

INDUSTRIAL, INSTITUTIONAL, STRUCTURAL,  
AND HEALTH RELATED PEST CONTROL

Category 7d: Fumigation

A Training Program for the Certification  
of Pesticide Applicators

Organized by:

William H Robinson, Extension Specialist, Entomology

LV  
5655  
A762  
1979m  
c.3

## TABLE OF CONTENTS

|  | Page |
|--|------|
| ACKNOWLEDGEMENTS.....                                | 1    |
| FOREWORD.....  | 2    |
| KEYS TO THE PROPER USE OF PESTICIDES.....            | 3    |
| INTRODUCTION.....                                    | 5    |
| NATURE AND EFFECTS OF FUMIGANTS.....                 | 7    |
| SOME MODERN FUMIGANTS.....                           | 14   |
| METHODS OF FUMIGATION.....                           | 37   |
| PRECAUTIONS, PROTECTIVE EQUIPMENT AND DETECTION..... | 58   |
| PESTS.....   | 85   |
| REFERENCES.....                                      | 99   |



## ACKNOWLEDGEMENTS

This training manual was compiled from a variety of sources. A majority was taken from a manual prepared by J. E. Dewey and R. F. Pendleton, Chemical-Pesticides Program, New York State College of Agriculture and Life Sciences at Cornell University. Materials from other sources have been utilized without full citation but with appreciation.

## FOREWORD

This training manual is intended to provide information that you may need to comply with EPA's Standards for Certification. It will help you prepare for the Certification examination prepared and administered by the Virginia Department of Agriculture and Consumer Services.

The emphasis of these standards and this training is on the principles of applying pesticides safely for man and the environment. It is not intended to provide you with all the knowledge needed. Additional information in the form of publications, short courses, field days, and professional meetings can be obtained from the local Cooperative Extension Service office in your area.

## KEYS TO THE PROPER USE OF PESTICIDES

1. Read the label on each pesticide container before each use. Follow instructions to the letter; heed all cautions and warnings; note precautions about residues.
2. Keep pesticides in the containers in which you bought them. Put them where children and animals cannot get to them, preferably locked-up and away from food, feed, seed, and other materials that may become harmful if contaminated.
3. Dispose of empty pesticide containers in the manner specified on the label.

SEE YOUR DOCTOR IF SYMPTOMS OF ILLNESS OCCUR DURING OR  
AFTER USE OF PESTICIDES

Trade and brand names are used in this publication only for the purpose of providing information. The Virginia Cooperative Extension Service and the Virginia Polytechnic Institute and State University do not guarantee or warrant the standard of any product named, nor do they imply approval of any product named to the exclusion of others which also may be suitable.



## INTRODUCTION

You have completed the core training for pesticide certification and now are about to start additional training for your commercial certification. This manual will give basic information for certification in the subcategory D, Fumigation, which is a part of Category 7 - Industrial, Institutional, Structural, and Health Related Pest Control. Many states have established a subcategory for fumigation because it is particularly hazardous. Fumigation requires special safety precautions, special equipment, special knowledge, and almost all fumigators are required by their city or county to have special licenses or permits.

The purpose of this manual is to:

- provide minimum category standards for certification,
- help you prepare yourself for category certification,
- provide identity to some problems common to fumigation procedures,
- identify some common pests,
- and provide information on fumigants, methods of application, special safety precautions, equipment maintenance, and operation.

This manual focuses on principles which apply to your operations and which will enable you to improve your competency to use fumigants. It will not make you an expert, nor is it a substitute for experience. Fumigation should be done by or under the direct supervision of experienced certified applicators.

### Standards for Certification

The Environmental Protection Agency has set minimum standards for certification of pesticide applicators. Among these standards is a section relating to your operations as a commercial applicator.

The specific standards from the Federal Register for Category 7 are as follows:

"Industrial, institutional, structural and health related pest control applicators must demonstrate a practical knowledge of a wide variety of pests, including their life cycles, types of formulations appropriate for their control, and methods of application that avoid contamination of food, damage and contamination of habitat, and exposure of people and pets. Since human exposure, including babies, children, pregnant women, and elderly people, is frequently a potential problem, applicators must demonstrate practical knowledge of the specific factors which may lead to a hazardous condition, including continuous exposure in the various situations encountered in this category. Because health related pest control may involve outdoor applications, applicators must also demonstrate practical knowledge of environmental conditions, particularly related to this activity."

Some of these standards are rather general because of the wide range of pest control operations covered in Category 7 and you may feel that they do not apply to fumigators. However, recognition of all potential hazards is advisable since you may become involved in unusual problem situations.

#### Pests

Commercial applicators must demonstrate a practical knowledge of a wide variety of pests, their life cycles, control methods, and chemical formulations that do not contaminate food or otherwise endanger humans for the environment. You must accurately identify the pests, apply the most effective and efficient control measures, and select the correct registered pesticides.

#### Concern for Others

Your greatest concern is that there is no pesticide exposure to your co-workers or harm to others. You can prevent such problems by recognizing potential hazards; notifying police, fire, and health officials; posting treated areas as required for good procedures; adhering strictly to label precautions; and, by safely storing and disposing of pesticides and pesticide containers.

## NATURE AND EFFECTS OF FUMIGANTS

Fumigants are pesticide chemicals that are in the gas phase at effective temperatures, as compared to smokes, fogs, and aerosols which are dispersions of very fine particles or droplets. Fumigants penetrate cracks, crevices, and the commodity being treated. As soon as the gas diffuses from the area, its effectiveness is lost and reinfestation can occur. Fumigants must be applied in enclosed areas. Fumigation is the process of distributing the fumigant as a gas through space and materials. Space fumigation is a term used to describe a wide range of treatments in enclosed spaces which are infested with pests or contain materials which are infested with pests. Soil fumigation (See Agriculture-Plant Manual) is the term for treating soil to control pests that are present. Space fumigation is the subject of this manual.

### Toxicity and Hazards

All effective fumigants are highly toxic to plants, animals, and man. They are often fast acting, odorless, and cannot be seen. In addition to being highly toxic, many are highly flammable. The fire and explosion hazard of some fumigants, particularly when combined with air as a source of oxygen, is serious and must not be overlooked. In some instances, oxygen depletion may result from the use of a fumigant, making the use of air breathing masks supplying outside air or oxygen essential. Absorption of the fumigant through the skin may be a hazard with some fumigants so that protective clothing must be worn in addition to protective respiratory devices.

Fumigants are dangerous materials. No one should undertake their use without thorough training and adequate precautionary measures to protect life and property. It is essential that the person applying the fumigants has a complete understanding of safe and effective techniques before attempting any fumigation job. When such training and precautions have been taken and followed, the hazards of the work are greatly reduced and the results highly effective.

## Factors or Variables Affecting Use

Many factors affect the use and effectiveness of fumigants. The stage of development and activity of the target pest is important. Active adult insects, for example, are easier to kill than inactive or hibernating adults. Immature insects generally require higher dosages or longer exposure than adults. The amount of free or open space in the area to be fumigated, the temperature, the porosity of product, the kind of product, the location of the pest within the product, and the structure to be fumigated all affect dosage and exposure period.

### Temperature

The most important factor influencing the action of a fumigant on a pest is temperature. As temperature increases, the volatility of the fumigant increases so that it is released more rapidly, disperses and penetrates more quickly, and sorption by the material being treated is reduced. In addition, the pest's rate of metabolism is usually higher so that the amount of fumigant required to kill the pest is less. As a result of these effects, dosages needed decreases as the temperature increases. Fumigants may not kill the pests if temperatures of the space are below 10°C (50°F) or above 46°C (115°F). Dosage and exposure periods vary for most fumigants with the temperature.

### Air Movement or Diffusion

It is necessary for a fumigant gas to be spread evenly and quickly throughout the space being treated. It must move or be moved into small crevices, cracks, or spaces within finely ground materials so that the gas will quickly come in contact with all the commodity and pests within the confined area. The ability to spread varies among gasses depending upon their weight and penetrating characteristics. Most of our modern fumigants require air circulation to avoid settling or stratification which may result in poor control in part of the area and excessive residues or phytotoxicity in other parts of the treated chamber. Diffusion or movement of the gas is favored by higher temperatures, lower air pressure,

shorter distances to be penetrated and higher initial concentration. The rate of evaporation of a fumigant into the treatment area is increased by stirring or moving the vapors rapidly from the evaporating surface. Air movement equipment is often used and in some instances is necessary for satisfactory fumigation. The type of equipment selected should fit the job. Fans are sufficient to stir up the air in relatively open areas. Confined areas with tightly packed commodities will require the use of blowers or ducts and pipes to move the air from one place to another. Once the proper mixture with air has been obtained the problem of stratification of heavier than air fumigants is greatly reduced.

Air movement resulting from poor seals will result in loss of the gas with resulting lower concentrations and poor control unless overdosed to offset loss from leakage.

With liquid-type fumigants in grain fumigation, mixtures of different fumigants may be used to provide ingredients whose vapors have differing rates and patterns of diffusion. The distance the gasses diffuse downward depends on the extent to which they are sorbed by the grain. Because of this, it may be necessary to have a mixture with different properties to kill insects at various depths and locations in the grain.

### Sorption

Sorption of fumigants is the association of the fumigant with the material and/or the surface being fumigated thus removing part of the fumigant from the vapor state. This includes binding of the fumigant within the material by actual penetration beyond the surface of the material (absorption) or the binding of the fumigant on the surface (adsorption). Some fumigants are much more subject to sorption than others. Commodities also vary greatly in their sorptive capacity. Finely ground products such as flour have a large surface and are more sorptive than whole grain or inert physical items such as machinery. When sorption is high, far higher dosages of fumigant are required than if all the gas or vapor was available to the pest. Diffusion is slowed down, requiring long treatment times, and the fumigant is released more

slowly from the treated commodity. In addition to longer aeration periods, slower release of the fumigant from the commodity may cause problems of toxic residues, off-flavors or odors, poorer germination, etc.

Both absorption and adsorption are reduced at higher temperatures. Adsorption is usually greater with fumigants of high molecular weights and low vapor pressures.

### Moisture

As the moisture content of a commodity increases, it becomes more difficult for the fumigant to penetrate it. This also increases the potential for residues exceeding legal tolerances. Adequate moisture, on the other hand, is required for the generation of some fumigants, and with living plants may reduce injury.

### Structure

The condition of the structure and the type of construction must be considered. A wooden structure, even when sealed well, will not retain fumigants as well as metals, plastic, masonry, or concrete. Fumigation in vacuum chambers provides increased efficiency.

### General Characteristics

In the table on page 12 the essential properties of some fumigants are given.

Molecular weight provides information as to the weight of equal volumes of gas under the same temperature and pressure. The molecular weight of oxygen is 32. Fumigants with a molecular weight lower than 32 are lighter (i.e., HCN) than air and those greater than 32 are heavier (i.e., ethylene dibromide) than air.

Boiling point provides information as to whether the fumigant is a gaseous-type fumigant or liquid-solid type. Low boiling fumigants such as methyl bromide which boil below room or moderate outdoor temperatures (20° to 25°C) are gaseous types kept in cylinders or pressure cans to

withstand the highest indoor or outdoor temperatures expected. Those with boiling points higher than 20° to 25°C are usually liquids or solids.

Boiling point is also an indication of the vapor pressure or the evaporation rate of the fumigant. The higher the boiling point or vapor pressure, the slower the rate of evaporation or vaporization.

Certain solid type fumigants such as calcium cyanide and aluminum phosphide are not fumigants themselves but must react with moisture in the air to form the fumigants after application. Other solid fumigants such as naphthaline flakes or paradichlorobenzene crystals sublime or evaporate to give off fumigant vapors.

Water solubility provides you with information as to the possibility of a fumigant gas being dissolved in water that may be present in the material being fumigated. HCN is highly soluble in water and cannot be used with fresh fruits and vegetables which contain water that may be accessible to the gas.

Fumigants may be soluble in other liquids and may react chemically with some ingredient in the commodity. Methyl bromide is soluble in some oils and in some cases products having a high oil content have high residues of inorganic or organic bromides present, resulting in a residue problem.

Flammability - The use of highly flammable compounds is not necessarily eliminated if the danger of fire or explosion can be controlled. This might be done by addition of other suitable compounds (carbon tetrachloride or carbon dioxide) or by using carefully planned fumigation procedures to eliminate these hazards.

ESSENTIAL PROPERTIES OF FUMIGANTS

| Name and Formula     | Molecular Weight | Boiling Point<br>(°C. at 760 mm.<br>pressure) | Solubility in<br>Water<br>(g./100 ml.) |
|----------------------|------------------|---|--|
| Acrylonitrile        | 53.06            | 77.0  | 7.5 at 25° C.                          |
| Carbon disulphide    | 76.13            | 46.3  | 0.22 at 22° C.                         |
| Carbon tetrachloride | 153.84           | 77.0  | 0.08 at 20° C.                         |
| Chloropicrin         | 164.39           | 112.0   | Insoluble at 20° C.                    |
| Ethylene dibromide   | 187.88           | 131.0   | 0.43 at 30° C.                         |
| Ethylene dichloride  | 98.97            | 83.0  | 0.87 at 20° C.                         |
| Ethylene oxide       | 44.05            | 10.7  | Very soluble at<br>20° C.              |
| Hydrocyanic acid gas | 27.03            | 26.0  | Very soluble at<br>20° C.              |
| Methyl bromide       | 94.95            | 3.6   | 1.3 at 25° C.                          |
| Phosphine            | 34.04            | -87.4   | Very slightly soluble                  |
| Sulfuryl fluoride    | 102.06           | -55.2   | 0.075 at 25° C.                        |

1/ From Monro, Manual of Fumigation for Insect Control.



IN COMMON USE FOR INSECT CONTROL<sup>1/</sup>

---

| Flammability<br>(% by volume in air) | Commodities Treated and Remarks<br>(Check labels for specific uses)  |
|--------------------------------------|--|
| 3-17                                 | Tobacco and plant products; also for "spot" treatment. Injures growing plants, fresh fruits, and vegetables. Marketed with carbon tetrachloride.                       |
| 1.25-44                              | Grain. Usually as ingredient of nonflammable mixtures.   |
| Nonflammable                         | Only weakly insecticidal. Used chiefly in mixture with flammable compounds in grain fumigation to reduce fire hazard and aid distribution.                             |
| Nonflammable                         | Grains and plant products. Safe with seeds; injurious to living plants, fruit, and vegetables. Highly irritating lachrymator. Bactericidal and fungicidal.             |
| Nonflammable                         | General fumigant. Particularly useful for certain fruit; may injure growing plants.  |
| 6-16                                 | Seeds and grains. Usually mixed with carbon tetrachloride.   |
| 3-80                                 | Grains, cereals, and certain plant products. Toxic at practical concentrations to many bacteria, fungi, and viruses. Strongly phytotoxic and affects seed germination. |
| 6-41                                 | General fumigant, but may be phytotoxic. Safe on seeds but not recommended for fresh fruit and vegetables.   |
| Nonflammable                         | General fumigant. May be used with caution for nursery stock, growing plants, some fruit, and seeds of low moisture content.   |
| Highly flammable                     | Grain fumigant; gas generated from tablets of aluminum phosphide.  |
| Nonflammable                         | Wood destroying and household insects, but not for food or drug products. Phytotoxic but little effect on seed germination.  |

## SOME MODERN FUMIGANTS

There are a number of good fumigants on the market. Each has its own properties, advantages, disadvantages, uses, and limitations. The following discussion of the various common fumigants is not intended to indicate any particular preference. You must make your own choice after you have identified the pest, considered the commodity (or structure) in which the pest is located, inspected the structure or other fumigation site, and after you have READ AND FOLLOWED THE LABEL.

### ACRYLONITRILE

Acrylonitrile is a colorless liquid. At high concentrations it is flammable and is usually mixed with carbon tetrachloride. It is heavier than air and has an odor of mustard. It is highly toxic to man and to insects. The established threshold limit of acrylonitrile exposure is 20 parts per million (ppm). (The threshold limit is the maximum permitted daily exposure, eight hours per day, five days per week). If gas masks are used (in lieu of more satisfactory respiratory devices) a black canister for organic vapors should be used. Volatilization is slow and usually requires the use of fans and several flat evaporating pans with wicks at atmospheric pressure. Detector tubes are available for field determination of both fumigation and threshold limit concentrations.

### ALUMINUM PHOSPHIDE (Phosphine (Phostoxin, Detia Gas-EX-B))

Aluminum phosphide is a solid, which in the presence of atmospheric moisture, breaks down and liberates a gas, hydrogen phosphide, otherwise named phosphine. The gas is colorless, but it has a penetrating carbide or garlic odor. Most people will notice the odor at very low concentrations.

Although hydrogen phosphide is slightly heavier than air, it has high molecular activity and does not tend to stratify. Fans, therefore, are not needed to assure even distribution of the gas. If the liberation of hydrogen phosphide from aluminum phosphide occurs too rapidly, an explosive

mixture can occur. Two manufacturers have found methods of controlling the rate of release of hydrogen phosphide. One formulates the aluminum phosphide with ammonium carbonate, the other with aluminum stearate and calcium oxide. These controlled release formulations preclude any explosion risk when used at normal application rates.

Hydrogen phosphide does not accumulate within body tissues in the same manner as methyl bromide. Any gas entering the body will be completely eliminated within 48 hours. Hydrogen phosphide is very toxic to humans. The threshold limit is only 0.03 ppm. Mathematically, this would indicate that the gas is about 60 times as toxic as methyl bromide. However, because of the manner in which hydrogen phosphide is liberated and because of the odor characteristics, the gas is far safer to handle than methyl bromide. As the formulated aluminum phosphide does not start to break down and liberate hydrogen phosphide for one to two hours after introduction into the fumigation facility, respirators are usually not needed during fumigant introduction. However, respirators should be nearby and ready for use if needed. If gas masks are used, they should be equipped with yellow canisters having an orange stripe around the base. Gloves should be worn when handling either the aluminum phosphide pellets or the residue that remains following fumigation.

At present, aluminum phosphide registrations by the two companies cover grain and grain products, nuts, cocoa and coffee beans, seed, bulk animal feeds (including dog food), cotton (cloth and unprocessed), feathers, human hair, rubberized hair, vulcanized hair, mohair, raw wool, many processed foods, and tobacco. It is effective against all stages of insect life. The tablets or pellets may be fed into the stream as the raw commodity flows into grain bins. In railroad cars, aluminum phosphide can be used for the in-transit fumigation of structural pests.

Aluminum phosphide, or its residue, must not be permitted to come in direct contact with any processed food. Phosphine gas, especially in the presence of moisture or ammonia, reacts with copper, silver, and copper alloys. Copper-containing equipment, especially electrical apparatus, may be severely damaged.

The aluminum phosphide - ammonium carbonate formulation (Phostoxin) is supplied in flasks containing 1660 pellets. Each pellet will liberate 0.2 grams of hydrogen phosphide. The flasks are resealable so the entire contents need not be used at one time. The aluminum phosphide - ammonium carbonate formulation is also supplied in tubes. Each tube contains 30 tablets. Each table will liberate one gram of hydrogen phosphide. The tubes, once opened, must not be resealed; therefore, the contents of each tube must be used at one time or the unused tablets discarded. The aluminum phosphide - aluminum stearate - calcium formulation (Detia Gas-EX-B) is supplied in vapor permeable bags packed in air-tight tins. Each bag will liberate 11 grams of hydrogen phosphide. Once the tins have been opened, the entire contents must be used or destroyed.

As indicated, one advantage of aluminum phosphide is that it can be used so very easily for fumigation. The cubic area of the space to be fumigated is calculated, and the appropriate number of pellets, tablets, or bags determined. Using gloves, the required number of pellets, tablets, or bags are counted out onto a tray or sheet of cardboard. The tray is then slipped under the fumigation tarp. As the aluminum phosphide will not begin to liberate hydrogen phosphide for one or two hours, this usually can be done without respiratory protection. If the tarp seals are tight, if all rips have been repaired, and if there is a little air movement in the warehouse or other structure, normal work can continue during the fumigation period. Warehouse personnel must be evacuated, of course, when the tarps are removed for aeration.

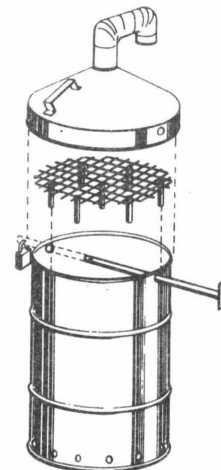
Gas measurement and leak detection are accomplished through the use of special glass tubes. Several reliable detector devices are available including the Kitagawa, NSA, Auer, and the Draeger. When air containing the fumigant is drawn through the tubes, a color change takes place. The amount of color change gives a reading of the gas concentration. Two different types of glass tube are used for reading hydrogen phosphide concentrations. The first measures from 0.1 ppm to 100 ppm and is used to locate leaks and to determine whether or not a fumigated space is safe to enter without respiratory protection. The second measures from 50 ppm to 2,000 ppm and is used to measure the gas concentration within the fumigation enclosure.

Fumigation with aluminum phosphide does take time. Normal exposure periods are for 72 hours. Build-up of the fumigant concentration is slow. It may take 12 - 48 hours before the desired concentration of gas is reached. If the atmosphere is very dry, the gas build-up may take even longer. In locations where the relative humidity is very low, the gas liberation can be speeded up either by placing a pan of water under the fumigation tarp, or by spraying water onto the floor or dirt. UNDER NO CIRCUMSTANCES SHOULD WATER BE PERMITTED TO CONTACT ALUMINUM PHOSPHIDE--AN EXPLOSIVE MIXTURE WILL RESULT. If dosages are lower than required at the end of the 72 hour period, control can frequently be obtained by extending the fumigation period. Aeration after aluminum phosphide is rapid. Open the doors and windows to assure good ventilation. Then, with respiratory protection, remove the sand snakes and lift the tarp at both ends of the stack. Aeration should be complete in one to two hours. If the fumigated commodity is not going to be used for some period of time, there is no objection to leaving the fumigation tarp over the commodity.

After fumigation, there will remain a powdery residue from the decomposed pellets, tablets, (Phostoxin) or bags (Detia Gas-EX-B). This residue will contain a very small amount of unreacted aluminum phosphide. This residue must be deactivated. The residue from the pellets or tablets should be stirred into a pail of water to which one-half cupful of detergent has been added. The dust is then stirred until it becomes saturated and sinks to the bottom. The residue from the bag formulation should be cut or torn open and the contents stirred into a bucket containing a mixture of water and nonionic surfactant (2% by volume). This deactivation procedure must take place outdoors. After the residue has been deactivated, the water may be poured down a sewer or buried without adverse environmental effects. However, check with local authorities for disposal removal.

In lieu of immediate disposal of the Detia Gas-EX-B bags it may be more practical, particularly in the case of smaller users, to collect spent bags and place them into an especially designed 55-gallon oil drum as illustrated on the next page. Note the cone shape, vented lid as well as the expanded metal false floor, the ten 1" diameter holes evenly spaced

around the bottom, the five 1" diameter holes in the bottom (not shown) and the locking device. The purpose of the drum is to provide a central, known collection point for bags known to be spent. When full, or at regular intervals, the drum can be transported directly to an approved disposal site. WITHOUT EXCEPTION, THE TRANSPORTATION MUST BE PERFORMED BY THE USER, BEING CERTAIN THAT WHEN THE DRUM IS EMPTIED THAT THE BAGS ARE IMMEDIATELY BURIED, OR BURNED IN THE CASE OF AN APPROVED PESTICIDE APPLICATOR.



The drum should be located in an open, secured area known to all and marked as the collection center for spent Detia Gas-EX-B.

Application Procedures Using Phostoxin (Aluminum phosphide-ammonium carbonate formulation)

Rail Car Fumigation. There are several methods of Phostoxin fumigation that have been developed for rail cars because of the high rate of insect contamination of commodities in this type of conveyance. First, a car should go through the preloading inspection and cleaning. The inspection determines the presence of insects and small holes or cracks that would allow the fumigant to escape. Then the door that will not be used for loading should be sealed. It can be taped, but the most effective method of sealing involves using a liquid adhesive painted around the door. Then secure a pre-cut 2 mil polyethylene sheet over the entire door. The next step is to check the volume of the boxcar; this aids in determining the dosage. After having gone through the preceding steps, it is time for the fumigation process. If the proper dosage, found on the label, is used, the entire contents of the car will be thoroughly penetrated by the gas. This means eggs, larvae, pupae, and adult stages of those insects listed on the label will be destroyed.

The Phostray, a cardboard tray specially designed for holding Phostoxin pellets, is one method of applying the fumigant. The pellets are placed on the tray filling the indentations. The cover is then sprayed with a liquid adhesive, placed over the Phostray and then pressed firmly in place. One or more Phostrays can be taped to a cardboard. Care should be taken



in making sure all edges of the trays are secured. The Phostray or group of trays should then be attached to the top of the load or inside the door used for loading.

Another method of Phostoxin fumigation employs special moisture-permeable envelopes. The dosage is determined in the same manner as the Phostray method. Ten Phostoxin pellets are placed in each envelope. Then, just as with the Phostray, the envelopes are attached in rows on a cardboard and fastened to the top of the load, to the wall at each end, or on the wall on either side of the door used for loading.

An additional and convenient method of fumigating involves the use of Phostoxin PREPAC pellets. Each tin contains four PREPACS (660 pellets), enough to treat the average rail car. PREPACS are removed from the tins and attached to the cardboard and then to the load or inside the door used for loading.

The next step, no matter what method of fumigating is employed, is covering the last door with polyethylene, then closing or sealing it with tape. As required by law, a warning sign must then be placed on each door. The date and time of fumigation and the date and time the car can be opened must be on both signs. Fumigating hopper cars with Phostoxin is done nearly the same as with boxcars. The main difference is that the fumigant is placed on cardboard trays over the hatch openings.

In any of the processes -- the Phos-tray, the special moisture permeable envelope, or the pellet PREPAC -- the procedure is changed only to the extent that the cardboard is pre-cut to fit either the round or slot type car. Tape is stretched across the opening to lend additional support to the cardboard. The hatch openings are then covered with polyethylene so that rain and dust will not get into the car during transit, and to act as an additional seal for the fumigant.



After the fumigant and polyethylene are in place, the hatch is closed and warning signs are then affixed on each hatch cover, and on each side of the car near the ladder. On the signs is the date and time of fumigation and of the opening of the car. If the gasket on the hatch cover is in good condition, no additional seal will be required. A damaged gasket should be taped. Tape the hopper car end vents. The car is now ready to roll, but the fumigator's job is not done. Any unused fumigant must be returned to a locked chemical storage area.

Empty Phostoxin containers are decontaminated with water and then all containers are disposed of as prescribed on the label. The stoppers and absorbent pads must be buried.

Phostoxin fumigations that involved the use of Phostrays and moisture permeable envelopes leave a dust that must be disposed of without leaving a trace of untreated aluminum phosphide. This is done with a well mixed detergent and water solution by dumping the dust into the same container and then stirring it until the dust becomes thoroughly saturated and sinks to the bottom.

With the PREPAC, the entire package is buried or immersed in water containing a wetting agent. Before using Phostoxin, the fumigator will have received instruction from his supervisor or other qualified person.



Automatic Pellet Dispenser. Preventive fumigating in grain handling operations will destroy all stages of insects from the egg to the adult form. Following are the basic procedures used in fumigating grain operations. First, an electric Phostoxin pellet dispenser that automatically dispenses the fumigant into the grain as it is placed in storage is anchored on the floor near the belt. Then a pellet discharge tube is attached and securely clamped to the extension arm of the dispenser. The tube allows the free fall of pellets onto the center of the grain belt. The pellet dispenser itself is driven by a one-twentieth horsepower rated motor allowing variable speed transmission, and all electric wiring is covered in the threaded rigid conduit in compliance with the National Electrical Code for use in Class II, Group G locations.

A clear plastic hopper allows the operator to observe the fumigant level. This hopper is removable for suggested daily cleaning. Water or other liquids should not be used in the cleaning process. Inside the hopper is a turning plate with 4 or 6 holes which allow the Phostoxin pellets to be dispensed into the grain. As a safety precaution, under the spring loaded lid is a small hopper containing a chemical absorbent pad designed to react with hydrogen phosphide in case it develops. This pad should be checked before each use and be replaced if it begins to harden. For disposal, the pad should be buried.

There is an explosion-proof switch attached over the belt. It automatically activates the dispenser when the grain is on the belt. Prior to fumigation, the turning speed of the belt is determined as denoted in tons or bushels. The switch and the variable transmission are adjusted, the transmission to the turning speed of the belt. The label should be consulted for dosage and exposure time.

Phostoxin pellets may now be poured directly from the flask into the dispenser, taking care to put in just enough for an hour run. Warning placards are now placed on bin covers and bottoms, each with the day and time of fumigation and day and time the grain can be removed. Once the fumigation has begun, the dispenser is checked to be sure it is operating, and also a check should be made at this time on the activating switch arm for proper adjustment. These checks should be made periodically during the

fumigating procedure. Additional Phostoxin pellets may be added as required. After fumigation, any unused pellets are returned to the flask by removing the hopper and inverting it over the flask. Then the unused fumigant is returned to a locked storage area.

Space or Tarp Fumigation. When fumigations are made inside a warehouse under tarps, a 2 mil covering is adequate to contain hydrogen phosphide, but a heavier material of 6 mil is recommended for outdoor fumigation. The lighter polyethylene could be torn by wind.

In any tarp fumigation, the stacked commodity is covered and sealed at the base with tape or sand snakes.

Several methods to dispense the fumigant can be used in tarp fumigation, including a Phostray which has been molded specially to hold Phostoxin pellets. The volume of the area to be fumigated is measured and the label is read to determine the dosage. The commodity will be thoroughly penetrated and all stages of those insects listed on the label will be killed if the fumigating procedure is carefully followed.

First, the Phostoxin pellets are put on the tray and a cover is attached over them. The fumigant is then placed under the tarp. Care should be taken to assure that the polyethylene does not rest on the tray or fumigant because this could lead to incomplete decomposition. Phostoxin pellets can also be used where the appropriate dosage is placed in special moisture-permeable envelopes, 10 pellets in each envelope. The envelopes are then taped to cardboard and placed under the tarp just as with the Phostray.

Still another procedure is the convenient Phostoxin pellet PREPAC. Each tin contains four PREPACS, 660 pellets which is adequate to treat approximately 4,000 cubic feet, or 165 pellets per 1,000 cubic feet.

Warning signs must be placed on all sides of the fumigated stack, each with the time and date of fumigation and the date when the tarp may be opened. When gas readings are to be taken, test lines are placed in the area to be fumigated. The test lines are first purged to draw gas into the line. The concentration can then be read on the detector tube. Several reliable detector devices are available including Kitagawa, MSA, the Auer, and the

Drager. The scale is read in parts per million hydrogen phosphide. A low range detection tube is also available to monitor the surrounding area for worker safety.

As long as cross-ventilation is maintained in the area, work may continue in the warehouse. The maximum allowable concentration for continuous worker exposure is 0.3 part per million. Large-space fumigations, such as in mills, require special experience and should always be carried out under the direct supervision of a trained fumigator. Among his duties are the notification of police and fire officials, and, where required by local ordinance, the posting of guards. The many intricacies of large-space fumigations, sealing vents, windows, and doors dictate that an experienced fumigator be in charge.

#### CALCIUM CYANIDE

Calcium cyanide is a dark grey powder which, in reaction with moisture in the air, produces hydrogen cyanide (HCN). See HCN, page 29 , for further information. It is formulated as dust for the control of burrowing rodents -- mice, moles, Norway rates, and woodchucks. The material is introduced into the burrow with a duster or foot pump. It should not be introduced into burrows that go under building foundations. A coarser sand formulation is available for fumigating greenhouses. Precautions should be taken as for hydrogen cyanide.

#### CARBON DISULFIDE

Carbon disulfide or carbon bisulfide is a colorless volatile liquid. Its vapors are heavier than air and highly explosive. Because of this it is usually used in a mixture with enough carbon chloride to eliminate the fire hazard. It has a sweetish odor when pure, but most commercial formulations contain hydrogen sulfide or other impurities which give it an unpleasant odor. Absorption through the skin can occur at higher concentrations as well as by inhalation. Prolonged contact with the skin of either the liquid or vapors can cause severe burns, blistering, or neuritis. The

established threshold limit of carbon disulfide is 20 ppm. When applying in a closed area, or when reentering a treated area, a gas mask with a black canister should be worn.

Its primary use in this country is as a grain fumigant. Detection in the field with a thermal conductivity analyzer can be made after calibration for carbon disulfide.

#### CARBON TETRACHLORIDE

Carbon tetrachloride is a colorless, volatile heavy liquid. Its vapors are heavier than air and have a characteristic odor. It can be used alone as a fumigant, but, because of its low toxicity to insects, high dosage needed, and long exposure periods, it is used primarily in mixtures with flammable fumigants such as ethylene dichloride, carbon disulfide and acrylonitrile (Acritet) to reduce fire hazards. It also aids in the distribution of some liquid fumigants.

Although not highly toxic to insects, it is highly toxic to man. The established threshold limit of carbon tetrachloride is 10 ppm. When applying inside a closed area, or reentering a treated area, a gas mask with black canister should be worn.

Carbon tetrachloride does not "mix" with alcohol. Persons who have consumed alcohol are much more susceptible to poisoning than those who have not. Vapors are not detectable by smell below 70 ppm in air.

#### CHLOROPICRIN

Chloropicrin is a yellowish liquid which vaporizes slowly at room temperatures. It is non-flammable. Chloropicrin is highly toxic to insects and is a powerful tear gas. It is often used with other highly toxic odorless fumigants in low concentrations to serve as a "Warning Gas." Chloropicrin is highly toxic to man. The established threshold limit is 0.1 ppm. Concentrations as low as 1 ppm produce an intense smarting of the eyes and the immediate reaction to leave in haste. Continued exposure may cause serious lung injury. If it is necessary to enter a treated area, a gas mask with black canister should be worn.

Chloropicrin-treated commodities are often unpleasant to handle because they may be extremely irritating from even low quantities diffusing from the treated material. It is also corrosive to metals.

Its primary use other than acting as a "Warning Gas" is as a soil fumigant. Chloropicrin cannot be used on any processed foods, in dairy, cheese, or meat plants, or where there are living plants, or on fresh fruits or vegetables. It can be used in treatments of small grains -- wheat, oats, barley, rye.

#### ETHYLENE DIBROMIDE

Ethylene dibromide is a colorless liquid. It is a non-flammable gas with an odor like chloroform. It evaporates slowly at room temperatures and is six times heavier than air so that vigorous circulation is needed for adequate distribution. Heat may be used to hasten evaporation.

Ethylene dibromide is more toxic to humans than methyl bromide and highly toxic to insects. Its chloroform-like odor is detectable to most people at about 25 ppm. The established threshold limit for ethylene dibromide is 20 ppm. When applying inside a closed area, or reentering a treated area, a gas mask with a black canister should be worn.

Ethylene dibromide is corrosive to some metals such as aluminum, magnesium, and alloys, and some paints may soften or wrinkle. It is also sorbed by many, many materials where its penetration is poor. It is used alone most commonly as a soil fumigant. It is widely used in mixtures with carbon tetrachloride, carbon disulfide, ethylene dichloride, and methyl bromide for treating food handling equipment, grain, and some fruit.

#### ETHYLENE DICHLORIDE

Ethylene dichloride is a liquid at ordinary temperatures, producing a colorless gas with a chloroform-like odor. Because both liquid and gasses are flammable, it is mixed with a non-flammable material such as carbon tetrachloride, usually at about 1 part to 3 parts of ethylene dichloride. It may also be corrosive to aluminum, magnesium, and alloys.

Major uses are as a commodity fumigant and/or spot treatment fumigant for milling, processing, and bakery equipment. Registrations have been for granary weevil, rice weevil, lesser grain borer, sawtoothed grain beetle, confused flour beetle, red flour beetle, Indian meal moth, Mediterranean flour moth, Angoumois grain moth, flat grain beetles, pea weevil, and bean weevil in grain, beans, peas, peanuts, and corn. Read the label to be sure the commodity and pest are listed that you wish to control. It is toxic to some plants and is soluble in fats and oils. It should not be used on those commodities.

The vapors of ethylene dichloride are heavier than air, are absorbed, and when used alone as the only fumigant, are slow to kill insects. Temperatures of the material to be treated should be above 60°F. If pan fumigation is used in a fumigation chamber, vigorous circulation of the air with a fan or blower is necessary to obtain complete volatilization of the liquid in the first hour and to obtain uniform distribution of the gas. Aeration may be necessary following fumigation. The established threshold limit of ethylene dichloride is 50 ppm. The quantities usually used exceed 2% of volume so that a standard industrial gas mask will not protect against full fumigation concentration. For this reason, airline masks ( page 61 ) are preferred. Because the fumigant is a liquid, a respirator is useful and can be worn during application. A gas mask with a fresh black canister may be worn to enter a treated area after fumigation following a period of preliminary aeration. The odor should indicate whether or not the canister is giving protection.

Ethylene dichloride is irritating to the skin. Its sickly chloroform-like odor can be detected at about 50 ppm. It causes dizziness at concentrations below those believed to inflict permanent damage. If one should experience these symptoms while working with ethylene dichloride, he should leave the area of fumigation immediately.

#### ETHYLENE OXIDE

Ethylene oxide is a gas at ordinary temperatures and a colorless liquid below 50°F. It is flammable and because of this is commonly mixed with carbon dioxide (Carboxide) or non-flammable halogenated hydrocarbon

refrigerant gasses (freon). Carboxide is a mixture consisting of 10% ethylene oxide and 90% carbon dioxide by weight. Ethylene oxide is the most active of the ingredients. The carbon dioxide component is added to reduce the explosion hazard of the ethylene oxide. (Ethylene oxide between 3% and 80% by volume in air is highly flammable and explosive). While not a true active ingredient, the carbon dioxide does increase the effectiveness of the ethylene oxide by stimulating insect respiration. Both component gasses are colorless and odorless. The ethylene oxide component is a liquid when under pressure and at low temperatures. Ethylene oxide also is water soluble. This solubility occasionally creates problems when fumigating in the presence of water. The water will take up the gas and later, after fumigation, the gas will evolve into the air.

The ethylene oxide component is lighter than air, and the carbon dioxide component is heavier than air. Fans must be used, not only to insure distribution of the gas in the fumigation enclosure, but also to prevent stratification of the two gasses. These fans must be of the non-sparking type. The threshold limits of human exposure are 50 ppm. If gas masks are used for respiratory protection, they should be equipped with canisters, color coded black. However, these canisters do not protect against carbon dioxide. A dosage of 25 pounds of Carboxide per 1000 cubic feet will be high in carbon dioxide (19.8%) and deficient in oxygen. An individual should not enter such an atmosphere without an air-supplying respirator.

Carboxide is very effective against insect eggs and other stages of insect life, but it does not penetrate items that are densely packed. Carboxide is registered for the control of insects in furs, clothing, spices, etc. Food items have established tolerances of 50 ppm. The principal use of Carboxide is against insects in commodities that could be damaged by other fumigants. It should not be used on any item containing salt, and liquid ethylene oxide will damage rubber.

Carboxide application rates are high -- up to 30 pounds per 1,000 cubic feet. Because of this high gas volume, tarps should be loosely draped over the stack and then sealed to the floor. Carboxide is supplied

in 60 pound steel cylinders. Flexible metal tubing, capable of withstanding pressures up to 700 pounds per square inch should be used for leading the gas from the cylinder to the fumigation enclosure. The tubing should be at least one-fourth inch in diameter. The outlet of the tubing should be placed high in the stack, and should be at least five feet away from any commodity. To prevent static electricity discharge, each cylinder must be grounded.

Contrary to the method of release of other compressed gasses, the valve on Carboxide cylinders should be opened wide. This is to prevent any differential separation of the ethylene oxide and carbon dioxide components. Because the gas release is rapid, the cylinders must be firmly tied to supports during the release period. The gas must not be heated during introduction. As with methyl bromide, the gas is weighed on scales to determine the amount released into the enclosure. Gas masks and other respiratory protection must be available during gas introduction, and rubber aprons should be worn. The fumigation period is usually 15 to 48 hours. Check the label for specific requirements. People not involved in the fumigation should not be permitted in the area during the fumigation period.

The ethylene oxide component is explosive. Halide gas detectors must not be used to determine gas leakage or gas measurement. Gas measurement is by a thermal conductivity unit, the same as used for measurement of methyl bromide gas concentrations. This unit will require special calibration for Carboxide. After the fumigation period is complete, windows and doors should be opened, and personnel wearing respiratory protection can remove the sand snakes and lift the tarp for aeration.

A 12% ethylene oxide - 88% freon mixture is also available; the freon serving the same purpose as the carbon dioxide in the mixture. Ethylene oxide has good properties of penetration and is effective at cool as well as warm temperatures. Usage, however, is not recommended below 55°F (12.8°C). The mixtures remain uniformly distributed over the long exposure periods, although the ethylene oxide is gradually sorbed out.



### Hydrocyanic Acid Gas

Hydrocyanic acid gas has been used commercially since 1886. Hydrocyanic acid is a colorless volatile liquid which changes to a gas at about 79°F. To most people, the gas has a characteristic odor of bitter almonds. Some people cannot smell Hydrocyanic Acid. The gas is lighter than air, which makes it quite different from other commercial fumigants. The liquid hydrocyanic acid will burn when ignited, but the gas is not considered explosive at concentrations normally used in fumigation.

HCN gas does not penetrate too well. This is both an advantage and disadvantage. The advantage is that it does not escape through oiled paper or caulking materials. It is not too difficult to seal up a structure for HCN fumigation. The disadvantage is that the gas does not always get to the site where the insect to be controlled is located. Another disadvantage is that it is readily absorbed by a number of materials; and, under cool conditions, desorption may be quite slow. This has created health problems. For example: the gas is readily absorbed by mattresses. Even after aeration (cool temperatures) the gas remained in a mattress. The body heat from a person sleeping on the mattress raised the temperature enough so that the HCN gas evolved. Such occurrences are not unique. HCN also desorbs slowly from a number of foods. Many fumigators handling HCN will overheat the structure during the aeration period, and aerate several times before they will allow anyone into a fumigated structure. HCN gas will stain fresh paints, greasy surfaces, and linens, and will destroy rayons. The threshold limit for HCN is 10 ppm. If gas masks are used for respiratory protection, the canisters should be color coded white with a green stripe. Of course, respiratory protection is of concern; but the biggest risk from HCN is skin absorption. At concentrations of eight ounces of HCN gas per 1,000 cubic feet, a man may be dangerously poisoned through skin absorption in five to ten minutes. It used to be said that the average life of a fumigator was five years. That was when hydrocyanic acid gas was the commonly used fumigant.

There are a number of formulations available, but the most commonly used are discoids (liquid hydrocyanic acid impregnated into an absorbant material) and the liquid in cylinders. The following applies to the use of the discoid formulation.

After the building is sealed (except for the escape door), cans of discoids are spotted at various locations within the structure. The discoids are supplied in two and five pound cans, each containing one pound and 2-1/2 pounds of HCN respectively. Under normal conditions (above 65°F), the rate of application is eight ounces of discoids per 1,000 cubic feet. After the cans are spotted, the fumigators, always working as a team of two, should make one or more dry runs. They should proceed from the most remote part of the structure, working toward the exit. They must never retrace their steps. Once the fumigators are sure of their route, they should put on their respiratory protection and start the fumigation process. The cans are opened with a special opening device and the discoids are scattered loosely onto previously placed layers of wrapping paper. The fumigators should not rush through the operation, but should work methodically along the previously planned route. Once they reach the exit, the structural seal should be completed. The fumigation period is normally for 12 to 24 hours.

Depending upon temperature, the aeration period may take from 3 to 24 hours. There is no good way to obtain gas concentration measurements during fumigation. Methyl orange - mercuric chloride test papers can be used, but it is difficult to get the papers into the fumigated space. These papers turn a deep red in ten seconds if the gas is 890 ppm. Glass tubes can be used to detect low concentrations (1 - 65 ppm). After aeration, the entire structure must be carefully checked for any gas residue. Mattresses and pillows must be individually checked, and structure occupants must not be allowed to reenter until you are sure that there is no risk. Finally, there is the clean-up. Wearing rubber gloves, the fumigators must retrieve each spent discoid. After gathering them up, they may be burned.

## METHYL BROMIDE

Methyl bromide by itself is a colorless, odorless, and tasteless gas. It is heavier than air, so it tends to settle out in low places. It also tends to stratify so fans are needed to assure thorough mixing of the gas with the air. It penetrates most commodities very well, and is effective against all stages of insect life. There is no fire hazard at normal rates of application. In fact, at one time methyl bromide was used in some fire extinguishers. Even so, you must be sure that all pilot lights and other open flames are turned off when you apply methyl bromide. As with all fumigants, methyl bromide is toxic to all forms of animal life. Additionally, repeated exposures to low doses of methyl bromide will accumulate in body tissue. The established threshold limit of methyl bromide exposure is 15 parts per million (ppm). When handling methyl bromide, you must have respiratory protection. If gas masks are used (in lieu of more satisfactory air-supply respiratory devices), the canister should be black colored for organic vapors. Methyl bromide is a fumigant that has many registered uses. READ THE LABEL. It can be used to control dry-wood termites, powder post beetles, the old house borers in structures; it can be used to control insect pests in a wide variety of dry food stores; and it has registration (and established tolerances) for the control of a large variety of grains, fruits, and vegetables. Be sure that your pest problem is included on the label.

Methyl bromide is supplied in 1 or 1 1/2 pound cans, or in steel cylinders of several sizes. In pressurized containers, methyl bromide is a liquid. Once the pressure is released, the liquid vaporizes to a gas. The material may be supplied either as 100% methyl bromide or as 98% methyl bromide plus chloropicrin. The chloropicrin (tear gas) serves as a warning agent. Not all of the uses registered for the 100% material are included on the odorized methyl bromide label. Chloropicrin mixtures should not be used on processed foods, in dairy, cheese or meat plants or where there are living plants or on fresh fruits or vegetables. It can be used on small grains (as of August 1977). The methyl bromide in small cans is ideal for small jobs. With these cans, a special applicator is required. The

applicator punctures the can, and polyethylene tubing will conduct the methyl bromide into the fumigation enclosure. Heating of the fumigant usually is not necessary.

Methyl bromide in cylinders is usually used for larger jobs. One-quarter-inch copper tubing is attached to the cylinder by a gas tight fitting. This tubing is then formed into a 25-foot coil which is immersed in a container of water heated to 150°F. The tubing from the heater to the fumigation chamber may be either copper or polyethylene. The fewer fittings, the better; it is most difficult to keep fittings from leaking methyl bromide. Since methyl bromide is heavier than air, the outlet of the introduction tube should be placed high with the fumigation enclosure. When methyl bromide changes from a liquid to a gas, it becomes very cold, and, even though the gas has been heated, there is a chance that the low temperature created will change a part of the gas back to the liquid state. For this reason, a pan should be placed directly beneath the outlet end of the tubing to protect the commodity from dripping methyl bromide.

After you have calculated the amount of methyl bromide required, the cylinder is placed on scales and weighed. From the total weight, subtract the weight of the fumigant required and set the new weight on the scales. When the scale beam balances, you have introduced the correct amount.

Fumigation with methyl bromide is relatively quick. An exposure of 24 hours or less is usually adequate.

While it probably is not necessary to actually wear a gas mask during the introduction of the gas (if the cylinders are outdoors), a mask should be readily available. Aprons should be worn to protect against any liquid methyl bromide. Gloves should not be worn. Any liquid methyl bromide trapped in the gloves will cause a burn. If methyl bromide should be spilled on shoes, take them off. Methyl bromide trapped in shoes will cause serious blistering.

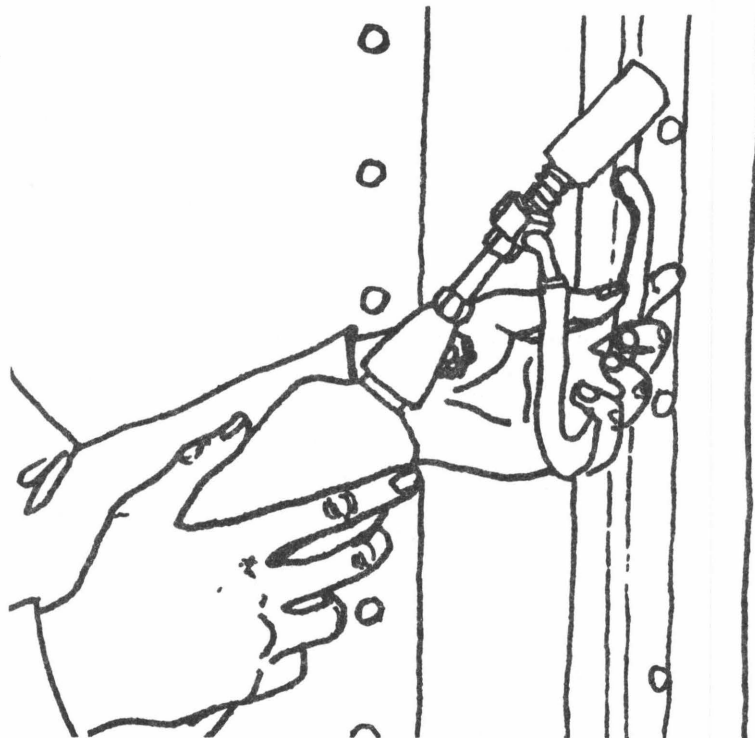
Once the gas has been introduced, you should check for leakage. If you use the odorized formulation, you will have no trouble finding a leak. It is better (and with the non-odorized formulation, it is essential) to check for leaks with a halide gas detector. With this device, a flame heats a

copper ring. Methyl bromide gas (as well as fluoride, chlorine, and the freons) passing over the heated copper ring will be colored. The depth of the color will depend upon the gas concentration. A very light green indicates a low gas concentration (25 - 50 ppm), while a royal blue color indicates a high gas concentration (1,000 ppm). All leaks must be repaired when found.

The gas concentration within the fumigation enclosure must also be measured to assure that you have an adequate gas concentration for a long enough time to

obtain the desired pest control. There are two devices on the market which work well. Both of these work on the thermal conductivity principle. One is the Fumiscope manufactured by Robert K. Hassler Company, Altadena, California; the other is the Gow-Mac unit manufactured by the Gow-Mac Instrument Company, Madison, New Jersey.

There are a number of items that should not be exposed to methyl bromide. Some react with the gas and create long-lasting odor problems. Other items may actually be damaged by the gas. The following items should not be fumigated: iodized salt; full fat soya flour; materials that may contain reactive sulfur compounds such as some soap powders, some baking sodas, and some salt blocks used for cattle licks; sponged rubber; foam rubber as in rug padding, pillows, cushions, and mattresses; rubber stamps and other forms of reclaimed rubber; furs; horsehair; pillows (especially feather pillows); leather goods (particularly white kid or any other leather goods tanned with sulfur processes); woolens



(extreme caution should be used in the fumigation of any angora woolens, and some adverse effects have been noted following fumigation of woolen suits, coats, blankets, hand knit woolen socks, sweaters, shawls, and woolen yarn); viscose rayons (those rayons produced or manufactured by a process in which carbon bisulfide was used); paper (silver polishing paper and most of the inexpensive writing paper cured by the sulfide process - some file folders will give off foul odors for a long period of time); photographic materials used in dark rooms; cinder blocks; and any materials that may contain reactive sulfur compounds.

All products containing charcoal should be removed before methyl bromide fumigation. Additionally seeds and bulbs that are to be used for planting; living plants or nursery stock; and fresh fruit and vegetables may be injured unless great care is taken. If these last items are to be fumigated, you should contact the methyl bromide manufacturer for details as to the precise procedures to be followed to prevent injury. Pets, fish, and birds will be killed if exposed to the fumigant.

You should also be cautioned about inorganic bromide residues from the soil. During fumigation with methyl bromide, additional inorganic bromide residues are added to the commodity. These inorganic bromide residues are absorbed by the commodity and are not removed during the aeration process. After repeated methyl bromide fumigations (as may occur with flour), inorganic bromide residues may exceed legal tolerances, and the Food and Drug Administration may seize the product. If this occurs, the last fumigator may be held responsible.

#### SULFURYL FLUORIDE (VIKANE)

Sulfuryl fluoride is a colorless and odorless gas which is a liquid when under pressure. It is supplied in heavy compressed-gas containers in various sizes. It is heavier than air, so it also tends to settle in low areas. It is non-flammable in all atmospheric concentrations, but it will change to a different, corrosive gas in the presence of open flame or electric heaters. It apparently does not accumulate in body tissue. The threshold limit has been established as 5 ppm. If gas masks are used for respiratory protection use fresh white canisters with

a grey stripe around the top. If it becomes necessary to enter a treated area, an air-supply respirator should be used.

Sulfuryl fluoride penetrates dry wood products very well, and is registered for the control of dry-wood termites, powder-post beetles, and wood boring beetles. It is an excellent fumigant for these insects. It is also registered for the control of bedbugs and clothes moths. It is not registered for use on any food or drug item. Such items must be placed in air-tight containers or removed from the structure. Because the gas can get into frost-free refrigerators and freezers, the contents must be removed from the structure or otherwise sealed from the gas. It should not be used on living plants. Additionally, items which might trap the gas (such as waterproof mattress covers) must be opened or removed from the structure. Sulfuryl fluoride does not react with the large number of items to produce odors or damage products as does methyl bromide. Very few items must be removed from the structure. However, all pilot lights must be turned off and heating devices, such as electric heaters, must be allowed to cool down to prevent formation of a corrosive gas. While it is very effective against insect larvae and adults, it is not effective against the egg stage at normal fumigation concentrations.

Some fumigators seal the structure with tape of laminated paper, but better gas retention is obtained if the entire structure is covered with a tarp. As with all structural fumigation, interior doors, closets, and interior vents should be left open to help with gas circulation. Sulfuryl fluoride is nearly odorless. Often, it is recommended that a warning agent be introduced prior to the introduction of the fumigant. To do this, place a handful of cotton in a shallow pan. Locate the pan in front of a fan. Pour one ounce of chloropicrin per 15,000 cubic feet onto the cotton. Complete the seal of the structure and turn on the fan. Allow five to ten minutes for chloropicrin circulation, then introduce the fumigant.

The sulfuryl fluoride should be introduced to the building from outside the structure. The introduction tubing should be 1/8" to 1/4" diameter polyethylene, polypropylene, or nylon tubing. The rate of fumigant release through larger tubing would be too great for good gas distribution. The tubing should be at least 62 mil thick to withstand the gas pressure.

Do not heat the gas. Since sulfuryl fluoride is heavier than air, it is necessary to use fans to help circulate the gas. The fans should be placed to insure good gas distribution, and they should be left running during the fumigation operation.

The manufacturer of sulfuryl fluoride has developed special slide rules, called FUMIGUIDES. These devices consider several factors: the cubic area of the structure, the condition of the structure, adequacy of the ground seal, wind temperature, and exposure time. Based on these factors, the FUMIGUIDE calculates the application rate to be used. Then, based on subsequent gas concentration readings, the FUMIGUIDE tells you how much gas must be added to achieve pest control. Gas concentrations are measured with a thermal conductivity unit (similar to the units used to measure methyl bromide or Carboxide fumigants) specially calibrated to read sulfuryl fluoride. Tubing should be run from various parts of the structure to one or more points outside the structure so that gas concentration readings may be obtained. There is no good device to detect sulfuryl fluoride leaks. The odor from the chloropicrin is the best guide to leak determination.

Aeration following fumigation is quite rapid. The gas desorbs rapidly. Once the tarp has been removed, or the windows and doors opened, the gas concentration should drop below 10 ppm in an hour or less. At very high final fumigation concentrations, the aeration period may last an hour and forty-five minutes. There is a small electric furnace together with a sampling tube that can be used to determine that the gas concentration is below the 10 ppm threshold limit.



## METHODS OF FUMIGATION

All methods by which fumigation may be accomplished have one factor in common -- some means to hold an adequate concentration of the fumigant for the time necessary to obtain pest kill. These various methods are: vault fumigation including vacuum chambers; atmospheric chambers, trucks, railway cars, ships, and buildings; tarpaulin fumigation which may be accomplished under a tarp indoors, outdoors, or by covering the entire structure; spot or local fumigation; and liquid grain fumigation.

### Vault Fumigation

Vault fumigation is referred to in this manual as including any structure of a permanent nature in which fumigation may occur as opposed to specialized vaults such as vacuum or atmospheric chambers used only for fumigation.

#### Vacuum Chamber

Vacuum chambers differ from other forms of vault fumigation in that the fumigation is conducted under vacuum rather than at atmospheric pressure. Vacuum chambers are large steel structures. One common chamber is built in sets of two, each 50' x 6' x 8'. Frequently, they are equipped with fans for recirculating systems. By using a vacuum, the fumigation time can be reduced from 12 to 24 hours plus, to 1-1/2 to 4-1/2 hours. The vacuum both denies the insect oxygen and facilitates rapid penetration of the commodity by the fumigant. By adding an air-wash cycle (breaking the vacuum and drawing a second vacuum), aeration is also rapid. Vacuum fumigation chambers are usually found at port facilities and near large warehousing operations. Ethylene oxide-carbon dioxide mixture and methyl bromide are most frequently used though HCN and acrylonitrile are also used. Aluminum phosphide cannot be used as phosphine is explosive under vacuum conditions.

There are two main methods of conducting vacuum fumigation: sustained-vacuum fumigation and nearly complete restoration of pressure. In the sustained vacuum method, the pressure is reduced, the fumigant introduced and the slightly reduced pressure or vacuum held until the end of the fumigation period.

In the restored pressure method, the pressure is lowered and restored in one of several ways.

1. Gradual restoration of atmospheric pressure. The fumigant is released and air then is slowly introduced until, after 2 or 3 hours, it is just below atmospheric pressure.
2. Delayed restoration with the vacuum being held for about 45 minutes following discharge of the fumigant, after which air is allowed to enter the chamber rapidly.
3. Immediate restoration following introduction of the fumigant by letting air rapidly into the chamber by opening one or more valves. This method has been widely used in this country for baled cotton.
4. Simultaneous introduction of air and fumigant in which special metering equipment meters a mixture of air and fumigant into the chamber.

At the end of any of the methods, air-washing is carried out. The fumigant/air mixture is removed and the chamber is then pumped several times until it is considered safe to open the door for unloading. The effectiveness of the different methods is about in the order presented with the sustained vacuum method following between methods 2 and 3 of the restored pressure methods.

The disadvantages of vacuum fumigation include the very expensive initial investment and the need to move the commodities into and out of the chambers. It cannot be used with certain tender plants, fruits, or vegetables which cannot withstand reduced pressure. The amount or dosage of fumigant required is usually 2 or 3 times greater than at atmospheric pressure.

Atmospheric Chamber (including trucks, railway cars and ships)

#### Atmospheric Vaults or Fumigation Chambers

These are usually small buildings located well apart from other structures. Some are specially built for fumigation, others are modified from other structures. Once an atmospheric vault has been built or modified for fumigation, it can be used again and again. Gas concentrations

can be monitored through a permanent arrangement. Commodities are easily moved in and out of the vault without special preparation. The fumigator does not have to compute the cube of the structure each time the fumigation will take place. Special preparation of the commodity, such as padding corners, is not necessary. Almost any fumigant can be used. And while safety precautions must be observed, fewer considerations are necessary. In addition to the initial cost of setting up a fumigation vault, the disadvantages include the cost of moving the commodity to and from the chamber, the limited quantity of items that most vaults will hold, and the economical utilization of the facility.

#### Trucks (Stationary) and Freight Cars (Stationary or in Transit)

Stationary trucks and freight cars are also examples of "vault" fumigation. These vehicles must be well constructed and in good repair. If they are not, they must be made air-tight or the entire vehicle must be tarped in order that the fumigant can be retained for the fumigation period. Movement of the freight car or truck during the fumigation usually results in loss of the fumigant. An exception to this is in-transit fumigation of rail cars using aluminum phosphide. As hydrogen phosphide continues to be generated, a low gas concentration is maintained. See pages 18 and 19 for details for railcar treatment with Phostoxin.

Fumigation of wheeled carriers is often convenient and economical in both time and labor by avoiding extra loading and unloading. It not only kills the pests in the commodity but also in the vehicle so that

live pests do not remain behind after unloading. Fumigation of incoming loads prevents the introduction of pests into clean areas.

### Shipboard Fumigation

Ship fumigations are also examples of vault fumigation but are highly specialized. Products needing fumigation may need to be treated before they can be unloaded. The extent of the area to be fumigated will depend on the amount of cargo involved. Size and depth of space to be fumigated and cargo present must be determined. If proper provision is made, any full cargo space can be fumigated. All piping, bilge openings, ventilator openings, and hatches must be sealed off. Heating and ventilator systems may be helpful in bringing the cargo to optimum temperature and for aeration.

Because of the specialized nature and problems of ship fumigation, you should be thoroughly familiar with the Technical Release from the National Pest Control Association, No. 18-72 Good Practices in Ship Fumigation, before undertaking any ship fumigation. In many instances, firms specializing in ship fumigation may be engaged.

Close cooperation with the responsible ship's officer, ship's agent, and USDA inspector (if involved) is essential. The Port Authority, fire and police departments should be notified, and guards arranged for if necessary. If most of the cargo space is fumigated, the entire crew should be accounted for and evacuated while fumigation is in progress. No one should be allowed to return until the ship is clear of fumigant and given a "Gas Free" certificate.

### Building Fumigation (by sealing)

This essentially is a modification of vault fumigation. The entire structure becomes a fumigation vault. By using this method, only those building contents which could be damaged by the fumigant need to be moved. Incidental control of non-target pests is usually obtained. Less material is needed to make the structure air-tight, but this advantage is usually offset by the labor required to find and seal gas leaks. The building is usually easily aerated. Exterior shrubbery

usually does not need to be moved. There are also many disadvantages. The occupants must be moved from the structure. Items that may be damaged by the fumigant must be moved from the structure. As the fumigant may diffuse through the wall, it may be difficult to maintain the required gas concentration. Insects in the exterior walls may not be killed as the gas concentration may be too low to be effective. Gas concentration test leads must be run throughout the structure. It may be difficult to compute the cube of the structure. It is very easy to overlook vents, cracks, conduits, etc., that may permit the escape of gas. In the past, HCN was the fumigant most commonly used in this type of fumigation.

#### Premises Inspection

Once it appears to you that fumigation will be required to control a pest problem, you must make a serious on-site inspection. You must ask yourself a number of questions and make a number of decisions. Frequently, the success or failure of the fumigation operation will depend upon what you learn, what you decide, and how you plan. Some of these questions should include: If the structure itself is not infested, could the infested items or commodity be moved from the building and fumigated elsewhere? Assuming that removal of the infested items from the building is not practical, can you fumigate them in place? Is there enough room between the commodity and walls or partitions so that you can seal the tarp to the floor? What is the cube of the commodity? What is the cube of the building? Can the structure itself be made reasonably airtight, or will it be necessary to tarp the entire building?

From what construction materials is the structure built? (Fumigants will pass through cinder block with no difficulty). Are there broken windows that must be replaced? Are there cracks in the ceilings, walls, or floors that must be sealed? Are there floor drains, sewer pipes, or cable conduits that will require sealing? There have been a number of fumigation failures because floor drains under stacked commodities went unnoticed. In one instance, the fumigant leaked into a telephone cable tunnel which led to an occupied building. No loss of life occurred, but

a number of people were made ill. How are you going to handle air conditioning ducts and ventilation fans? Are there fireplaces, flues, stove pipes? Will interior partitions interfere with fumigant circulation? Are the interior partitions gas tight so that they can be relied upon to keep the fumigant from entering other parts of the structure?

Are there parts of the building not under the control of your customer? Can these other operations be shut down during the fumigation? What are the building contents? Can any of them be damaged by the fumigant? Can such items be removed during the fumigation? If they cannot be removed, can they be otherwise protected?

Where are the gas cut-offs? Where are the pilot lights? Where are the electric outlets? Of what voltage are they? Will the circuits be live during fumigation? Can the outlets be used to operate your fumigant circulating fans?

Look outside the building. If you tarp the entire structure, can you make a good, tight ground seal? Is there shrubbery next to the building that might be damaged either by the fumigant, or by your digging to make an airtight fumigation seal? Can this shrubbery be moved? How far is it to the nearest building? Does that building have air conditioning? Does it have air intakes that could draw the fumigant inside -- particularly during aeration?

How are you going to aerate your structure after fumigation? Are there exhaust fans, and where are the fan switches? Are there windows and doors that can be opened for cross ventilation? Does the building contain any high priority items that may have to be shipped within a few hours notice? If so, can you make provisions for interrupting the fumigation and aerating the building within a certain time requirement?

Is the structure to be fumigated so located that your operations may attract bystanders? (If so, you should consider asking for police assistance to augment your own guards). Where is the nearest medical facility? What is the telephone number of the nearest poison control center?

Once you are convinced that you have covered everything, prepare a checklist of things to do and of materials needed. Don't rely upon

your memory. Then finally, two questions: What has been overlooked? Is fumigation still the best method of controlling the pest problem?

### Tarpaulin Fumigation

Tarpaulin fumigation involves the placement of a gas-tight material over the commodity or structure to be fumigated. The tarps may be specially made for fumigation, such as impregnated nylon, or they may be sheet polyethylene. Impregnated nylon tarps may be used again and again; they are very strong and resist ripping. Many sections of impregnated nylon tarps can be clamped together, so there is no limit as to the size of the stack or structure that may be covered. Polyethylene tarps can be used in thicknesses from 1-1/2 mil up to 6 mil. The thinner material can be used only once, and is for indoor work. Four and six mil material can be used outdoors, and, if you are lucky, the six mil material can be reused. Since clear polyethylene breaks down in sunlight, black polyethylene films should be used outdoors. It is normal to use gas-impervious adhesive tape instead of clamps to join various sections of polyethylene film together. In addition to considering the material to use for tarpaulin fumigation, consideration must be given to the method of obtaining a ground seal. If they are smooth, concrete and asphaltic surfaces are satisfactory. Wood surfaces are not. With wood, and frequently with soil surfaces, it is necessary to place a section of the tarp material beneath the stack as well as over it.

There are several methods of obtaining a good ground seal. Of course, you must allow enough tarp material to skirt out from the stack. This skirt should extend outward at least 18 inches. Then loose sand, sand snakes, or water snakes are used to hold the skirt to the ground surface. Snakes are merely tubes of cloth or plastic filled about 3/4 full with sand or water. Don't fill them too full or there will not be enough ground contact to make a good seal. A word of caution about using water snakes. If the floor is not level, the water will run to one end and the seal will be poor. The snakes should overlap each other

about 1-1/2 feet. Sometimes it is easier to use adhesive tape and make a direct seal to the floor. In this case, snakes are not needed. Occasionally, you may find a stack placed too close to a wall to obtain good ground seal. If the wall is reasonably impervious, the tarp may be sealed directly to the wall.

### Indoors

If it is determined that a stack of items is infested and requires fumigation, it is best to conduct the operation indoors. Indoors, the stack is protected from wind and rain. If for safety, or other reasons, the storage area is not suited for fumigation, then it is better to move the commodity to another indoor location rather than to fumigate outdoors. This you will have determined when you first inspected the structure. The commodity to be fumigated should be on pallets. With most fumigants, it will be necessary to keep all persons not connected with the fumigation operation out of the area where the fumigation is being conducted. If partition walls are not impervious to the fumigant, the entire building will have to be evacuated. If you are using aluminum phosphide, these restrictions are not so rigid. With aluminum phosphide, after the fumigant is introduced, work can continue in the area as long as you are sure that there is no fumigant leakage. Of course, warning signs will be posted on the stack.

If you are using any fumigant except aluminum phosphide, you will have to erect tarp supports which are one to two feet higher than the stacked commodity. This is to make certain that there will be adequate circulation of the gas during the initial stages of the fumigation. The gas introduction tubes should then be secured to the top of one of the



supports. A pan or other device should then be placed beneath the gas introduction tube outlet to protect the commodity from any liquid fumigant. Next, all of the corners must be well padded to prevent the tarp from tearing. The lighter the polyethylene tarp, the more chance there is for tears. If the stack is large, non-sparking fans must be so placed that gas circulation will be assured. These fans must be run for one-half to one hour after the introduction of the fumigant. You must also run tubing from various positions in the stack (usually, one located high in the stack, one at an intermediate location, and one at a low location) to the position where you will be sampling the gas concentration. After all of this is done, the tarp can be placed and sealed to the floor. Because of the molecular activity of hydrogen phosphide, the air dome, tubing, and fans are not necessary if you are using aluminum phosphide. Of course, you will have to obtain the cube of the space beneath the tarp so that you can calculate the amount of fumigant to use.

#### Outdoors

The same principles as stated above apply to fumigation outdoors. The difference is that the fumigation tarpaulin must be of a stronger material. Six mil material is better. Clear polyethylene tends to become brittle from ultraviolet rays of the sun. If the polyethylene tarp is to be kept in place after the fumigation is completed, or it is planned to reuse the tarp, black polyethylene should be considered for use. Black polyethylene is more resistant to the effects of sunlight. There is, however, some danger in using black polyethylene. If the tarp spans several stacks, it may conceal gaps between stacks, or other voids, and personnel working on top of the tarp may fall through. If fumigation has begun, such a fall could be fatal.

It is more difficult to obtain a good ground seal outdoors. It may even be necessary to place a layer of loose sand on the skirt to obtain any sort of a good seal. Additionally, steps will have to be taken to protect against unanticipated bad weather (if you know that the weather will be stormy, delay fumigation). Place braces over the stack (but under the tarp) so that rain will not accumulate in any low spots.

Also place weighted ropes (sandbags make good weights) over the tarp as protection against wind. If the tarp bridges stacks, workers will have to be very careful not to fall through the void while they are working atop the stacks. The black polyethylene is not transparent.

#### Entire Structure

This type of tarpaulin fumigation is normally reserved for the control of dry-wood termites or wood-boring beetles. The fumigants normally used are sulfuryl fluoride (Vikane) or methyl bromide. HCN is also registered for this purpose, but because of better penetration and increased safety, sulfuryl fluoride or methyl bromide is preferred.

Items which could be damaged by the fumigant must be removed. Building occupants will have to be evacuated for the entire fumigation and aeration period. All pilot lights, flames, and electrical appliances will have to be turned off. Tubing for drawing air samples will have to be placed at several places within the structure. It is well to introduce the fumigant into the structure at several locations. Non-sparking electric fans should be placed so the fumigant will be circulated throughout the structure for one-half to one hour after the introduction of the fumigant.

If methyl bromide is used, it should be the formulation containing 2% chloropicrin. If sulfuryl fluoride is used, chloropicrin should be introduced into the structure 15 minutes before the sulfuryl fluoride is introduced. (To introduce the chloropicrin, place a handful of cotton in a shallow dish and set the dish in the air stream of one of the electric fans. Pour chloropicrin over the cotton. Use one ounce of chloropicrin for each 10,000 - 15,000 cubic feet of space to be fumigated).

If ornamental vegetation is too close to the structure to permit the tarpaulin to be sealed to the ground, the vegetation will have to be moved. All edges of the structure which could puncture or tear the tarpaulin will have to be well padded. Workers should wear shoes with non-skid soles, and all ladders should be strong and braced. Tarp sections then may be carried to the roof-top for further assembly. If impregnated nylon is used as the tarp material, the joining of sections is usually by

special fumigation clamps. The edges of adjacent tarp sections are rolled together and clamped. Clamps can be used with polyethylene, but adhesive polyethylene tape may be better. Once enough sections have been joined, the completed tarp can be dropped off the sides of the building and any additional clamping or taping completed. If the building top is flat, sand snakes should be used to hold down the tarp. If the roof is peaked, weighted ropes should be thrown over the tarp to prevent the tarp from billowing. Excessive billowing of the tarp can ruin a fumigation job, and all possible measures should be taken to prevent this from occurring. The tarp should be drawn as close to the building as possible. If a high capacity electric fan is placed in one doorway and directed outward, a partial vacuum will be created and will draw the tarp against the structure. The excess tarp material at the corners of the structure then can be drawn together and taped down. As in any fumigation, the ground seal is very important. The ground should be level and devoid of vegetation. If the soil is porous, the soil around the perimeter of the building should be soaked with water to prevent escape of the fumigant through the soil. The tarp skirt must be at least 24 inches and weighted down by an ample amount of loose sand. If sand snakes are used, they should be doubled or tripled. The ground seal must be weighted enough to withstand any unexpected wind.

#### Spot or Local Fumigation\*

Fumigants, both spot and local, are used in many flour mills, mix plants, and some packaging operations for the prevention of insect development inside processing equipment. Spot and local fumigants are highly toxic and must be handled with extreme care. Gas masks with organic vapor canisters must be worn for respiratory protection. Severe burns can result if the fumigant is allowed to remain in contact with the skin after an accidental spill. In the event fumigants are accidentally spilled on the skin, the affected area must be washed immediately with soap and warm water. Should you accidentally spill a fumigant on

---

\*Procedures condensed from AOM Series #16

your clothing, remove the clothing immediately and wash the skin beneath the spill. Do not wear the same clothing until it has been thoroughly aired or washed. Rings and watches must be removed when handling liquid fumigants to prevent burns or dermatitis underneath them.

Particular care must be taken to prevent spilling or allowing fumigants to drop on shoes. Leather will hold the fumigant vapors for several days. Shoes on which fumigant has been spilled must be removed immediately and be allowed to air-out until all traces of fumigant odor have dissipated before being worn again.

Gloves must never be worn while handling liquid fumigants because they readily absorb the vapors and will cause severe burns.

Fumigants and alcohol do not mix. Never handle liquid fumigants if you have indulged in any alcoholic beverage, including beer, in the previous 24 hours.

Two types of fumigant application equipment are in general use -- the Little Squirt from Ferguson Fumigants or the Infuco Spot-App unit from Industrial Fumigant Company. Both types of equipment are designed to deliver a predetermined amount of fumigant. Flour mills, being multi-storied structures, are equipped with stand-pipe systems consisting of a reservoir tank on one of the upper floors and a copper line extending downward with valves and outlets fitted with quick couplings on each of the lower floors. The Little Squirt system is designed to handle spot fumigants. The Infuco Spot-App unit is available in two-ounce and four-ounce fumigants. The four-ounce unit is adjustable, and may be set to deliver two fluid ounces of fumigant or up to four fluid ounces. Stainless steel extension tips are available to reduce the opening size required for the Spot-App unit. This permits the use of spring-lid oil hole covers on equipment where dusting would be a problem. These oil hole covers come in two types threaded for installation on a metal surface such as an elevator boot, or tapered for installation in wooden surfaces like the top of a sifter. The application points are located to permit all of the fumigant to be dispensed inside the machinery, reducing the exposure of personnel to fumigant vapors.

The application points for the fumigant are located where there is an accumulation of static or non-moving stock which will hold the fumigant and slowly release the vapors; in places such as elevator boots behind the feeder rolls on older style roll stands, directly on the feeder rolls on newer type rolls, in purifier conveyors on old-style wooden purifiers, with screw conveyors or in the air chamber and feeders of the newer type Buhler or Miag purifiers, pick-up conveyors or where there are easily accessible openings on pick-up conveyors. Other application points are at the rear side of Draver feeders, in the top of each sifter section, the inlets of feed finishers, directly below elevator heads in each side of each elevator leg, or in the canted or sloped area directly beneath the elevator head pulley (this area in most conventional or bucket type mills is inaccessible for cleaning and is often overlooked in spot fumigations), at automatic flour scales, automatic feed scales, the inlets leading to cyclone dust collectors, vertical air trunks, and horizontal air trunks. All application points should be plainly marked, particularly where ladders must be used in reaching overhead areas where the application point may not be visible from the floor level. A checklist, or chart, should be prepared for each plant, showing the location and number of application points on each floor. As each point is treated, the appropriate location should be checked on the chart to be certain that no points were missed before moving to the next floor.

Preparations must be made before the plant is shut down. In the mills, the feed should be cut and the mill allowed to run for 30 to 45 minutes to remove as much stock as possible. During this period, rubber mallets should be used to tap on spouting, elevator legs, and sifters to loosen as much residual stock as possible. Outlet channels in sifters should be checked at this time to be certain that none are blocked or choked. Boots and other machinery containing static stock are not cleaned-out prior to the fumigation.

A notice is placed on the plant bulletin board a few days in advance of the fumigation to advise employees of the date, time, and length of fumigation, and to advise them that they are not to enter the plant under any circumstances while it is under fumigation.

After shut-down, all dust collector vents should be sealed using polyethylene sheeting or large plastic bags. On pneumatic mills, or where filters are used, dampers or a series of slide valves are usually located in the air discharge system. It is important to close dust collectors and filter vents to contain the fumigant within the machinery. Thermal currents and drafts can make a spot fumigation a total failure because vapors may be discharged to the atmosphere before reaching a killing concentration within the machinery.

All windows must be closed, the fire doors between floors closed, and all outside doors must be closed. In warm weather, doors and windows may be closed as the application is completed on each floor. Warning signs must be placed on each exterior entry door. Other doors, which can only be opened from the inside must be securely fastened or locked. Local codes may require you to notify fire and police departments as well as any alarm services. Some labels now require a guard to be posted.

When it is necessary during the winter months to check the operation of the boilers, the outside entrance to the boiler room must be used rather than entering through a section of the plant under fumigation. Warning signs must be placed on the doors which connect the boiler room to the plant.

The length of exposure time is important for an effective fumigation. Follow the label instructions on your fumigant container. Exposure periods of less than label instructions are not effective. At least two hours before any employee is allowed to enter the plant, an employee wearing a gas mask opens the doors and opens the necessary windows and dust collector vents to allow any remaining fumigant vapors to dissipate. The warning signs are then removed from the exterior doors. Exhaust fans are then started. The mill machinery is not cleaned prior to start-up. Upon start-up of the mill, the first few sacks coming off are set aside and allowed to aerate until all fumigant vapors have dissipated. The set-off stocks are later fed back into the feed streams.

These are a few basic rules that must be followed in carrying out a spot fumigation. Never attempt to do a spot fumigation alone. At least two employees must be present. The applicators must wear gas masks fitted

with correct vapor canisters specified for the fumigant used. The applicators must remain on the same floor at the same time or be within sight or hearing distance of each other. No one is to enter or remain in the plant during application of fumigant unless he is wearing an approved gas mask. When the fumigant vapors are considerably heavier than air, the fumigant application begins on the lower floors and proceeds upward. This allows the applicator to work in a less hazardous atmosphere.

Spot fumigants are intended for use inside machinery only. Never apply spot fumigants in open areas or around the bases of equipment; this wastes fumigant and increases the likelihood of the applicator being splashed.

Fumigants must be properly stored in a remote and well-ventilated area of the plant which is posted with appropriate warning signs. The storage area must be kept clean and well-organized. The fumigant storage areas must be kept locked when not occupied.

Before anyone uses a gas mask, the mask inspection log must be checked. This will tell you when the mask was last cleaned, inspected and the canister installation date. The tape on the bottom of the mask canister protects the canister while it is in storage. The date that this canister was first used has been entered in the space provided on the reverse label.

Remember, your safety is of prime importance to you, to your family, and to your employer. Be sure to follow these instructions on every spot fumigation, so that it is both effective and safe.

#### Liquid Grain Fumigation

Fumigation of grain by liquid fumigants can be accomplished by direct mixing (vertical storage), or surface application (flat storage). In direct mixing, the fumigant is applied to the grain so that it is distributed as evenly as possible. This is done while the infested grain is being run into the storage for the first time or being transferred from one bin to another. Application may be from automatic applicators which apply liquid intermittently or continuously, or by ordinary watering cans with the sprinklers left on, or by means of ordinary piping or tubing with the appropriate amount being added for

each 1,000 bushels as it passes on the belt. In vertical or upright storages, it is usually the practice to use an extra dosage for the first 1,000 and the last 1,000 bushels to ensure adequate distribution and provide control of surface infestation. Covers are closed immediately after treatment, or, if no roof is present, the grain should be covered with a gasproof sheet as in tarpaulin fumigations.

In surface application, the liquids are sprayed evenly over the top surface of the grain. The gasses slowly evolve and diffuse downward through the grain. The method is usually used when the grain cannot be turned, or as an emergency measure. Application is usually made by sprayers, and, if possible, should be made from outside the bin or storage through a manhole, roof hatch, window, or door.

Application procedures\* for liquid fumigants are discussed in the following paragraphs.

The area where grain is treated should be properly posted.

Two people must always be present and in view of one another when fumigating.

Fumigants must be stored in safe and locked areas and should be stacked neatly. Mask must be worn when fumigating.

Alcohol and fumigants do not mix. Alcohol, including beer, should not be consumed for at least 24 hours prior to fumigating. Safety equipment for fumigation should be assigned to those individuals responsible for fumigating. A full face face mask should be used. This will protect the eyes as well as the respiratory tract.

The selection of a canister must be for the specific type gas used. Notice the expiration date on all canisters. Check to make sure gaskets



\*Condensed from AOM Series #15



are in place. Place hand over bottom of tube and breathe-in to determine if there are any leaks.

Masks are available into which glasses can be built. Sideburns should be kept trimmed -- long bushy sideburns may interfere with proper seal of mask. Gloves should not be worn. Jewelry, such as watch and rings, should not be worn.

Fumigants require a specific dosage time. Be sure to check the label so this can be adhered to. Dosage is also a major consideration and the label again should be checked to determine the proper level. Fumigants are available in different size containers. Fumigants should not be placed on man-lifts to be elevated to upper floors, but should be carried instead. Fumigants may be poured directly from 5-gallon cans into bins or may be added from a 55-gallon drum to the grain stream in a spout.

Bulk systems are more involved. Bulk tanks should be located in an isolated, well protected area. Each tank should be properly labeled with a sign posted on the side of the tank. Before grain is unloaded, a sample of incoming grain should be taken and checked for insect activity. Grain may be treated as it is initially placed in a bin or as it is turned. With the bulk system, the fumigant is moved by a pump to a reservoir located on the bin deck. When not in use, the pump is safely locked-out. When ready to fumigate, the lock is removed and the pump turned on. The fumigant level in the reservoir is controlled by a valve located below the reservoir.

A plastic enclosed glass metering cylinder is used to measure the amount of fumigant needed. To release the fumigant, the valve directly underneath is opened and the fumigant flows by gravity into the bin or may be added to the grain stream. After the fumigant has been added, the bin should be properly marked. A notice is posted in the control room that the bin is under fumigation and grain should not be used and the pump should be locked-out. Hands should be thoroughly washed and shoes aired if contaminated. The sign should be removed after the fumigation period is complete. Masks should be cleaned and sanitized and placed back in the case.

SAMPLE CHECKLIST FOR PREFUMIGATION BUILDING INSPECTION

This sample checklist contains items that may not be relevant to a particular fumigation job, and items which should be considered on some particular fumigation jobs may have been overlooked. The fumigator is advised to modify this sample checklist to meet his own needs.

SITE LOCATION: ADDRESS: \_\_\_\_\_

STRUCTURE

Roof & Attic

Material: \_\_\_\_\_ Fumigant tight: yes \_\_\_\_\_ no \_\_\_\_\_  
Monitors: yes \_\_\_\_\_ no \_\_\_\_\_. Monitor vent control location: \_\_\_\_\_  
Exhaust fans: yes \_\_\_\_\_ no \_\_\_\_\_  
Cube: \_\_\_\_\_

Second Floor

Exterior walls

Material: \_\_\_\_\_  
Windows: None \_\_\_\_\_ Good \_\_\_\_\_ Broken \_\_\_\_\_  
Exhaust fans: yes \_\_\_\_\_ no \_\_\_\_\_

Partitions

Material: \_\_\_\_\_  
Doors: Sliding \_\_\_\_\_ Swinging \_\_\_\_\_ Number \_\_\_\_\_

Floors: Material: \_\_\_\_\_

Cube: Section 1: \_\_\_\_\_ 2: \_\_\_\_\_ 3: \_\_\_\_\_ 4: \_\_\_\_\_ Total: \_\_\_\_\_

First Floor

Exterior walls

Material: \_\_\_\_\_  
Windows: None \_\_\_\_\_ Good \_\_\_\_\_ Broken \_\_\_\_\_  
Exhaust fans: yes \_\_\_\_\_ no \_\_\_\_\_  
Doors: Sliding \_\_\_\_\_ Swinging \_\_\_\_\_ Overhead \_\_\_\_\_

Partitions

Material: \_\_\_\_\_  
Doors: Fire \_\_\_\_\_ Sliding \_\_\_\_\_ Swinging \_\_\_\_\_ Overhead \_\_\_\_\_

Floors

Material: \_\_\_\_\_  
Ducts/Tunnels: yes \_\_\_\_\_ no \_\_\_\_\_  
Drains: yes \_\_\_\_\_ no \_\_\_\_\_ Trapped: yes \_\_\_\_\_ no \_\_\_\_\_

Cube: Section 1: \_\_\_\_\_ 2: \_\_\_\_\_ 3: \_\_\_\_\_ 4: \_\_\_\_\_ Total: \_\_\_\_\_

Basement

Exterior walls

Material: \_\_\_\_\_  
Windows: None \_\_\_\_\_ Good \_\_\_\_\_ Broken \_\_\_\_\_  
Exhaust fans: yes \_\_\_\_\_ no \_\_\_\_\_  
Doors: Fire \_\_\_\_\_ Sliding \_\_\_\_\_ Swinging \_\_\_\_\_ Overhead \_\_\_\_\_

Partitions

Material: \_\_\_\_\_  
Doors: Fire \_\_\_\_\_ Sliding \_\_\_\_\_ Swinging \_\_\_\_\_ Overhead \_\_\_\_\_

Floors

Material: \_\_\_\_\_  
Ducts/Tunnels: yes \_\_\_\_\_ no \_\_\_\_\_  
Drains: yes \_\_\_\_\_ no \_\_\_\_\_ Trapped: yes \_\_\_\_\_ no \_\_\_\_\_

Cube: Section 1: \_\_\_\_\_ 2: \_\_\_\_\_ 3: \_\_\_\_\_ 4: \_\_\_\_\_ Total: \_\_\_\_\_

Electrical

Main Panel: Location: \_\_\_\_\_  
Voltage: 220: \_\_\_\_\_ 110: \_\_\_\_\_  
Outlets needed: Location \_\_\_\_\_

Heating

Type: Electric \_\_\_\_\_ Steam \_\_\_\_\_ Oil \_\_\_\_\_ Gas \_\_\_\_\_ Cut-off location \_\_\_\_\_  
Pilot lights: None \_\_\_\_\_ Location: \_\_\_\_\_  
Other open flame sources: \_\_\_\_\_ Location \_\_\_\_\_

Telephones

Number: \_\_\_\_\_ Location: \_\_\_\_\_

BUILDING CONTENTS

| <u>Item</u> | <u>Location</u> | <u>Fumigant Damage Potential</u> |           | <u>Customer Controlled</u> |           |
|-------------|-----------------|----------------------------------|-----------|----------------------------|-----------|
|             |                 | <u>yes</u>                       | <u>no</u> | <u>yes</u>                 | <u>no</u> |
| _____       | _____           | _____                            | _____     | _____                      | _____     |
| _____       | _____           | _____                            | _____     | _____                      | _____     |
| _____       | _____           | _____                            | _____     | _____                      | _____     |
| _____       | _____           | _____                            | _____     | _____                      | _____     |

BUILDING EXTERIOR

Distance to street/sidewalk: \_\_\_\_\_  
Distance to nearest building: \_\_\_\_\_  
Distance to nearest telephone: \_\_\_\_\_ Location: \_\_\_\_\_ Number: \_\_\_\_\_  
Shrubbery to be moved: yes \_\_\_\_\_ no \_\_\_\_\_  
Risk of fumigant to adjacent buildings: yes \_\_\_\_\_ no \_\_\_\_\_

FIRE DEPT. LOCATION: \_\_\_\_\_ TEL NO: \_\_\_\_\_  
 POLICE DEPT. LOCATION: \_\_\_\_\_ TEL NO: \_\_\_\_\_  
 MEDICAL FACILITY LOCATION: \_\_\_\_\_ TEL NO: \_\_\_\_\_  
 POISON CONTROL CENTER: \_\_\_\_\_ TEL NO: \_\_\_\_\_

SAMPLE FUMIGATION CHECKLIST

Site Location: Address: \_\_\_\_\_

Customer Name: \_\_\_\_\_

Type fumigation: Building \_\_\_\_\_ Interior stack \_\_\_\_\_ Exterior stack \_\_\_\_\_ Vault \_\_\_\_\_  
 Pest: \_\_\_\_\_ Commodity: \_\_\_\_\_ Fumigant: \_\_\_\_\_

| Building Cube:       | Amount | Fumigant | Required | Units |
|----------------------|--------|----------|----------|-------|
| Stack #1 cube: _____ | "      | "        | "        | "     |
| Stack #2 cube: _____ | "      | "        | "        | "     |
| Stack #3 cube: _____ | "      | "        | "        | "     |
| Total cube: _____    | "      | "        | "        | "     |

Stack corners padded: \_\_\_\_\_  
 Test leads in place: \_\_\_\_\_  
 Introduction tubes in place: \_\_\_\_\_  
 Commodity temperature checked: \_\_\_\_\_ Temperature: \_\_\_\_\_  
 Fans in place: \_\_\_\_\_ tested \_\_\_\_\_  
 Tarps folded at stack corners: \_\_\_\_\_ taped down: \_\_\_\_\_  
 Tarps sealed to floor: \_\_\_\_\_ Ground: \_\_\_\_\_ Method: \_\_\_\_\_  
 Tarps checked for tears: \_\_\_\_\_

All building vents/windows/doors sealed: \_\_\_\_\_

Fumigant scales/measuring devices on hand: \_\_\_\_\_  
 Fumigant concentration measuring devices on hand: \_\_\_\_\_ Type: \_\_\_\_\_  
 Fumigant leak detectors on hand: \_\_\_\_\_ Type: \_\_\_\_\_  
 Number of approved masks on hand: \_\_\_\_\_ Type: \_\_\_\_\_  
 Crew briefed on emergency procedures: \_\_\_\_\_ Time: \_\_\_\_\_  
 Building cleared of people: \_\_\_\_\_ Time: \_\_\_\_\_  
 Warning signs posted: \_\_\_\_\_ Location: \_\_\_\_\_ Time: \_\_\_\_\_  
 Guards posted: \_\_\_\_\_ Number: \_\_\_\_\_ Locations: \_\_\_\_\_ Time: \_\_\_\_\_  
 Time fumigant introduced: \_\_\_\_\_  
 Time authorities notified: Fire: \_\_\_\_\_ Police: \_\_\_\_\_ Health: \_\_\_\_\_  
 Tarps/building checked for leaks \_\_\_\_\_ Repaired: \_\_\_\_\_

Fumigation Foreman

\_\_\_\_\_  
 Signature

SAMPLE FUMIGANT CLEARANCE CHECKLIST

Site Location: Address: \_\_\_\_\_

Customer Name: \_\_\_\_\_

Fumigant: \_\_\_\_\_ Pest: \_\_\_\_\_ Commodity: \_\_\_\_\_

Fumigant Concentration: At introduction: \_\_\_\_\_  
12 hours \_\_\_\_\_  
24 hours \_\_\_\_\_  
48 hours \_\_\_\_\_  
72 hours \_\_\_\_\_

Concentration/time schedule met: yes \_\_\_\_\_ no \_\_\_\_\_ Additional time required: \_\_\_\_\_ hours

Number gas masks available for aeration: \_\_\_\_\_ Type: \_\_\_\_\_ Protection minutes \_\_\_\_\_

Time area vacated for aeration: \_\_\_\_\_

Time tarp lifted or building opened: \_\_\_\_\_

Blowers used: yes \_\_\_\_\_ no \_\_\_\_\_

Aeration time allowed: \_\_\_\_\_

Device(s) used to check for residual fumigant: \_\_\_\_\_

Building check:

Attic clear: yes \_\_\_\_\_ no \_\_\_\_\_  
2nd floor clear: yes \_\_\_\_\_ no \_\_\_\_\_  
1st floor clear: yes \_\_\_\_\_ no \_\_\_\_\_  
Basement clear: yes \_\_\_\_\_ no \_\_\_\_\_

Did you check the following for trapped residual fumigant?: waste baskets \_\_\_\_\_;  
closets \_\_\_\_\_; toilet bowls \_\_\_\_\_; files \_\_\_\_\_; desk drawers \_\_\_\_\_;  
floor drains \_\_\_\_\_; ducts \_\_\_\_\_; sumps \_\_\_\_\_; other low places \_\_\_\_\_.

Building clear: yes \_\_\_\_\_ no \_\_\_\_\_. Additional aeration required: yes \_\_\_\_\_ no \_\_\_\_\_  
Additional time allowed: \_\_\_\_\_ hours.

Remarks:

Time building certified for reoccupancy: \_\_\_\_\_

Signature \_\_\_\_\_  
Fumigation Foreman

## PRECAUTIONS, PROTECTIVE EQUIPMENT AND DETECTION

Fumigants as a class are the most toxic of all pesticides. Their natural properties of being highly volatile, penetrating, and highly toxic make them a threat to human life if not used with proper precautions. On the other hand, if fumigants are used with proper precautions and protective equipment, they can be used with the same relative degree of safety as many other industrial operations.

Several of the specific precautions necessary for a particular fumigant or method of fumigation have been discussed, when appropriate, in previous chapters. General precautions and the care and use of safety equipment will be discussed here.

In addition to the regulations administered by the Environmental Protection Agency concerning the handling of pesticides and certification, attention is also called to the fact that the Occupational Safety and Health Act has responsibility for the use of pesticides. Part of their regulations state:\*

"Application. Protective equipment, including personal protective equipment for eyes, face, head, and extremities, protective clothing, respiratory devices, and protective shields and barriers shall be provided, used, and maintained in a sanitary and reliable condition wherever it is necessary by reason of .... chemical hazards .... encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation, or physical contact."

You may be cited by EPA and/or OSHA for failing to follow instructions in the use or care of protective equipment as well as for the misuse of a pesticide. Directives issued by these agencies and instructions on pesticide labels must be observed. The information given here is to help you better appreciate the need of following procedures for protection and some general instructions. No safety suggestions can cover all situations. Follow the label instructions. Remember there is no substitute for good common sense.

\*Subpart I, Paragraph 6950.1, Section 1910.32, General Requirements

### Threshold Limits

When working with fumigants, it is essential to know the levels of concentration which are not safe, as well as the length of time one can be exposed without adverse effect, including repeated exposure during normal working hours. These concentrations are referred to as "threshold limits" and are generally given in parts per million (ppm). The limits should be used as general guides and not as fine lines between safe and dangerous concentrations. The threshold limits for each of the fumigants discussed have been included with the discussion of each fumigant and are given in the table below, with odor threshold values and single infrequent exposure reported in the literature, as a further guide in the safe use of fumigants.

#### Threshold Estimates for Odor and Maximum Exposures Believed

##### Safe for Man

|                         | Approx.<br>odor<br>threshold | Single exposures<br>not more than once a week |           |             | Repeated<br>exposures<br>8 hours/<br>day<br>5 days/<br>week |
|-------------------------|------------------------------|---|-----------|-------------|---|
|                         |                              | 7<br>Hours                                    | 1<br>Hour | 0.1<br>Hour |   |
| Parts per million (ppm) |                              |   |           |             |   |
| Acrylonitrile           | 35-100                       | 40  | 100       | 200         | 20  |
| Carbon disulphide       | 30-60                        | 100   | 200       | 500         | 20  |
| Carbon tetrachloride    | 60-70                        | 50  | 300       | 3000        | 10  |
| Chloropicrin            | 1-3                          | 1   | 1         | 5           | 0.1   |
| Ethylene dibromide      | 25                           | 50  | 200       | 800         | 25  |
| Ethylene dichloride     | 50                           | 200   | 1000      | 2000        | 50  |
| Ethylene oxide          | 300-1500                     | 150   | 500       | 2000        | 50  |
| Hydrogen cyanide        | 1-5                          | 20  | 40        | 200         | 10  |
| Methyl bromide          | None                         | 100   | 200       | 1000        | 20  |
| Phosphine               |                              | 1   | 25        | 50          | 0.3   |
| Sulphuryl fluoride      | None                         | 200   | 400       | 2000        | 5   |

#### Warning Gasses

Materials such as chloropicrin may be added in low concentrations to an odorless fumigant so that one may be made aware of the presence

of a harmful gas. Such a gas is valuable for warning or alerting operators or others in the area or in the vicinity of the fumigation. However, they must not be relied upon as the only safeguard for protection, any more than you would rely upon the detection of a fumigant by its own odor. It must be stressed that:

- individuals vary in their ability to detect odors and levels of odors
- the warning gas may have different physical properties than the fumigant and the mixture may stratify or separate or be sorbed at a different rate, providing a false sense of security
- odors do not tell you the concentration of fumigant present

Warning gasses serve a useful purpose but are not foolproof. Use them as one of the tools, not as the only one!

#### Respiratory Equipment

Respiratory protective equipment is of two basic types: 1) air supply masks -- those which supply uncontaminated air from outside to the mask or those which carry the air with them (self contained breathing apparatus) and 2) air purifying masks -- those which purify the air (gas masks and cartridge respirators) by removing gasses and particles from the air. In fumigation work, and particularly in emergencies, the air supply mask is preferred, but the air-purifying gas masks are the most commonly used. Neither the air supply or purifying types prevent absorption through the skin unless of special design.

Some individuals have difficulty breathing with air-purifying masks. These individuals should use a respirator which supplies air from its own supply or from the outside. If the specific exposure concentrations are suspected or exceeding the concentration or time limitations of the canister of a gas mask, then only an air supply mask should be used. Individuals who have punctured ear drums may draw fumigant vapors in through the ear as a result of creating a slight negative pressure during inhalation. Any fumigant drawn this way will be exhaled into the respirator facepiece and a poisonous concentration may build up inside the respirator. It is usually possible for persons with this defect to obtain



complete protection by using cotton earplugs smeared with oil. Individuals wearing respirators as part of their work should have physical examinations to make certain they are physically fit to wear respirators safely.

### Air-Supplying Respirators

These respirators supply fresh clean air from an outside source or cylinder rather than purifying air at the location of use. They should have a blower or positive pressure to assure an air supply. Their use is required where oxygen has been depleted or an unknown concentration of fumigant exist. Although more expensive, there are several reasons for using devices other than full-face gas masks with chemical canisters for respiratory protection. Canisters have limited life and must be replaced. Special canisters must be available for each fumigant. The canister provides no protection at abnormally high fumigant concentrations. They provide no protection in spaces where oxygen is deficient. Air supply respirators, like gas masks, should be properly fitted and used according to instructions.

### Air-Line Masks or Hose Masks With Blower

These devices have face pieces similar to the canister gas masks, but, rather than having canisters, the masks are attached to hoses which lead to an air pump. The air pump is usually powered by a gasoline engine. The air then passes through a filter. One air pump can supply air for several air lines and masks. The device permits the fumigators to operate within a space being fumigated for an indefinite time. (Note: These devices do not protect against skin absorption of the fumigant). The disadvantages are: the fumigator's movement is somewhat restricted because he must tow the air-line. The air-line can become caught or kinked which will shut

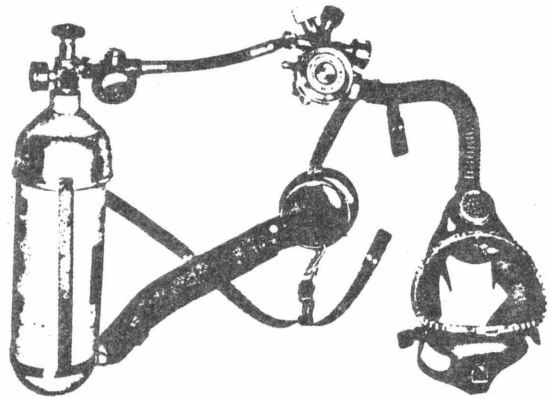


off the air supply. The engine may fail. The air-pump must be located so that contaminated air is not pumped to the fumigator. Care should be taken to avoid cutting or damaging the hose. Already-purchased Bureau of Mines approved air respirators will be approved for use until March 31, 1980.

#### Self-Contained Breathing Apparatus (SCBA)

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

Air Pack - With this device the full-face mask is attached to a tank of air carried on the back of the fumigator. It gives the fumigator the mobility of the canister mask, and does not tie him to an air pump. Except for concern about skin absorption of the fumigant, the fumigator can work in any gas. With the popularity of SCUBA diving, it is not



difficult to get the air tanks refilled. Depending upon the size of the tank, the air supply will last up to an hour. There is usually a warning bell that can be set to warn the fumigator when his air supply is running low. The disadvantage of the air pack is that the fumigator has to carry a heavy tank while he completes his work. Already-purchased Bureau of Mines approved self-contained breathing apparatus will be approved for use until March 31, 1979.

Oxygen Breathing Apparatus (OBA) - The oxygen breathing apparatus is similar to the air pack, but instead of a tank to carry, a special canister generates the oxygen supply. The canister is lightweight and is usually worn on the chest. To operate, the fumigator places the canister into its place, tightens up a wheel screw, and blows into the air supply tube once or twice. The moisture from the breath activates the chemicals in the canister, which then provide a supply of oxygen. The supply is good for about one hour. There is usually a warning bell

that can be set to warn the fumigator that the life of the canister is about expired. Care must be taken and the directions given closely followed for the disposal of the oxygen generating canisters.

Already-purchased Bureau of Mines approved self-contained breathing apparatus will be approved for use until March 31, 1979.

### Air-purifying Respirators

Respirators of this type are designed to remove particulate matter from the air, or to remove toxic vapors that may be present, or to remove both particulate and toxic vapors. These respirators are limited in their capacity to purify air by the size of the cartridge or canister, the concentration of toxic vapors, and by the ability of the contents of the cartridge or canister to remove the toxic substance.

#### Chemical Cartridge Respirator

These respirators, in addition to being equipped with filters to remove fine particles, have one or two chemical cartridges which remove the toxic gasses and vapors either chemically or physically by absorption. The sorbent volume is small and its lifetime is generally short. These respirators are used for low concentrations and short exposure periods. Cartridge respirators are not suitable for use with fumigants. The cartridges are too small and they tend to leak around the facepiece.

#### Gas Mask or Canister Respirators

These respirators are equipped with canisters containing the sorbent for removal of the toxic gasses and filter for removal of particles. Besides protecting the face from absorption they contain more sorbent than cartridge respirators so they may be used for higher concentrations of toxicant and/or longer periods of exposure. These respirators are suitable for use with fumigants.

Because gas masks are air-purifying devices, designed solely to remove specific contaminants from the air, their use must be restricted to situations in which the air contains at least 19.5% of oxygen by volume and generally no more than 2% concentrations of toxic gasses and vapors by volume. The canister must be suitable for protection against

the fumigant being used. If the oxygen content or concentration of fumigant is not known, it is recommended that they be measured with instruments (such as Drager Detector Tube #CH 31601) under the conditions as they exist to make certain the correct canister and respirator is used. The life of the canister is limited and varies with the fumigant used and the fumigant concentrations. The maximum permissible limits are usually stated on each canister. Do not exceed maximum limits.

### Canisters

There are four sizes of canister available for most gas masks -- the chin size or smallest canister should not be used in fumigation work due to its low capacity and concentration limitation. The industrial size canister is most used in fumigation, but many recommend the use of the super size canister which has a greater capacity. The largest N size canister has about twice the capacity of the industrial size.

Each canister is also color coded with appropriate stripes for quick and easy recognition of its type and limitations. A grey stripe around the top of the canister indicates the presence of a filter for the removal of dust or certain other particulate matter.

The canister color code for the various fumigants are:

| <u>Fumigant</u>                | <u>Color Code</u>         |
|--------------------------------|---------------------------|
| aluminum phosphide (phosphine) | Yellow with orange stripe |
| ethylene dibromide             | Black                     |
| ethylene chloride              | Black                     |
| ethylene oxide                 | Black                     |
| hydrocyanic acid gas           | White with green stripe   |
| methyl bromide                 | Black                     |
| sulfuryl fluoride              | White with grey stripe    |

The canister selected should be one that is produced by the manufacturer of the mask that you plan to use.

The period of safe use of the canister depends on a number of variables, including:

- the type of canister
- the size canister
- the kind and concentration of gas breathed
- the length of exposure period
- the rate of breathing
- whether or not there is more than one gas present
- the temperature and the humidity at time of use.

Never use a canister after expiration date of shelf life listed on the canister.

If chloropicrin is present, it must not be depended upon as a warning gas because the canister may remove chloropicrin even after it has become saturated with the fumigant, i.e., methyl bromide. Several signs will alert you to an expiring canister. Feel the canister occasionally. If it is very hot to the touch, or if there is high resistance to breathing, or you detect an odor, taste, eye or nose irritation, or if any nausea, dizziness, or ill feeling develops, you should return immediately to fresh air.

#### Approved Air-purifying Respirators for Pesticides

All respirators intended for use with pesticides, not fumigants (see below), must be approved jointly by the Mining Enforcement and Safety Administration (MESA) and the National Institute of Occupational Safety and Health (NIOSH). Approval numbers beginning with the letters TC are assigned to all respirators approved by the new agency. This number must be on the box containing the facepiece. Cartridges and filters approved for pesticides are necessary and must have the TC number affixed to them plus the part number of the replacement part. Gas masks will have the number 14G following TC. Respirators having numbers other than TC numbers (i.e., BM numbers) are no longer approved unless they can be upgraded to meet requirements through the use of appropriate parts and canisters.

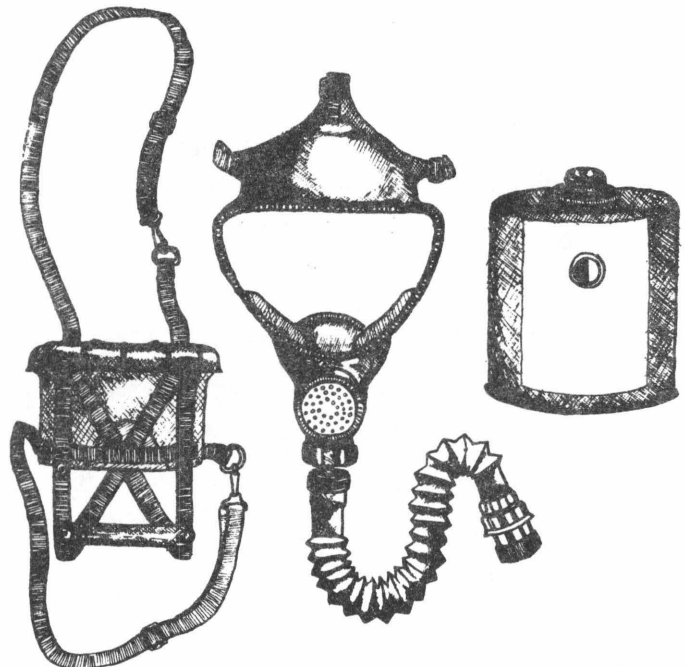
Fumigants at this time are not treated as pesticides by MESA/NIOSH, but as hazardous gasses. Approved masks and respirators for pesticides are not intended for protection in hazardous atmospheres containing fumigants. Gas masks for use with fumigants are controlled by previously established standards and regulations. Dates have not been set when they will also be required to have been approved by MESA/NIOSH and bear TC numbers.

### Principle of Operation

The gas mask, when properly assembled and fitted, is a compact air purifying unit which furnishes protection against those harmful gasses or vapors listed on the canister label. During inhalation, the air enters the canister through the bottom and passes into the interior. Here the air is chemically purified or the harmful gasses or vapors neutralized. The purified air then passes through the corrugated rubber tubing into the molded channel of the facepiece, some of these channels direct the purified air to the lenses to reduce fogging. During exhalation, the air is expelled from the facepiece through the exhalation valve which is designed to permit near normal conversation. This valve outlet also serves as a drain for moisture which may condense from the operator's breathing within the facepiece. An inhalation valve at the bottom of the canister prevents the exhaled air from being expelled through the canister.

### Care of Respiratory Equipment

Each person should have his own respirator and his own canister. Canisters should not be shared with others. Preferably, canisters should not be reused and should never be reused following an emergency use. If the canister is to be reused, a written record



of date used, length of time, and gas concentration should be kept. When a canister is no longer useful, or is being discarded because of use, destroy or mutilate the top so that no one else can use it.

The respiratory mask should be cleaned and disinfected after each day's use and at least once a month. If the mask is not to be sanitized immediately, the interior should be wiped out with a clean cloth, preferably one saturated with isopropyl alcohol. To sanitize masks, prepare a solution of cleaner-sanitizer and warm water, and immerse the mask in this solution.

The interior and exterior of the mask should be scrubbed with the cleaning solution and a sponge. The mask should be thoroughly rinsed with warm water and be allowed to dry. During cleaning, it should be inspected for tightness of connections, rubber deterioration, and the facepiece for a tight seal. A record of these cleanings and inspections should also be kept.

Replacements or repairs should be made only by experienced persons using parts designed for that particular respirator.

After cleaning and inspection, the mask should be placed in its carrying case. When not in use, the mask should always be kept in the case to protect it against dust, sunlight, heat, extreme cold, moisture, and damaging chemicals.

### Fitting and Testing the Respirator

The respirator must fit well to effectively protect the wearer. A cleanly shaven face and short sideburns make a good fit easier. Insert the chin into the lower part of the facepiece and pull the headbands back overhead. To obtain a firm and comfortable fit against the face at all points adjust the headbands as follows:

1. See that the straps lie flat against the head
2. Tighten lower or neck straps
3. Tighten the side straps
4. Place both hands on headband pad and push it toward the neck
5. Repeat operations 1 and 2
6. Tighten forehead and front strap a few notches

To be sure the mask is perfectly tight before using, test by squeezing or pinching of the corrugated breathing tube or by holding the hand tightly over the inlet end of the canister. Inhale gently so that the facepiece collapses slightly and hold your breath for 10 seconds. If the mask is tight, it will remain collapsed while you hold your breath. If a leakage is detected around the face seal, readjust the head harness straps and repeat test until there is no leakage detected. The facepiece must pass the tightness or "good fit" test before entering a toxic atmosphere. No protection will result unless all of the air is drawn through a suitable canister or from a source of clean air.

If a leak in the facepiece cannot be found, check the hoses and connections to make sure they are tight and in good condition. A new rubber washer for the mask hose is supplied with each new canister. This washer must be in place when attaching the hose to the canister, or vapors could enter at this point. Be sure and check for this washer. If a leak still exists, try a new corrugated breathing tube. If, after removal of the seal or your hand from the canister inlet, you find you cannot breathe, the canister has a blockage. Destroy and replace the faulty canister. If the respirator is an air supply type, check the facepiece and breathing tube as for the gas mask. If a self-contained breathing apparatus, check air tank for amount of air, leakages, and valve efficiency. Test valves, connections, and hose on supplied air respirators.



for amount of air, leakages, and valve efficiency. Test valves, connections, and hose on supplied-air respirators.

### Use of the Respirator

The respirator should be ready for use at all times, and, when not being worn on a job, it should be on hand for emergency use if needed. The following checklist is for proper use of your respirator.

1. Determine type of hazard. If the air is deficient in oxygen, less than 19.5%, do not use a gas mask and canister, use an air supply respirator. If in doubt, always use an air supply respirator.
2. Remove from case and if more than one person uses respirator, check all rubber parts and fittings for deterioration and tight fit.
3. Check canister, if a gas mask, for expiration date of canister; and, if canisters are used more than once, for effective time still left. If in doubt, use a new canister.
4. Select the proper canister for the gas that is to be used or present. Make sure that it is the proper canister by reading the label carefully. Also make sure it is the same make canister as the mask it is to be used in.
5. If a new canister, put in a new washer that comes with each canister.
6. Remove tape from the bottom of the canister covering the intake port.
7. Connect mask and canister.
8. Put on in fresh air.
9. Check for proper fit and leaks.
10. Check the time and when you should be out of the fumigated area.
11. Enter cautiously into the contaminated area. Return to fresh air immediately if irritating gasses, odors, or symptoms of distress are noticed.
12. After completion of the job:
  - clean and inspect respirator
  - record date of cleaning, and, if canisters are reused, time canister was used

- if canister effective time is expended, mutilate top so that it cannot be used and discard
- return respirator to carrying case and place in storage area

#### Other Protective Equipment

The requirements for protective clothing vary with the fumigant being used. Because of this, the label should be read and followed. Often, all that is needed is tightly woven cloth coveralls. Where skin absorption is a problem, impermeable clothing may be required during exposure.

The need for wearing gloves when handling fumigants also varies. For example, gloves are not worn with liquid fumigants or methyl bromide, but with some solid fumigants, gloves are required. Read the label!

If spills on clothing, gloves, shoes, adhesive or other bandages occur, get to fresh air immediately, remove all contaminated clothing immediately. Do not wear contaminated clothing again until it has aired for several days.

Whenever possible, two-way radio communication between employees applying fumigants or, in emergencies, entering treated areas should be provided.

An emergency respirator of the air supply type, especially if canister-type respirators are being used, a safety harness, or rescue belt, first aid equipment, and antidotes where applicable should all be readily available in case of need.

#### Detection Equipment

Detection equipment should be a part of every fumigator's operational and safety equipment. If used properly, detectors will help eliminate some of the practical hazards to the fumigator, detect excessive leaks in a building or poor seal of tarpaulins, determine the dosage requirements in future fumigations, determine full fumigant concentrations during actual exposure, measure the success of the aeration process as indicated by the presence or absence of fumigant vapors. Although many detectors can be used for more than one fumigant, be sure it can be used for the fumigant you are using, that it is calibrated for your fumigant, and that you know how to read it.

## Halide Gas Detector

While the halide gas detector has been used for many years, its importance is enhanced by the development of treatments employing enclosures other than the conventional fumigation chamber. It is an operational as well as a safety device, since the elimination of migrant leaks increases the efficacy of operation and reduces harmful concentrations outside the area under treatment. As a precautionary measure, it should be used regularly in rooms in which chambers are located, particularly when the building also houses offices or other occupied work areas.

The halide gas detector is used to indicate the presence and approximate concentration of methyl bromide in the air. This is accomplished by passing the air to be tested over a red hot copper plate or cone through or over which flame is passing. The intensity of colors imparted to the flame indicates the presence and concentration of methyl bromide in the air. The leak detector also reacts similarly with many other halide gasses, including freon, carbon tetrachloride, and ethylene dibromide. None are accurate for quantitative determinations. The following are the approximate methyl bromide concentrations associated with the color intensity of the flame:

| <u>PPM</u> | <u>Lbs/1000 cu. ft.</u> | <u>Flame Color</u>       |
|------------|-------------------------|--------------------------|
| 0          | 0                       | No color                 |
| 25         | 0.00625                 | Faint fringe of green    |
| 50         | 0.0125                  | Moderate green           |
| 125        | 0.031                   | Green                    |
| 250        | 0.0625                  | Strong green             |
| 500        | 0.125                   | Strong green-blue fringe |
| 800        | 0.20                    | Strong blue-green        |
| 1000       | 0.25                    | Blue                     |

This table of flame colors for various ppm's of methyl bromide applies only when the detector is operated at its most sensitive rate; that is, when the flame is reduced to the lowest rate sufficient to keep the reactor plate or cone red hot. Also, in using the detector at night, the flame has a bluish cast which has to be taken into consideration.

Basically, all halide detectors are quite similarly constructed, differing only in detail. Each consists of a fuel tank, a valve assembly to regulate fuel flow, a burner head assembly where the fuel and air mix and unite, and the reaction plate or cone assembly where the visible flame reacts in color to the halogen fumigants. The air mixture to be tested is fed to the burner head assembly by an attached search hose. The fuels used include kerosene, alcohol, acetylene, and propane. They are readily available at refrigeration supply dealers.

The halide detector is relatively trouble free. However, the burner head orifice is extremely small and must be kept free of dust or other clogging debris. The reaction plate or cone will need replacing occasionally.

The halide leak detector is made operable by holding a lighted match in the window opening of the burner tube and turning the valve slowly to the left. After the reaction plate or copper plate has heated to a red hot color, the flame should be adjusted to the minimum size to maintain that color. The detector is now ready for use and this is accomplished by holding the open end of the search hose on, in, or near the area or article to be tested. As the air sample thus drawn into the burner passes over the heated reaction plate or cone, the flame color changes if methyl bromide or any other halogen is present.

Since the operating halide leak detector contains an open flame, there must be a strict adherence to the obvious safety practices. Even when not in operation, it is advisable not to store the detector in a frequently inhabited room, the fuel being a flammable gas under pressure. They cannot be used in the presence of flammable or explosive gas such as gasoline vapors and some halide gasses such as ethylene dichloride or methyl chloride. Do not use the halide detector in mills, elevators, or other enclosures where there is a possibility of dust explosion.

## Thermal Conductivity Analyzers

The thermal conductivity analyzers (TCA) are scientific instruments specifically designed for determining the concentration of fumigant gasses within the chamber or other enclosure while the actual fumigation is being conducted.

Several types of TCA are available (Fumiscope, Fumiscope Jr., and Gow-Mac). They are light in weight, readily portable by hand, completely contained in one compact cabinet, and require no auxiliary equipment. Electrical current is passed through a wire with the final temperature of the wire affected by the composition of the air around it. To do this, it contains a thermal conductivity cell, a meter, a gas pump, controls, and may contain a gas flow meter. It operates on regular 115 volt alternation current or battery power. A gas drying tube is also included. This should be used with any TCA.

The difference in the thermal conductivity of the fumigant-laden air as compared with pure air is converted into electrical energy and is indicated on the meter as concentration in ounces of fumigant per 1000 cubic feet. TCA's are available calibrated by the manufacturer prior to delivery for methyl bromide and other fumigants. They are used primarily for methyl bromide, carbon disulfide, carbon tetrachloride, ethylene oxide, and sulphuryl fluoride. They are not suited for mixtures of fumigants.

Although the TCA is designed to measure methyl bromide concentrations in the range of 0-100 oz. per 1000 cu. ft. (with close approximations up to 110 oz.), and is within 5 percent of accuracy in this range, it may be modified to measure 0-200 oz. for a modest fee, by being sent directly to the manufacturer. Since the TCA's galvanometer responds linearly to gas concentrations, the methyl bromide-calibrated instrument may be used for measuring certain other gasses by the use of specific multiplication factors which have been determined by laboratory studies. For example, carbon tetrachloride concentrations may be determined by multiplying the meter reading by 1.0, ethylene dichloride by 1.05, carbon disulphide by 0.85, and ethylene dibromide by 1.6.

In using the TCA, it should be borne in mind that the instrument is sensitive to a number of gasses other than methyl bromide, and these must be eliminated for a true reading.

Carbon dioxide may occasionally be troublesome in this regard, particularly with fruits. If a pre-fumigation test indicated significant quantities, a tube of sorbing material (usually sodium hydrate, such as Caroxite, a Fisher Scientific Company product), should be placed in the sampling line.

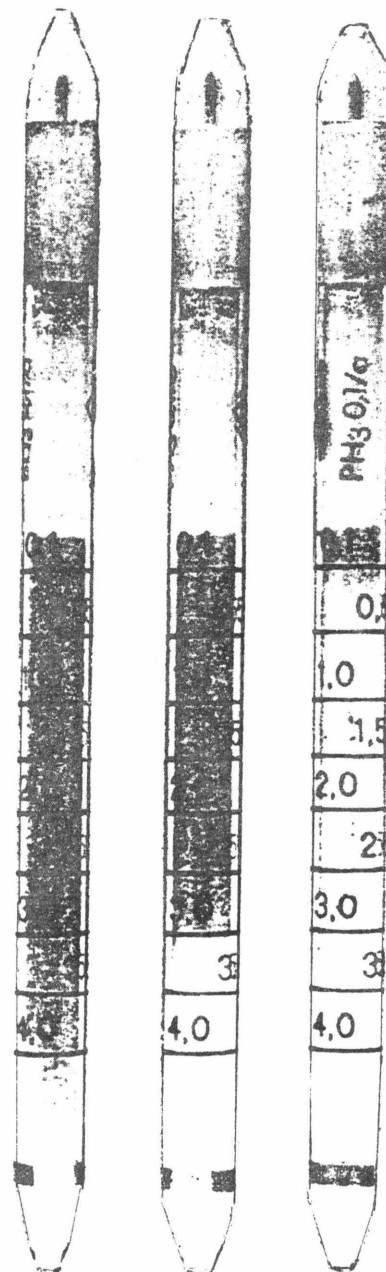
When long sample lines into the area fumigated are used, a small vacuum pump may be used to draw the air-gas sample from the test point to the end of the line. This speeds up the readings on the gas analyzer.

#### Glass Detector Tubes

These are sealed tubes, through which, after breaking the seal, the air being sampled is drawn by pump or bellows. The tubes are specific for the fumigant being measured and produce a color reaction proportional to the concentration of the fumigant present. Suppliers of these tubes and testing devices include Auer, Drager, MSA, and Kitagawa.

Detector tubes are available for acrylonitrile, ethylene oxide, hydrogen cyanide, methyl bromide, phosphine, and probably others. For some fumigants, high range and low range tubes are available. The high range is used for determining working concentrations and the low range to assure a safe working atmosphere.

A measured amount of air is drawn through the tube. Readings are made directly from the printed scale on the tube. If there is no reaction in the tube, it may be used again. Tubes stored at room temperatures or lower have good shelf life -- 2 years and longer.



### Interference Refractometers

These instruments are designed to utilize differences in the refractive index of gasses to measure fumigant concentrations. They are simple to operate and the readings are reproducible under uniform conditions once the instrument is carefully calibrated. They are available for methyl bromide and carbon tetrachloride.

### Color Indicators

These indicators are tapes or packets which are placed in or on the material being treated to determine the intensity or duration of treatment based on the proportion of color development. These have been used with ethylene oxide in particular. Use with methyl bromide produces no color change and requires titration after removal from the fumigated area. Test papers impregnated with silver nitrate to determine concentrations have been reported.

### Transporting A Fumigant

Due to the highly toxic nature of fumigants and the lack of control over fumes released as the result of leaks, spills, or other accidents, the following precautions should be taken:

1. Do not transport fumigants by public transportation such as subways, buses, trains, or taxis.
2. Do not transport fumigants through tunnels without the knowledge and permission of the proper authorities.
3. Carry appropriate respirators or gas masks close to the occupants of any vehicle in which fumigants are being transported.
4. Mark the vehicle in which a fumigant is being transported by attaching to the front, back, and sides of the vehicle signs with words in red, "Danger-Poison Gas", and a Skull and Crossbones symbol - all large enough to be read 20 feet away.

In the event of a leak in the fumigant container during transit, one should:

1. Put on respirator or gas mask
2. Open windows in vehicle
3. Drive as fast as safety permits to vacant areas and open containers completely to dispose of fumigant

4. Notify the police -- ask for help to keep danger area clear of people

### Symptoms and Emergency Treatment for Acute Poisoning by Fumigants

#### Halogen Fumigants

##### Symptoms

Carbon Tetrachloride - Acute: Anorexia, nausea, vomiting, diarrhea, abdominal cramps, headache, vertigo, stupor, cardiac arrhythmias, hepatic and renal damage, pulmonary edema, respiratory depression, death. Chronic: headache, dizziness, renal and hepatic damage, aplastic anemia, visual disturbances, fatigue.

Ethylene Dibromide - Irritation of eyes and respiratory tract, central nervous system depression, headache, excitement, severe vomiting, marked weakness, tinnitus (sensation of noise ringing or roaring), pallor, vertigo.

Ethylene Dichloride - Irritation of respiratory tract and conjunctiva, corneal clouding, equilibrium disturbances, narcosis, and abdominal cramps.

Methyl Bromide - In acute exposures, the effects are on both respiratory and central nervous systems. These effects may be somewhat delayed, but rarely for longer than 24 hours in the case of respiratory symptoms and seldom over 48 hours for central nervous system effects. It may act as a lung irritant from mild bronchitis to pulmonary edema and respiratory failure. Symptoms may include cough, chest pain dyspnea, and eventually wet breathing often complicated by broncho-pneumonia.

Central nervous system effects usually accompany, or follow by several hours, respiratory effects. Symptoms include intense nausea and vomiting, dizziness, double or blurred vision, unusual fatigue, headache, loss of appetite, abdominal pain, staggering gait, and slurred speech. Convulsions are an ominous sign. Following excitation, central nervous system depression may intervene. Muscle weakness and respiratory paralysis may occur. Methyl bromide may produce cutaneous blisters and kill via dermal exposure.



Sulfuryl Fluoride - First symptoms expected are nausea, respiratory irritation, and central nervous system depression, excitation may follow. Treat symptomatically.

#### Treatment

1. In methyl bromide poisoning, early treatment with BAL may be considered if given before symptoms appear. First remove patient from the contaminated area.
2. Remove all contaminated clothing and wash contaminated skin.
3. Restrain confused, maniacal patients. Barbituates for convulsions.
4. May require specific therapy for acidosis, pulmonary edema, bronchospasm (use epinephrine subcutaneously), respiratory paralysis and/or kidney failure.

#### Cyanide Fumigants

##### Symptoms

Acrylonitrile - Weakness, lightheadedness, headache, nausea, sneezing, abdominal pain, vomiting, loss of consciousness, cessation of respiration, and death.

Calcium Cyanide and Hydrogen Cyanic Acid - When a massive dose is experienced, unconsciousness and death can occur without warning. If proper precautions are taken in fumigation work, this is unlikely to happen.

There are preliminary symptoms which serve as a warning of poisoning by inhalation or contact. They are irritation of the mucous membrane of the eyes, throat, and upper respiratory tract; burning sensation on the tongue; metallic taste in the mouth; feeling of pressure in the forehead; sharp pains in the head; giddiness and disturbed equilibrium; nausea and vomiting.

Following ingestion, bitter, acrid, burning taste followed by constriction of membrane in throat.

Salivation and nausea without vomiting. Anxiety, confusion, and dizziness.

Variable respirations -- inspiration short and expiration prolonged.

Odor of bitter almonds in breath and vomitus. Initial increase in blood pressure and slowing of heart followed by rapid and irregular pulse, palpitation, and constriction of chest.

Unconsciousness, convulsions, and death from respiratory failure.

## Treatment

Poisoning by HCN gas may not be fatal if prompt action is taken. Do not rush an unconscious man to the hospital. Prompt action on the spot is essential.

1. Do not breathe gas yourself even for a short time. If it does not overcome you, it will cut down your strength. Rescuers entering a contaminated area must be adequately protected with self-contained breathing apparatus and any protective clothing which may be necessary. Canister-type gas masks are not dependable under circumstances of possible high concentrations.
2. Carry patient to fresh air, and lay him down. Fresh air does not mean out of doors in cold weather. Many men have walked from a warm room containing gas only to collapse in the cold outside air. Take the patient to a room free of gas and comfortably warm. Remove contaminated clothing, but keep patient warm. Start the following first-aid treatment immediately and call a physician.
3. Use artificial respiration if breathing has stopped.
4. Break an amyl nitrite pearl in a cloth and hold lightly under the patient's nose for 15 seconds. Repeat 5 times at about 15-second intervals.
5. Never put anything in the mouth of an unconscious person.

Suggested care by a physician.

1. The physician will decide on further administration of amyl nitrite while a 3 percent solution of sodium nitrite solution is being prepared.
2. Intravenous injection (even of nonsterile solution) of 10 ml of 3% sodium nitrite over 2-4 minute period. DO NOT REMOVE NEEDLE.
3. Through same needle give 50 ml of 25% solution of sodium thiosulfate over 10 minutes.
4. If symptoms recur, repeat the nitrite and thiosulfate.
5. Stomach lavage with 1:5000 potassium permanganate should follow the above procedure.
6. Oxygen therapy and whole blood transfusions may be necessary if nitrite induced methemoglobinemia becomes severe.

The patient should be watched for at least 24 to 48 hours. If signs of poisoning reappear, injection of both sodium nitrite and sodium thiosulphate should be repeated, but each in one half of the previous dose.

### Phosphine Fumigants

#### Symptoms

Phostoxin; Detia Gas Ex-B - Slight or mild poisoning - fatigue, buzzing in the ears, nausea, pressure in the chest, and uneasiness which might pass in fresh air.

Medium to heavy poisoning - general fatigue, nausea, stomach-intestine symptoms with vomiting, stomachache, diarrhea, disturbance of equilibrium, strong pains in the chest, back pains, a feeling of coldness, and dyspnea. May develop hemolytic icterus and cough with sputum a green fluorescent color.

Severe poisoning - rapidly results in strong dyspnea, cyanosis, agitation, ataxia, anoxemia, unconsciousness, and death. Death may be immediate or in days by edema of the lungs and collapse, or by paralysis of central respiratory system as well as by edema of the brain.

Breath and vomit will have odor of carbide. Will turn silver nitrate paper black.

#### Treatment

Remove patient from contaminated area into fresh air.

Make him sit or lie down, keep warm with blankets.

Call a physician.

No specific antidote. Keep patient quiet and warm. May need to treat incipient pulmonary edema with venesection, oxygen, and hypertonic glucose (50%) infusions. Intravenous isotonic solutions are contra-indicated.

### Other Fumigants

#### Symptoms

Carbon Disulfide - Acute: Euphoria, restlessness, mucous membrane irritation, nausea, vomiting, unconsciousness, terminal convulsions. Chronic:

psychic disturbances ranging from extreme irritability to mania with hallucinations, tremors, auditory and visual disturbances, weight loss, and blood dyscrasias.

Ethylene Oxide - Irritation of nose and eyes, headaches, vomiting, shortness of breath, diarrhea, loss of equilibrium, changes in the blood.

#### Safety Precautions Checklist For Fumigation

This checklist is provided to bring together in one place the major considerations for fumigation jobs. It emphasizes safety steps to protect lives and to prevent fires. The checklist is general and cannot be expected to apply to all fumigants in all types of situations. It is to be used only as a guide.

#### Preliminary Planning and Preparation

1. Become fully acquainted with the size and commodity to be fumigated, including:
  - A. The general layout of the structure, connecting structures, and escape routes, above and below ground. Draw or have a sketch of structure to be fumigated.
    - i. Check equipment to ensure that product flow has ceased and that equipment has been made as tight as possible to prevent drafts or leakage.
    - ii. Check all spouts, conveyors, conduits, heat pipes, or other possible openings leading from the areas to be fumigated.
  - B. The number and identification of persons who routinely enter the area to be fumigated, and the proximity of other persons and animals.
  - C. The specific commodity, its mode of storage, and its condition.
  - D. The previous treatment history of the commodity, if available.
  - E. Accessibility of utility service connections.
  - F. Nearest telephone or other communication facility.
  - G. Emergency shut-off stations for electricity, water, and gas.

- H. Current emergency telephone numbers of local Health, Fire, Police, Hospital, and Physician.
  - I. Name and phone number of executives of structures involved.
2. Select a fumigant or combination of fumigants registered by the Environmental Protection Agency for the required work.
    - A. Make certain 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.
    - B. Check, mark, and prepare the points of application if the job involves spot fumigation.
  3. Study directions, precautions, and antidotes on the label and in the manufacturer's instruction manual.
  4. Notify local Health, Fire, and Police Departments and other security personnel, Poison Control Center, occupants of structure and neighboring structures about the proposed location, chemicals, date, and time of application, the type of gas mask and other safety equipment required, and the fire-hazard rating.
  5. Inform local medical personnel of your fumigation practices and specific materials you will use.
  6. Provide authorities with literature about safety measures for the materials to be used.
  7. Arrange for standby equipment and replacement parts, and outline an alternate plan of action.
  8. Inform all employees of the operational schedule, potential hazards to life and property, required safety measures, and emergency procedures.
  9. Prepare warning signs for posting near treated areas, provide for security of buildings, and arrange for any necessary watchmen so that all entrances and exits may be observed.
  10. Have first aid equipment (including antidotes) available.
  11. If possible, plan for application from outside the structure.
  12. Seal all cracks, crevices, open fireplaces, broken windows, holes, pipes, chutes and conveyors.

13. Plan to ventilate the treated space and commodities after the required exposure time is reached. Make this plan before you begin the treatment.
14. Identify the areas to be used for fumigant storage, and provide the conditions required by the manufacturer's directions.
15. Make sure that no open fires, running motors, or hot surfaces such as heat pipes or electrical appliances and fixtures are within the space to be fumigated.
16. When necessary, provide fans for even distribution of the fumigant.
17. Provide gas sampling or detection devices.

#### Personnel

1. Assign at least two persons to each fumigation.
2. In circumstances where entry into a fumigated area is essential, use a "buddy" system - two workers, or groups of two.
3. Know location of all entrances and exits.
4. Know location of all fumigants and aerating fans.
5. Have rehearsed plan and know what they are to do and the route of exit.
6. Have removed rings, jewelry, watches as required. Have gloves if needed.
7. Make certain that all employees actively taking part in a fumigation are in good physical condition, and that they:
  - A. Have had physical examinations at least annually. Employee health records should be current.
  - B. Have abstained from alcoholic beverages for 24 hours before and will abstain for 24 hours after a fumigation job.
  - C. Have no colds or other conditions which impair breathing.
  - D. Are not undergoing medical or dental treatment, unless a physician certifies they may work with fumigant chemicals.
8. Instruct all operating personnel about first aid, emergency procedures, antidotes, and decontamination.

9. Report any accidents to employer or supervisor. Personnel handling fumigants should be cautioned to report any indications of illness or physical discomfort, regardless of how minor it may seem. Some examples are dizziness, diarrhea, nausea, headache, and lack of coordination.
10. Instruct all operating personnel about the hazards that may be encountered if selected chemicals are misused, and about the selection, operation, and maintenance of protection devices.
11. Have the necessary protective equipment and know where emergency equipment is located.

#### Just Before Application of Fumigant

1. Open all doors and drawers inside building.
2. Shut off pilot lights, gas lights, disconnect electrical equipment. Put out fires.
3. Seal all freezers and refrigerators containing food. Place all food in sealed containers.
4. Make a final check to make sure all occupants, pets, and goldfish have been removed from structure.
5. Place warning signs at all entrances and exits.
6. Place watchman where he may observe all entrances and exits.

#### Application Procedures and Fumigation Period

1. Apply all fumigants in accordance with the manufacturer's recommendations.
2. Post areas to be treated immediately before application.
3. Apply fumigant from outside where appropriate.
4. Caution personnel applying fumigants not to enter the area where fumigant gas or vapor is being discharged, except in extreme emergencies.
5. Take into consideration prevailing wind and other weather factors.
6. Provide watchmen where required.

### Post-Application Operations

1. Provide watchmen where necessary.
2. Ventilate and aerate in accordance with structural limitations.
3. Turn on all ventilating or aerating fans where appropriate.
4. Use a suitable gas detector before reentry to determine fumigant concentration. Some fumigants do not provide adequate odor warning, and some areas aerate slowly.
5. Remove warning signs when aeration is complete.
6. Dispose of empty containers.
7. Return unused chemicals to properly and clearly labeled containers, and store them properly.



## PESTS

Fumigants are lethal to most pests. Rodents, bats, birds, insects, and other related Arthropods are all susceptible to fumigants and will be killed during a fumigation job if they are on the site. However, since almost all of the jobs requiring the services of fumigators involve insects as the principal target, this manual is designed primarily to give information on methods, materials and safe handling of fumigants as they are used to control insects and other pests relating to the site.

Insects are among the most important and numerous of the pests in homes, apartments, public buildings, rest homes, nursing homes, hospitals, schools, and business establishments. Fortunately, only a portion of the many hundreds cause serious damage. Many insects enter buildings only accidentally or seeking protection. Some, however, are occasionally serious. Some of the more common and important insects are discussed here, but there is no attempt to discuss all insects that the professional fumigator may be called upon to control.

### Stored Product Pests

Insects cause vast losses of stored products worldwide. In addition to the direct loss of the product that is consumed, there is the usually greater loss from spoilage, contamination, and goods made inedible and unmarketable.

#### Moths

Moths are important pests of stored products. The larvae damage food by eating large amounts of it, but are even more of a problem because they contaminate food so that it cannot be consumed or sold as human food. They often leave the infested products and move about inside the structures. Excessive populations may lead to microorganism problems. Also encountered are moths that attack fabrics and other material of animal origin such as woolens (clothing, carpets, upholstery, tapestry, etc.), fur, and feathers; such damage usually occurs when clothing is stored for an extended period of time. Some of the more common and important moths, but not all, are listed.

Almond Moth (*Cadra cautella*)

Adults have 4 wings; about 5/8-inch-long wing spread. Forewings are brown to grey, a pale wavy band near tip and a darker band across the middle.

Larvae are dirty white, with brown or black spots along back; about 1/2 inch long when full-grown. Five to six generations per year.

Found in dried fruits, nuts, and pet foods, but most frequently infesting candy of chocolate and nuts.

Angoumois Grain Moth (*Sitotroga cereaella*)

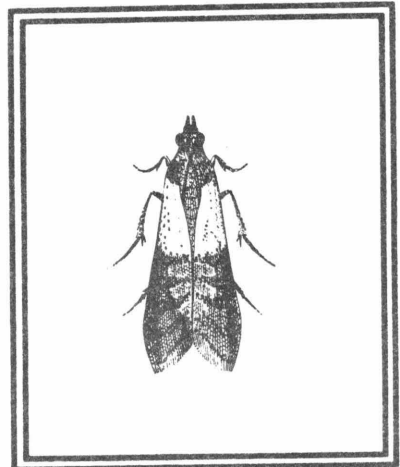
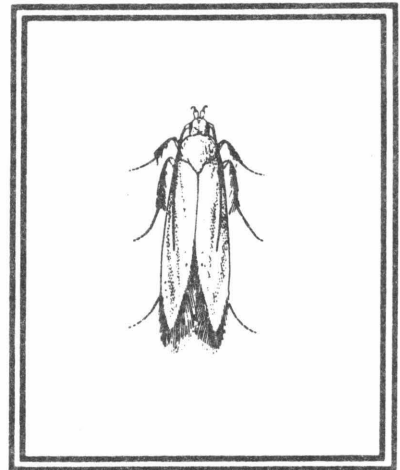
Adults have 4 wings, about 1/2-inch-long wing spread. Forewings are pale yellow. Hind wings are grey and pointed, resembling a pointed finger.

Larvae attack whole grain and feed inside the grain.

Very common in South. First attack usually takes place in the field and continues generation after generation in storage. Six to seven generations per year, but in heated warehouses, there may be as many as 12. Pupae found inside grain. On emergence, they leave a round flap over the hole in the grain.

Indian Meal Moth (*Plodia interpunctella*)

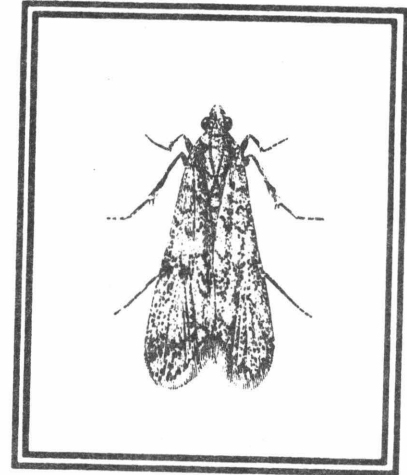
Adults have 4 wings; about 3/4-inch-long wing spread. Forewings are grey near body and reddish near tip. Head and thorax are reddish. Larvae spin large amounts of silk webbing in and over food. Larvae feed on surface. Five to six generations per year. Prefer flour, but feeds on many raw, processed, and packaged dry foods including dried fruit, seeds, powdered milk, chocolate, candies, and a number of other items.



Mediterranean Flour Moth (*Anagasta kuehniella*)

Adults have 4 pale grey wings. Wing spread 3/4 inch. Front wings have wavy lines. Adults rest with head and thorax held high.

Larvae spin large amount of silk in and over food. Larvae feed on surface of food. Larvae have lateral dark spots on each segment of abdomen. These spots indicate this species rather than Indian Meal moth. Three to four generations per year. Larvae leave feeding area to pupate. Prefer flour, but infests wheat, bran, nuts, chocolate, seeds, biscuits, beans, and dried fruits.



Meal Moth (*Pyralis farenalis*)

Adult forewing light brown, patches at tip and base, dark brown. Wing spread about 1 inch.

Larvae spin peculiar silk tubes containing food material. Three to four generations per year. Usually found in damp or spoiled grain, bran, or meal.

To eliminate moth infestations on food and stored grain products, find and destroy infested materials, then treat the area where they are stored. Infested materials can be fumigated. Thorough cleaning is essential to remove spilled food products, followed by good housekeeping to prevent reinfestation. Routine thorough cleaning of all food handling equipment, plus preventive spot fumigation may reduce or eliminate large-scale food-plant fumigation.

Beetles

Beetles are important pests of stored food. Usually both the larva and the adult will feed on foodstuffs. Under ideal conditions, they can have six or more generations per year and quickly become a serious problem. The adults have a pair of thin inner wings covered by a pair of thick leathery outer wings. Life cycle includes eggs, larva, pupa, and adult.

Rice Weevil (Setophilus oryzae)

Granary Weevil (S. granarius)

About 1/8 inch long and dark brown. Mouthparts drawn into elongate snout. Larvae are small, white legless grubs that feed and develop inside individual kernels of grain.

May attack grain prior to harvest and in storage. Will also attack grain products which are caked or manufactured into hard items, such as spaghetti, that are large enough for the larva to get into.

Rice weevil can fly, has two pale spots on each wing cover, and pronotum (top of thorax) has round punctures -- the granary weevil cannot fly, has no pale spots on the wing covers, and punctures on the pronotum are elongate.

Lesser Grain Borer (Rhizopertha dominica)

Small cylindrical, slender, polished, dark brown or black beetle, about 1/8 inch long.

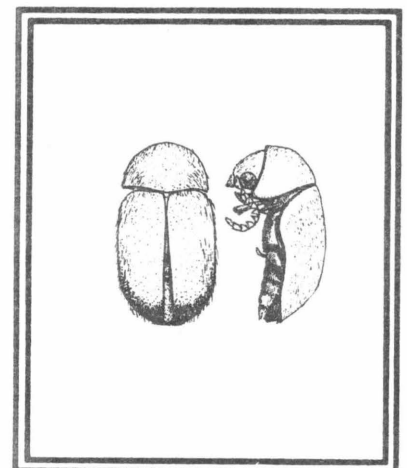
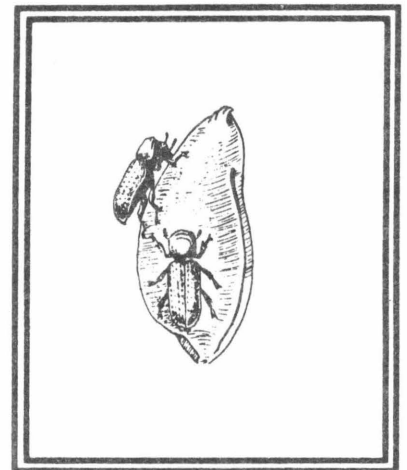
Head turned downward - very strong mandibles, or can cut through wood.

Adult is strong flyer. It is a problem of grain only, and no cereal products. Larvae feed on flour, grain dust, or broken whole grain.

Drugstore Beetle (Stegobium paniceum)

Cigarette Beetle (Lasioderma serricorne)

Small, squat, reddish brown adults, usually less than 1/8 inch long. Head on adult bent down and not visible from above. Feeds on almost all dried plant and animal material including tobacco; spices such as red pepper, cayenne



pepper, ginger, and paprika; drugs; grain, dried raisins; and cereal products. Can penetrate most paper packaging materials.

Cigarette beetle can fly - drugstore beetle seldom flies.

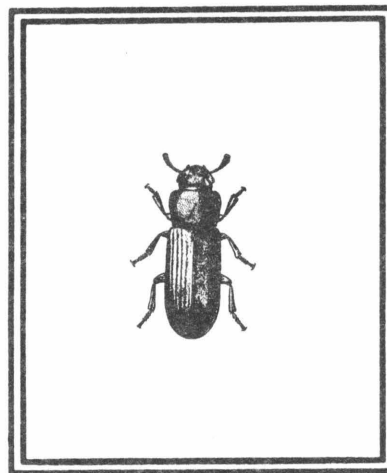
Confused Flour Beetle (Tribolium confusum)

Red Flour Beetle (T. castaneum)

Elongated, flat, shiny, reddish brown adults about 1/8 inch long.

A serious pest of flour mills - feed on cereal grains and dried foods including flour, cereal, nuts, spices, and many others. Do not penetrate sound grain nor most packaging. Feeds by scraping the surface of foods or eating finely ground material.

Red flour beetle is strong flyer, the confused flour beetle cannot fly.



Minute Brown Scavenger Beetles (Lathridiid species)

Adults 1/16 inch long, brown oval in outline. Antennae have terminal clubs. Thorax longer than wide, sometimes with small projections.

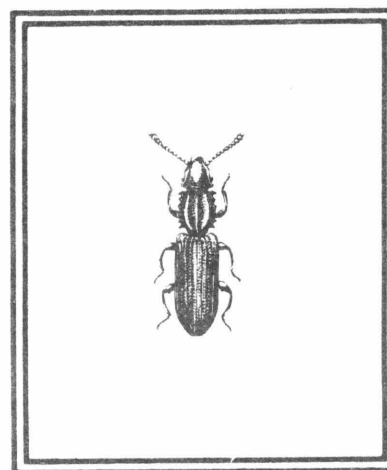
Attracted to grain, starch, or paper products upon which mold is growing; seldom found in dry places. A common pest on malting floors and in areas where grain may ferment, but not known to feed directly upon grain. Even though beetles may occur in numbers, they are frequently overlooked because of their small size.

Sawtoothed Grain Beetle (Oryzophilus surinamensis)

Merchant Grain Beetle (O. mercator)

Adults 1/8 inch long, elongate, dark brown, and flat. Adult has sawtoothed-like projections on side of thorax. Do not fly.

Most common insect pest of stored products, feeding on almost all dried foods. It is unable to attack sound grain, does not penetrate packaged

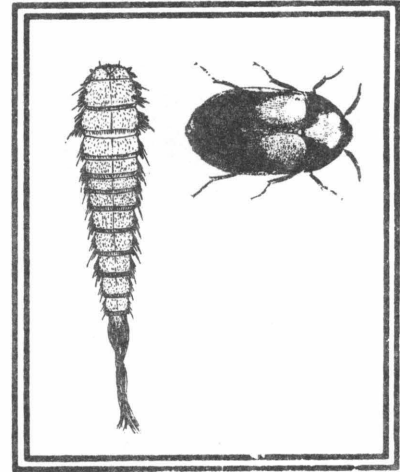


flour other than thin wrapping such as cellophane. There may be six to seven generations per year.

Larder Beetle (Dermestes lardarius)

Adults 1/4 inch long, elongate, oval in shape. Dark brown with broad, whitish band across front third of wing covers, band speckled with darker spots. Antennae clubbed.

Larvae is a very hairy brown insect which feeds upon various animal related products such as smoked meats and bacon. Frequently, found in large numbers associated with masses of dead insects which have collected at windows or ventilators in secluded areas of buildings. Four or more generations per year.

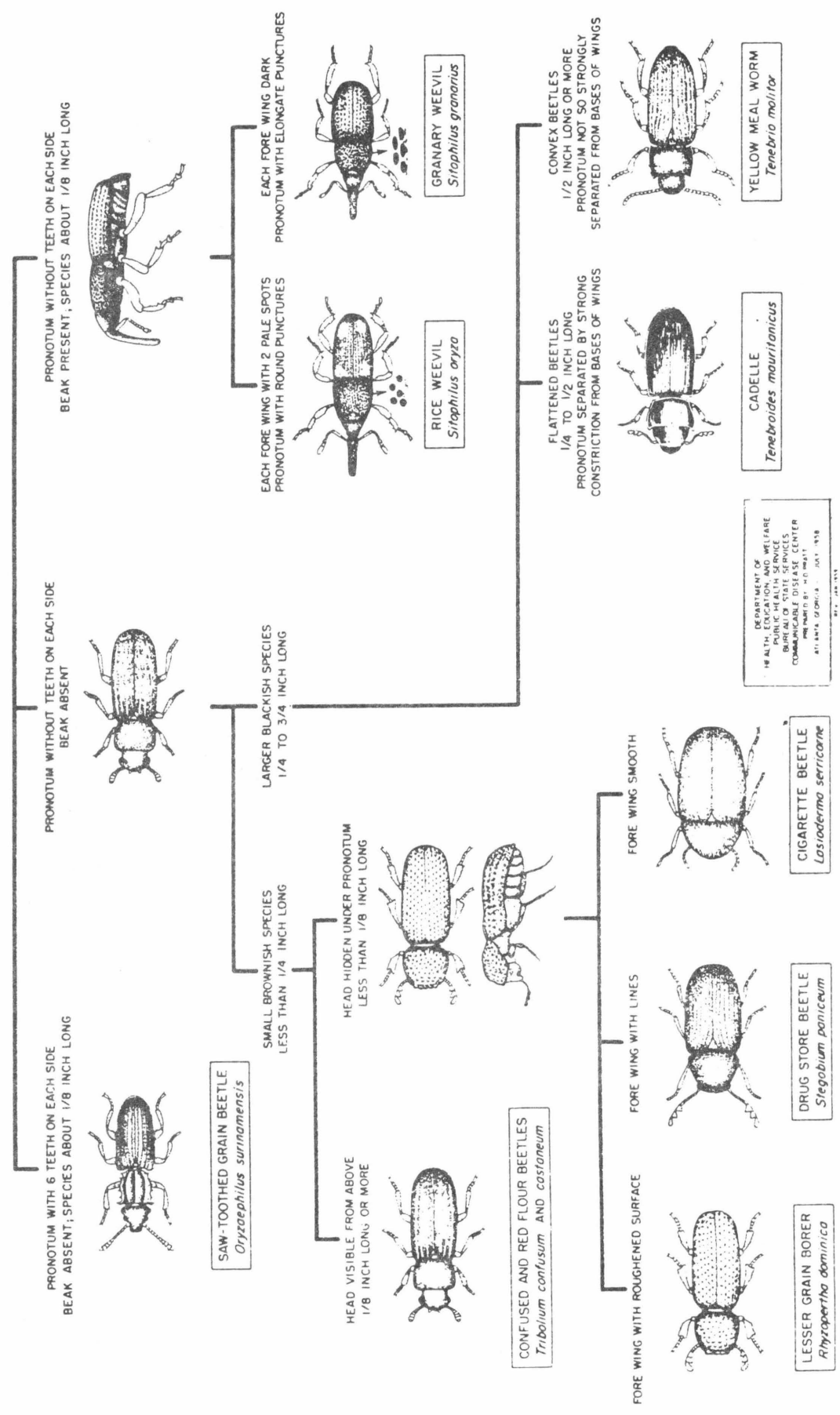


Other Dermestid Beetles (Trogoderma species)

Several different species of oval shaped beetle, including the black carpet beetle and the Khapra beetle. Distinguishing characteristics between species are difficult to find. An expert is needed to tell the differences.

Larvae are tapered with head at large end. Prominent bristles or hair often found at pointed end of larva. They feed in waste grain, grain dust, flour, powdered milk, candy, dehydrated soup, cigarettes, woolen products, furs, feathers, and hair. Infestations are common in old boxes of clothing, overstuffed furniture, woolen carpets, and piano felt. When these insects are present, their cast larval skins can usually be found in or nearby the commodity. Often, the presence of adults in an area may be the first sign of an infestation.

# PICTORIAL KEY TO SOME COMMON BEETLES AND WEEVILS ASSOCIATED WITH STORED FOODS



To eliminate infestations of grain and flour beetles, find and destroy infested products and treat the area where they are stored. Infested materials should be fumigated. Thorough cleaning is essential to prevent reinfestation.

Control of dermestids in food products should be the same as for other food infesting beetles. In fabrics, prevention, by cleaning fabrics correctly and storing them in tight containers with moth crystals, is an important part of control.

### Pests of Wooden Structures (Buildings, furniture, etc.)

One type of structural pest may do extensive damage to wood and wood products by making tunnels, cavities, galleries or emergence holes for nesting, breeding, and shelter. An example is the carpenter ant. The other type of wood-dwelling pest not only uses the wood as shelter, but also as a source of food. Termites are typical of this group.

Insects such as carpenter ants, carpenter bees, and subterranean termites cannot live entirely within their wooden galleries, but must leave them periodically for food, water, or other vital functions. This makes them vulnerable to residual insecticides, baits, or tracking powders and these are the treatments usually applied rather than fumigation. If they are exposed to fumigants at the site, for instance in a food processing plant or office building, they will be killed, but the infestation will not be controlled.

Those structural pests whose life cycles take place in part or entirely within the wooden galleries are not as vulnerable to outside chemical treatment and often fumigation is the only or most logical approach. Fumigation can be done either in vaults or under tarps for movable objects, or as whole-structure fumigation where the infestation is within the wood of the structure itself. Dry wood termites, powderpost beetles, and old house borers are this type of insect.

#### Dry Wood Termite (Kalotermes approximatus)

Dry wood termites are found occurring naturally in a narrow strip from Cape Henry, Virginia along the Atlantic Coast south to Florida, along the



Gulf of Mexico, and from Mexico to Northern California on the Pacific Coast. They are occasionally found in the Northeast in furniture and other moveable objects, usually the result of pieces being moved from areas of natural occurrence into new areas.

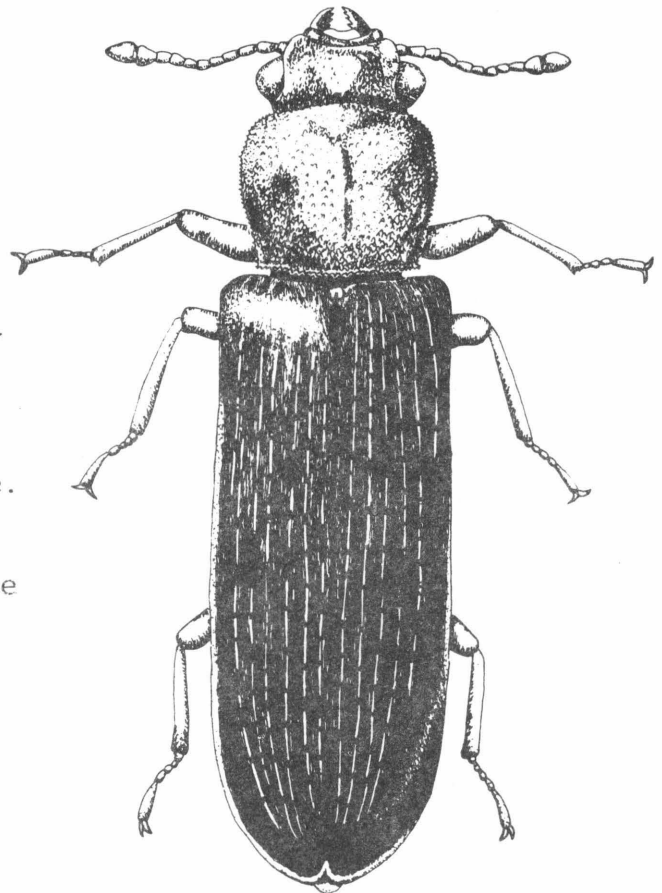
Dry wood termites have a caste system similar to subterranean species. Unlike subterranean and damp wood termites, they live and feed on sound, dry seasoned wood. They have no soil connection and need no moisture source. They do not construct earthen tubes.

Control consists of eliminating the colony. In the Northeast, this can be accomplished by treating the infested furniture or wood through vault fumigation, or by drilling it and injecting chemicals into the galleries. Fumigation of the whole structure may be the only practical and effective method in areas of natural occurrence.

#### Powder-Post Beetles (*Lyctus* spp.)

The larvae of these beetles feed in seasoned wood, leaving in their tunnels the undigested wood particles in the form of a very fine wood dust or powder, hence the name "powder-post". The adult beetles range from 1/12 to 1/5 inch in length, but since they are rarely seen, their recognition is not important. Rather, it is important to be able to recognize the damage done by their larvae.

The evidence most commonly seen by the pest control operator is the emergence holes in the wood surfaces made by the emerging beetles. These holes range in size, depending upon the powder-post beetle species, from 1/16 to 1/4 inch in diameter. If only a single generation of larvae has fed within the wood, it is usually still structurally sound,



but the feeding of generation after generation can reduce the interior of the wood to chiefly a mass of powder.

An important fact to keep in mind regarding powder-post beetles is simply that before the female will attach her eggs to a piece of wood, she first actually tastes the wood to be sure it contains enough starch and sugar to nourish her offspring. If she is prevented from doing this by a wood coating of any kind (paint, varnish, whitewash, etc.), she will not deposit her eggs and thus the wood, if protected on all surfaces, is not attacked by powder-post beetles.

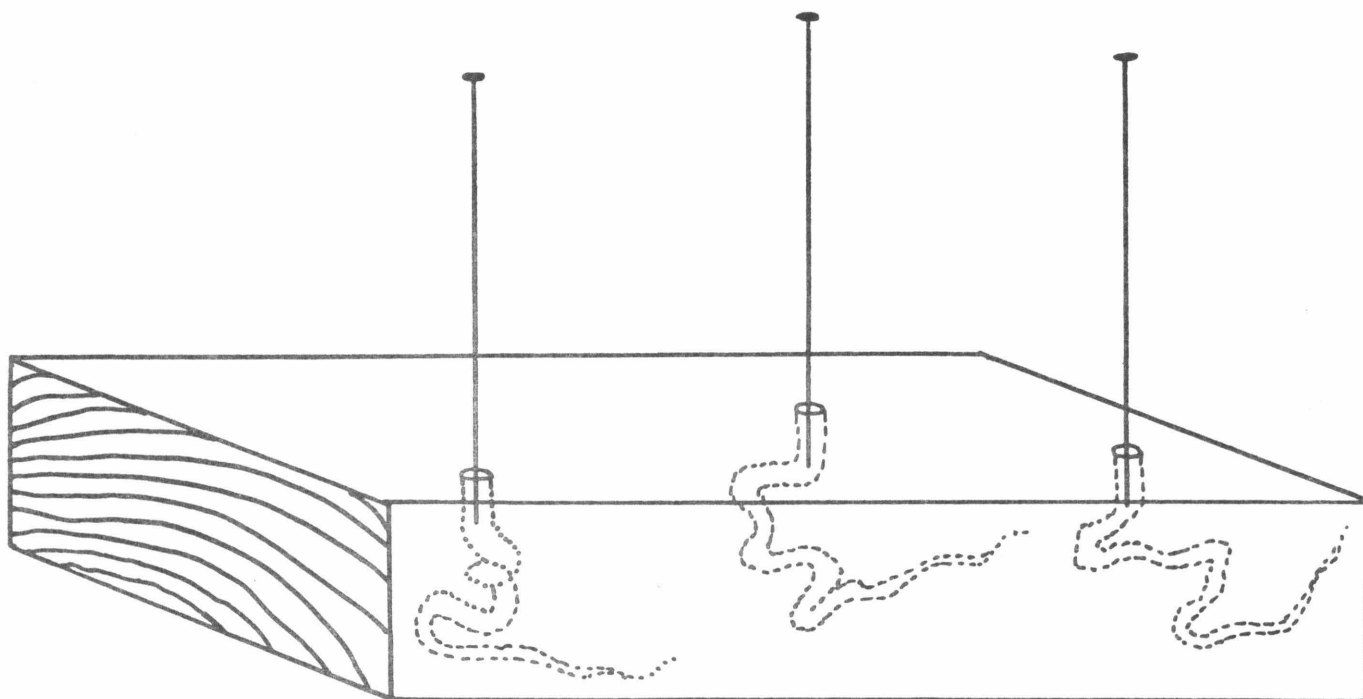
The chief kinds of powder-post beetle problems encountered by the pest control operator are discussed below.

#### Problems in Hardwood Flooring

Floors of recently constructed buildings sometimes show infestations appearing as emergence holes, usually restricted to a few boards in an entire room. If such powder-post beetle emergence holes are probed with a pin or a needle, the hole will be found to be shallow and at right angles to the wood surface. The usual cause of this kind of powder-post beetle infestation was the inadvertent use of one or two pieces of infested flooring lumber when the floor was laid. Probably the wood received its infestation in the warehouse through being held in storage too long, but if no emergence from the flooring lumber has yet taken place, there was no way of knowing that a particular piece was infested. Prevention is a matter of better warehouse management.

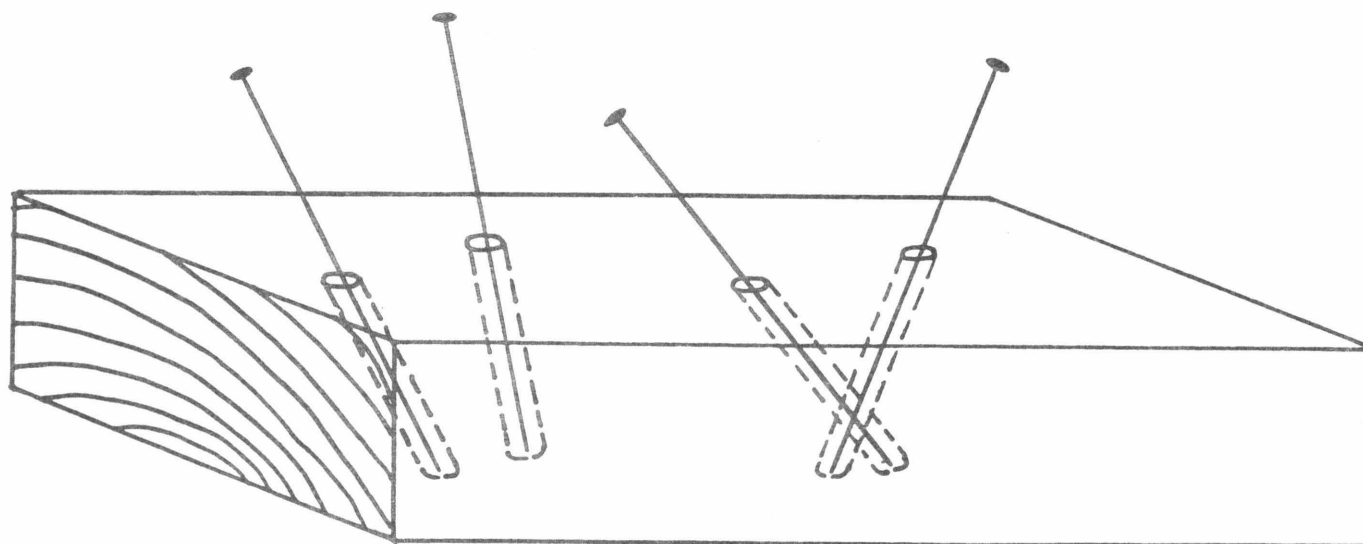
Fortunately, only the single generation of powder-post beetles will emerge as the presence of floor fillers, varnishes, and waxes prevent further deposition of eggs. No pesticide treatment is needed nor is there need to fear that emerged beetles will attack the structural members of the building. This is so because the beetle species which feed in such hardwoods as oak or maple do not attack such coniferous wood as spruce or fir. However, very old hardwood furniture on which the finish has become weak or perhaps been stripped, can be attacked.

A group of beetles commonly called pinhole worms and ambrosia beetles sometimes construct larval tunnels clear of frass in hardwoods of dying or



Powder-post Beetle Emergence Holes In Wood

NOTE: pins perpendicular to wood surface and shallow penetration



Wood With Borings of Pinhole Worms and Ambrosia Beetles

NOTE: Oblique angles of pins inserted in burrows and generally deep penetration of pins.

recently felled trees. When such trees are cut into lumber, as for hardwood flooring, the plane of the sawcut expose these tunnels at the surface as a variety of small holes closely resembling the emergence holes of powder-post beetles. A limited number of such holes is permitted by grading rules in some classes of hardwood flooring. However, when such a floor is sanded and finished, the sander is likely to cause such holes to become packed with its wood dust. The sealer and finishes which are then applied "seal in" the wood dust, making the hole completely invisible to ordinary inspection. Only years later, after the sealing materials have broken off, does the hole "suddenly appear" with wood dust coming from it. Often, this is interpreted as evidence of activity, but there are no insects.

To distinguish this condition from powder-post beetle damage, probe the holes with a pin or a needle. If the holes were caused by pinhole worms or by ambrosia beetles, the pins will enter much more deeply and at a variety of angles to the floor surface. No insects are present, and no pesticide treatment is necessary.

#### Problems in Very Old Buildings

Pest control operators are sometimes called to treat supposed infestations of powder-post beetles in the structural members (sills, joists, girders, etc.) of old houses. Here, the presence of an abundance of emergence holes from which wood dust is falling is being interpreted as evidence of an active infestation. In almost every case, the supply of starch-and-sugar-containing sapwood was exhausted by the beetle, and the infestation has died off more than a century ago. Only the heartwood, devoid of starch and sugar, is intact and carrying the weight of the house (as it was intended to to).

To determine whether there actually is an active infestation, examine 100 holes at random. Look for any that are "fresh" or "clean", like a fresh sawcut, not darkened or discolored from long exposure to the air. If there is an active infestation, the prevention of reinfestation by coating the wood with a non-toxic, permanent surfacing material is the best approach.

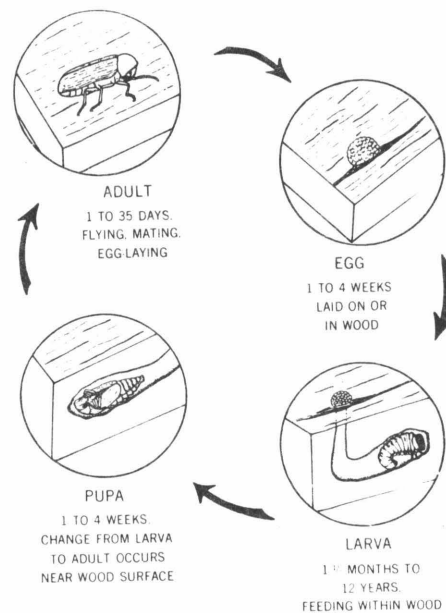
## Problems in Furniture and Other Manufactured Articles

It is sometimes important to prevent the emergence of powder-post beetles to avoid the disfiguring holes in valued articles. If the item is small enough, or if it can be easily **disassembled**, confinement in a freezer with temperatures near 0°F is often the surest way of destroying the pests. Articles of tropical origin can be rid of the insects within a few days by this method, but our native species of powder-post beetle are remarkably cold hardy and require longer periods of exposure to these temperatures. No chemical treatment other than vault fumigation is likely to penetrate in lethal quantities to prevent emergence.

### Old House Borer (*Hylotrupes bajulus*)

The common name of this insect can be completely misleading. It is as likely to attack suitable timbers in recently constructed houses as it is old ones and is mainly a pest of newer structures. The old house borer requires the seasoned, wide-grain wood of such softwoods as pine, spruce, and fir, available in a wood surface to which no paint or other permanent finish has been applied.

The adult beetles range in size from 1/2 to 1 inch in length, but, like the powder-post beetle, are rarely seen. Like the powder-post beetles, the larvae of this beetle excrete into their tunnels the wood particles or frass from which they have extracted the starch and sugar. Extensive excavation along the grain results, leaving only a very thin "shell" of the original wood surface held in place by a few solid remnants of the wood interior. Sometimes the frass is



so densely packed that it forms a cake. The emergence holes of the adult beetles are often surprisingly few in number, considering the extent of damage, and are slightly oval and 1/4 inch or less in diameter.

An old house borer infestation often continues over several decades or more. The life cycle is usually from 3 to 12 years, but may take much longer under unfavorable conditions. Thus, the conspicuous damage is most likely to occur in attics and other areas only infrequently examined. However, an infested piece of wood is sometimes used in building a new structure, and the emergence holes of the adult beetles may then appear at the surface of such materials as hardwood, plaster, drywall, and other hard and unlikely substances.

### Control

Where a continuous, "ongoing" infestation is found to exist, control is also usually a long-range project. If the affected timbers still have the structural strength to carry the load imposed, the application of permanent, non-toxic surfacing materials, plus the closing of the emergence holes with plug of injectable caulking material, will prevent reinfestation. Annual inspection to close any new holes is necessary. In widespread infestations, spot treatments with residual sprays may not work and it may be necessary to fumigate.

### Deathwatch Beetle (*Xestobium rufovillosum*)

### Furniture Beetle (*Anobium punctatum*)

These beetles are members of the family Anobiidae. Mature adults are brownish in color, about 1/3 inch long, and may be recognized by the roughly diamond shaped thorax when viewed from above.

The Anobiids infest all types of seasoned wood, including building timbers, framing lumber, furniture, and woodwork. Poor ventilation and high humidity favor reinfestation.

The larvae are slightly curved and wrinkled, have 3 pairs of short legs and are covered with fine hairs. The deathwatch beetle gets its name from the ticking sounds the adult makes that can be heard at night when the house is quiet.

## GENERAL REFERENCES

- Cotton, Richard T. 1963. Stored Grain and Grain Product Pests. Burgess Publishing Co., Minneapolis, Minn. 318 pp.
- Mallis, A. 1969. Handbook of Pest Control (Fifth Edition). McNair Dorland Co., New York. 1158 pp.
- Morgan, Donald P. 1976. Recognition and Management of Pesticide Poisonings. Environmental Protection Agency (WH-569). Office of Pesticide Programs. EPA-540/9-011. Washington, D. C. 20460. 56 pp.
- Monroe, H.A.U. 1969. Manual of Fumigation for Insect Control (Second Edition). FAO No. 79 UNIPUB, Inc., 650 First Avenue, P. O. Box 433. New York, NY, 10016.
- Truman, Lee C., Bennett, Gary W., and William L. Butts. 1976. Scientific Guide to Pest Control Operations (Third Edition). Pest Control Magazine, Cleveland, Ohio, 44102. 276 pp.
- Wilbur, Donald A., Mills, Robert B., and John R. Pederson. Manual of Grain and Cereal Products - Insects and Their Control. Department of Entomology, Kansas State University, Manhattan, Kansas.

\*\*\*\*\*

## SOME PERIODICALS

- California Vector News. Vector Control Section, California Department of Health, Berkeley, CA, 94704. Monthly. Free.
- Federal Register, Superintendent of Documents. Government Printing Office, Washington, D. C., 20402. Daily. \$50/yr.
- Pest Control Letter. P. O. Box 383-T, San Bruno, California, 94066. Weekly. \$45/yr.
- Pest Control Magazine, 9800 Detroit Avenue, Cleveland, Ohio, 44102. Monthly. \$8/yr.
- Pest Control Technology, Somick Publishing, Inc., P. O. Box 12356, Cincinnati, Ohio, 45212. Monthly. Free.
- Pesticide and Toxic Chemical News, Food Chemical News, Inc., 420 Colorado Bldg., 1341 G. St., N.W., Washington, D. C., 20005. Weekly. \$160/yr.

