Elam for typing the manuscript.