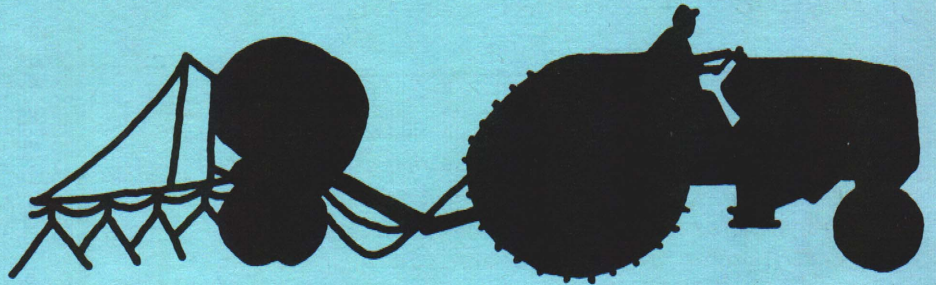
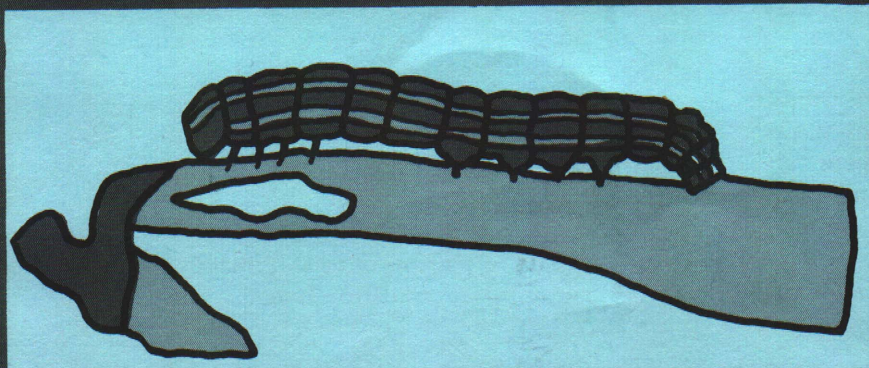
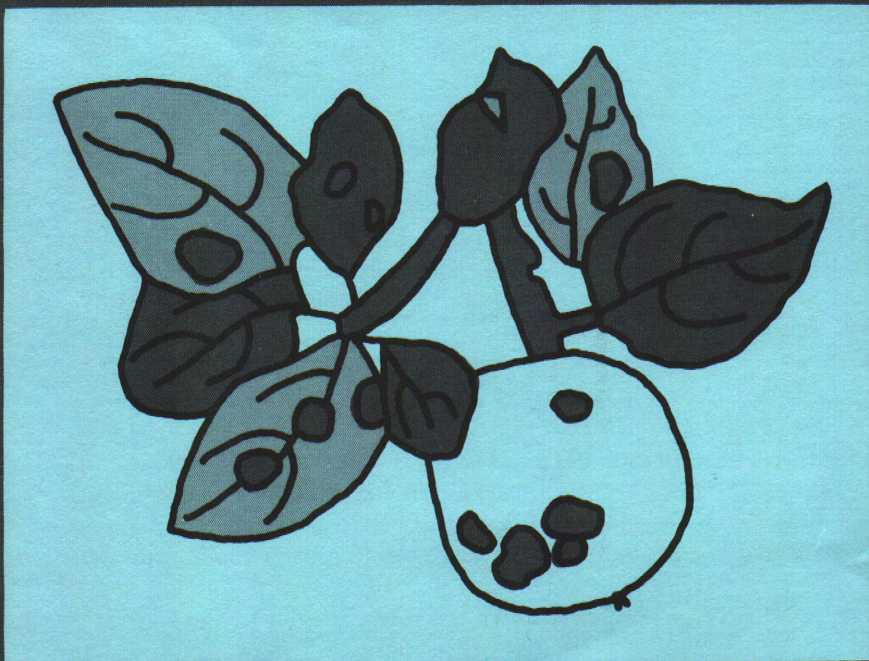


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SAFE, EFFECTIVE USE OF PESTICIDES

A MANUAL FOR PRIVATE APPLICATORS



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PREFACE

This manual is intended to assist private applicators (farmers), who may use or supervise the use of fumigants for the control of grain pests, prepare for certification under the Michigan Pesticide Control Act of 1976. The manual was prepared by Dr. Robert F. Ruppel of the Department of Entomology of Michigan State University with assistance from staff members of the Michigan Department of Agriculture.

A list of self-help questions and instructions for completing the questions are at the end of the manual. If you encounter difficulties in using the manual, please consult your County Agricultural Extension Agent or representative of the Michigan Department of Agriculture for assistance.

Some suggestions for studying the manual are:

- 1. Find a place and time for study where you will not be disturbed.*
- 2. Read the entire manual through once to understand the scope and form of presentation of the material.*
- 3. Then study the manual carefully. You may want to underline important points in the manual as you study each section.*
- 4. Answer, in writing, the self-help questions at the end of the manual. These questions are intended to aid you in your study and to help you evaluate your knowledge of the subject. As such, they are an important part of your study.*

SECTION I: Insects in Stored Grains

Importance

Grain prices are based on clean, dry, wholesome grain. Anything that lowers the quality of the grain also lowers its price. Insects and their damage can cause reduction in grain quality, or even make the grain unsalable. The insects or their parts, droppings or webbing, and the broken grains, odors, and even heat and moisture that they cause in grain all contribute to the loss.

Identification of Stored Grain Insects

There are many species of insects that can damage stored grain. Farmers' Bulletin 1260, "Stored Grain Pests," available from the U.S. Department of Agriculture, is an excellent reference for identification of stored grain insects. Your County Extension Agricultural Agent also can help you identify the insects that you find in stored grains.

Controlling Insects in Stored Grain

- Keep grain clean and dry.
- Use good sanitation.
- Make regular inspections.
- Prevent insect infestations.
- Control established insect infestations.

Clean dry grain: The first defense against insects is to keep the grain clean and dry. New grain should be dried and thoroughly cleaned before it goes into storage. Only a few insects, such as the Angoumois grain moth and bean weevil, can increase in clean, dry, whole grain.

Sanitation: Nearly all insect infestations in stored grain can be traced to old grain, sacks of old seed, spills, and trash within the storage area itself. Many insects species can build up in grain containing broken grains and flour. Isolating old grain stock, and a thorough cleanup of the bin, area, and equipment before bringing new grain in for storage will greatly reduce the threat of insect problems.

Information on sanitation for stored grain areas is given in Michigan State University Extension Bulletin E-934, "Controlling Insects in Stored Grain," available from your County Extension Agricultural Agent.

Regular Inspections: As noted, the new grain should be dried and thoroughly cleaned before it goes into storage. The stored grain should be inspected regularly for temperature, moisture, off-odors, mold, and for insects and their damage during storage. A special problem has been inadequate ventilation of grains in farm storage. This results in condensation of water at the surface of the bin and permits infestation of many insects. Once started, the heat and moisture generated by the insects and accompanying molds can allow the insects to penetrate deeply into the grain. A great number of species (even cockroaches and book lice) can reproduce in moist grains.

Information on proper management and ventilation of grains is given in Extension Bulletin E-799, "Drying and Storing Shelled Corn," available from your County Extension Agricultural Agent. Good management is essential to grain protection. There is no way of preventing insect damage to grains that are going out of condition because of moisture or dockage.

Preventing infestation: The stored grain insects are found everywhere. Some of them can fly and are capable of starting their infestation in the field; however, field infestation is rare in Michigan. Adding a grain protectant, a small amount of residual insecticide, to the grain as it is put into storage is one method of protecting the grain. Grain protectants kill insects that contact them. They will not kill insects within the grains nor are they effective against established infestations of stored grain pests. They should be *applied* before the grain is infested. The use of grain protectants is discussed in the bulletin "Controlling Insects in Stored Grain." Excess residues of the pesticides used to control the pests can also make the grain unfit for sale. We must protect our grains, but we must be careful in how it is done.

Established infestations: Fumigants are used to control established infestations of stored grain pests. Fumigants have an advantage over grain protectants because: (a) the fumigant kills the insect within the grain and not after it emerges; and (b) fumigants can stop established infestations of insects. Fumigants are toxic penetrating gases. They can be hazardous if not used with full precautions. Some points of the safe, effective use of fumigants in stored grain are presented in this manual.

SECTION II: Fumigants

Mode of Action

Fumigants are effective as toxic gases. The gases can penetrate into the grain mass and into the grains themselves to kill insects within the grains, as well as on the surface of the grains. We sometimes think of smokes, mists, or aerosols of pesticides as fumigants. They are actually fine solids or liquids that stay on the surface and do not penetrate through an object as does a true fumigant. This ability to pass through a grain and other things is a special advantage of a fumigant. This same ability makes fumigants a special hazard as they can escape from a bin readily and expose the surroundings to the toxic gas. They are effective, but they must be carefully used.

Classes

There are several classes of chemicals used as grain fumigants. The characteristics of the more common fumigants are shown in Table 1. They all share the common ability to penetrate and kill insects in grains. They differ in their abilities to penetrate and to kill different species and stages of insects, however. They also differ in their hazards and their effects on different types of grains.

Formulations

Fumigants are most frequently sold as mixtures containing two or more compounds. This is done to reduce the hazard or to increase the range of effectiveness of a single fumigant. There are several types of formulations.

TABLE 1. Some Common Grain Fumigants.

Fumigant	Some Trade Names	Common Uses
Acrylonitrile	VCN	Spot fumigation; marketed in mixture with carbon tetrachloride
Carbon disulphide	20/80	General grain fumigant; marketed in mixture with carbon tetrachloride
Carbon tetrachloride	—	weak fumigant; used to reduce fire hazard
Chloropicrin	Larvacide, Picfume	Grains; safe with seeds; highly irritating
Ethylene dibromide	Bromofume, EDB	General fumigant
Ethylene dichloride	Dowfume 75, EDC	Grains and seeds; usually marketed in mixture with carbon tetrachloride
Ethylene oxide	Oxirane, ETO	Grains; damages seeds
Hydrocyanic acid	HCN	Grains and seeds
Methyl bromide	Metho-O-Gas	General fumigant; low-moisture seeds
Phosphine	Phostoxin	Grains
1, 1, 1-trichloroethane	Chlorothene	Grains; used to reduce fire hazard

1. Compressed gases — gases under pressure that move out as soon as they are released. The compressed gases are applied through piping after the bin has been filled.
2. Liquids (also called "pour-ons") — liquids that form gases when they are poured or sprayed on the grain. The liquids are applied by spraying them on the grain surface after the bin has been filled.
3. Solids — granules, wafers, or packages of solid materials that release gases when mixed with the grain. The solid fumigants are added to the grain by hand or by special equipment as the grain is moving into the bins.

Characteristics

The characteristics of each fumigant, the mixture of the fumigants, and the type of formulation all influence the safety and effectiveness of the commercial fumigants. You should choose the specific

fumigant that is most suitable for your exact use. Information on the different fumigants is available in manufacturers' brochures and technical sheets that are available from your fumigation dealer. Instructions on the use of the specific fumigant are given on the label of the product. You should read the manufacturer's literature and *READ THE LABEL* on the container before you buy the product to be sure that the fumigant is the best one for your intended use and also that you can handle it safely.

A SPECIAL WARNING

Grain fumigants are intended for use only in the whole grains specified on their label. Do NOT use them in grains other than those given on the label. Do NOT use them for seeds except as directed on the label for their use in seeds. Do NOT use them in grains that contain high moisture or dockage. Do NOT use them in milled or processed food or feed.

SECTION III: Factors Affecting Fumigation

Temperature

Fumigants are effective as gases. The effectiveness, therefore, is controlled by the physical laws affecting the movement of gases. Temperature is extremely important as it controls the speed of penetration and release of the fumigant into and out of the grains. Low grain temperatures (generally less than 50°F.) slow down the movement of the gas and can result in inadequate control of the insects. Higher dosages, longer fumigation times, and prolonged aerating may be needed when temperatures are moderately low (usually less than 60°F.). The adjustment for grain temperature is given on the label of the fumigant that is used.

Moisture

High moisture and dockage in the grain also retard the movement of the fumigant. The gas is simply absorbed and held by moist or finely divided pieces of grain. Trying to fumigate moist seed is especially bad as fumigants that are safe in properly dried seed can ruin the germination of moist seed. Moist or high dockage grain should be cleaned and dried before fumigation is attempted.

Bin Construction

The type of construction of the bin is also of importance in the safe, effective use of fumigants. A concentration of a fumigant must be held in the

grain long enough to assure kill of insects. This means that the bin must be as tight as possible. Tightly sealed steel or concrete structures are required for some fumigants. Carefully caulked wooden bins can be used, with precautions, with some other fumigants. Covers of polyethylene or plastic-coated nylon can be used (once again, with precautions) to assure effective fumigation in loosely constructed buildings. The covers can also be used over even tightly sealed grain bins to reduce the loss of the fumigant at the top, especially on windy days.

Depth of Grains

The shape and the depth of grain in the bin also affect the fumigant. Tall, narrow elevators or bins are best as they present a minimum of open surface at the top for the loss of the gas. A cover should be used whenever possible over grain in a wide bin. The fumigants can only penetrate for a limited depth into a grain mass. This depth should not be exceeded unless provision is made for the greater depth of grain.

Ventilation

The fumigants are heavier than air and sink through the grain. Grains in the cone at the top of the mass can, therefore, escape fumigation. Grain should be leveled before it is fumigated. Penetration of the entire grain mass, especially in deep bins, can be assured by recirculating the fumigant in the grain. This can be done by sealing the top of the bin (with a cover if needed) and using the ventilator to pull air and fumigant from the bottom and deliver it to the top of the grain. (See Fig. 1). Recirculation can reduce the amount of fumigant needed and can be a savings where grains are to be routinely fumigated. A good system of ventilation is also required to aerate the grains after fumigation. Provision for ventilation should be made wherever fumigants are to be used.

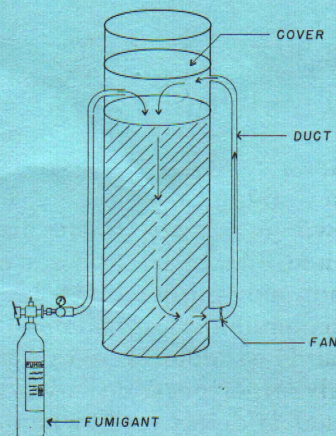


FIG. 1

Instructions on the practicality of use and the adjustments in dosage needed for different types of bins, depths of grain, and use of recirculation are given on the label of the fumigant. Read these instructions and precautions carefully. A mistake could lead to a hazard or to an unsatisfactory control of the insects.

SECTION IV: Safety with Fumigants

Reading the Label

Fumigants are toxic gases. They are dangerous to man as well as insects when inhaled. The fumigant can also be toxic when swallowed or absorbed through the skin, and some of them are irritating and cause burning of the eyes and skin. The label on the container notes how the fumigant can be dangerous, gives symptoms of poisoning and first aid instructions, and also has instructions for use by a physician in case of poisoning. These should be read and understood before *buying* the product. The labeled container should be taken to the doctor along with a suspected victim of poisoning so that the doctor will know what fumigant was used and will have the instructions on treatment that are given on that label. **READ THE LABEL.**

Protective Equipment

Instructions on the safety equipment and special precautions needed to prevent accidents are given on the label. The safety equipment should be available from your fumigant dealer. Be sure that you get the exact type of equipment and use it in full accord with the instructions. *A special note:* Full face gas masks are intended for brief exposure to low concentrations of gas. They are not safe for prolonged use or in heavy concentrations of gas. Get out of high concentrations and stay out until they have dissipated.

Warning Agents

Fumigants have distinctive odors. Unfortunately, the odor cannot be relied on to detect the gas. Chloropicrin, or tear gas, is mixed with some fumigants as a warning gas as low concentrations of chloropicrin will cause eye or skin irritation that are easier to detect than an odor. Even chloropicrin is not foolproof and it in itself can be a hazard at moderate concentrations.

A simple halide gas detector — or a thermal conductivity analyzer, if possible — should be obtained and used to detect leaks where fumigation is a common practice. This equipment and instruc-

tions on its use can be obtained from your fumigant dealer. The safest way of avoiding accidents, however, is to: (a) follow the instructions exactly; (b) limit your exposure to a minimum; and (c) stay away from the fumigated grain until it is definitely safe to handle.

Flammability

Some fumigants are fire or explosion hazards under some conditions. These too, are spelled out on the label along with precautions to reduce these hazards. The fumigants may also be corrosive to some materials or damage or leave bad odors in other materials. These, too, are given on the label and the fumigants should not be used where they can contact such materials.

Storage of the volatile fumigants is a special hazard. This hazard can be reduced by buying the fumigant just before it is needed and, thus, keeping it around for a minimum time. The fumigant should be stored on sturdy shelving in an area away from people, livestock, seed, or feed. The storage should be locked and posted to warn others away. Fumigants can leak from faulty valves or damaged containers. Ventilation should be provided for the storage area and used for some time to clear the air of fumes before you enter.

Worker Safety

As a safety measure two people should always work together when fumigating. They should keep each other always in sight and be prepared to help each other out of the area if necessary. The fumigant should be handled and applied exactly as directed on the label. Time of exposure to the fumigant can be minimized by setting up, adjusting, and checking everything thoroughly before opening the fumigant container. Remove all obstacles to a clear, fast exit from the area before starting. Work your way up wind or toward the exit if several lots of grain are to be fumigated at the same time. Compressed gases are a special hazard because of their pressure. A blown line can present a real danger. Be sure that all components used with compressed gases are made to withstand the pressure.

Warning Signs

The fumigated bin should be posted with large warning signs just before fumigation and every possible means of restricting access to the area made. Special warning signs are available from your fumigant dealer or the manufacturer. The area should be checked frequently for stray children, livestock, or pets. The specified period between application and reentry to the area should be followed.

Aeration

Use the proper safety equipment when entering the area to start aeration. Stay only long enough to be sure that aeration will be satisfactory and then get out. Do not reenter the area until aeration is complete. Allow plenty of time. Improper aerations could leave a hazardous, or at least excessive, residue in the grain. Be sure to remove the warning sign after it is safe to enter the area. Do not leave the signs up or people will get used to seeing them and will not believe that a danger really exists.

SECTION V: Applying Fumigants

Following the Label Instructions

The fumigant, formulation dosage, and equipment used for grain fumigation are varied to fit special situations. You should read and follow the instructions for your intended use given on the label of the container or in the technical sheets from the manufacturer. Be especially sure to make the adjustments for dosage required for temperature, bin shape, and the like that are noted above. Once again, these will be given on the label of the container. Some general procedures for different types of grain fumigation are given in this section.

Fumigation Under Covers

Bagged grains can be fumigated in a bin or silo just like bulk grain. Bagged grains or bulk grain can also be fumigated under a tight cover of polyethylene or special plastic-coated nylon if necessary. The fumigation should be done in a well-ventilated area where there is no traffic. The grain should be placed on a smooth cement floor or placed on a piece of covering. Leave a margin of about 4 feet of cover around the pile if a floor cover is used. The tubing for the application of the fumigant should then be put in place. Cover supports of old boxes or cans or anything else that will

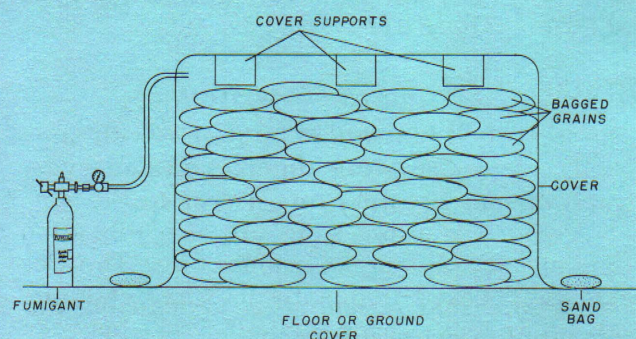


FIG. 2

not cut the cover should be placed on top of the pile to allow some air space at the top. (See Fig. 2).

The material used as the covering should be checked and any holes or worn spots sealed with tape. The cover should be placed over the pile with margins of cover about 4 feet wide around all sides. The margins of cover should be sealed to the floor or the floor covering using sand, dirt, or "sand snakes" (lengths of plastic tubing filled with sand or water). The equipment should be thoroughly checked, full ventilation of the area assured, the proper amount of fumigant applied, and warning signs posted.

The cover should be left in place for the period required for effective fumigation. The cover can then be removed. Make sure that the area is well ventilated before you go into it. Use the specified safety equipment and even then remove the cover and get out again as quickly as possible. Keep the area well ventilated to provide the required aeration of the grain. Do not move the grain until it has been well aerated and is clear of fumigant. The covers can be reused if they are kept clean, dry, and free of holes.

Using Solid Fumigants

Solid fumigants are sold as discs, wafers, or paper packages. The gas released from them penetrates the grain rapidly and they are most commonly used in tightly sealed bins. They are added to the grain as long as the grain is being placed in the bin. This is usually done from the top of the elevator where the fumigant will drop in and be mixed with the grain. The fumigants are simply dropped in by hand or are metered into the grain using special equipment.

Using Liquid Fumigants

Liquid fumigants are poured or pumped on the surface of the grain after it has been put into the bin. The liquids usually penetrate slowly and are mostly used in the more loosely constructed bins. They should be pumped as a solid stream or as very coarse droplets. Do not apply them as fine sprays that could drift out of the bin. They should be pumped from the outside of the bin whenever possible. If they are poured on the surface, one person with safety equipment should do so quickly while someone else stands by where the operator can be seen at all times. Sealing, posting, and aerating with liquids are done as with all other fumigants.

Using Compressed Gases

Compressed gases, as noted, require special equipment that can withstand their pressure. They

require special valves and pressure regulators for their use. This equipment must be carefully adjusted and maintained. The compressed gases can be applied completely from outside of the bin, which is a safety feature. They penetrate rapidly and are best, and safest, when used in tightly sealed bins. Be sure that all seals are tight before opening the fumigant container. Special care should be taken to assure full ventilation around the fumigated area when the compressed gases are used within buildings. A halide gas detector is recommended to locate leaks when gases are used indoors.

Spot Fumigation

Fumigants are used to clean bins and equipment of insects before new grain is brought in. These spot fumigants are especially useful in clearing hard to reach, enclosed places (like elevator boots) of the pests. They are *NOT* intended for use in fumigating whole buildings—only small, enclosed areas.

The area to be fumigated should be checked for likely places for spilled grain and insects. Easy access to the areas should be provided so that the fumigation can be made quickly. The amount of fumigant to be used in each area should be determined in advance. The time for fumigation should be when traffic can be eliminated—perhaps over a weekend.

The building area in which the fumigation is to be made should be sealed as tightly as possible. The spot fumigant should then be applied following the label instructions on safety equipment and dosage. Start at the point furthest from the exit and work toward the exit. Access to the fumigant area should be barred and warning signs posted. The building should be ventilated, from the outside if possible, and allowed to aerate for the required period. The fumigants can kill rats, mice, and birds. You should check and remove their bodies before resuming operations.

SECTION VI: Factors Affecting the Action of Fumigants on Pests

Temperature

The most important environmental factor influencing the action of fumigants on insects is temperature. In the range of normal fumigating temperatures from 10°C. to 35°C. (50°F. to 95°F.), the concentration of the fumigant required to kill a given stage of an insect species decreases with the rise in temperature. From the purely biological standpoint this is mainly due to the increased rate of metabolism of the insects' response to the rise in temperature. Also, physical absorption of the fumigant by the material containing the insects is reduced and proportionately more fumigant is available to attack the insects.

Life Stages

The state of development and activity of the target pest is important. Active adults normally are easier to kill than inactive or hibernating adults. Immature stages of insects generally do require higher dosages or longer exposure for complete mortality than do active adults.

Type of Material

Insect activity when observed shortly after exposure to slow-killing fumigants, such as methyl bromide and ethylene dibromide, may be disappointing to inexperienced persons. The effect on insects that have been exposed to lethal dosages of these gases is accumulative and regardless of how long it takes to kill them they never recover. It should be noted that some fumigants, such as carbon disulphide and cyanide, at sublethal concentrations may anesthetize insects so that they appear to be dead shortly after fumigation only to revive and continue a normal life.

Self-Help Questions on Grain Fumigation

Now that you have studied the section, answer these questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them in the text. Erase your answer and write in the correct answer if your first answer is wrong.

- 1. Can most insects increase in clean, dry, whole grain?*
- 2. How important is sanitation in reducing the threat of insect problems?*

3. *What are some things that stored grain should be inspected for frequently?*
4. *How do grain protectants kill insects?*
5. *What advantage do fumigants have over grain protectants?*
6. *Are aerosols fumigants?*
7. *Why are fumigants frequently sold as mixtures containing two or more compounds?*
8. *Why should you read the manufacturer's literature and the label on the container before buying a fumigant?*
9. *Why is temperature important when a fumigant is used?*
10. *Can fumigants that are safe in properly dried seed do damage to moist seed?*
11. *How can the loss of fumigant at the top of the bin be reduced?*
12. *How can penetration of the entire grain mass be assured?*
13. *Should the labeled container be taken to the doctor along with a suspected victim of fumigant poisoning?*
14. *Are full face gas masks safe for prolonged use or in heavy concentrations of gas?*
15. *Why is chloropicrin mixed with some fumigants?*
16. *How can hazards of storing fumigants be reduced?*
17. *How can time of exposure to the fumigant be minimized?*
18. *What can happen if warning signs are not removed when it is safe to enter the area?*
19. *Can covers used for fumigating be reused?*
20. *How do solid fumigants work?*
21. *Should liquid fumigants be applied as fine sprays?*
22. *What special equipment do compressed gases require?*
23. *In what type of area are spot fumigants useful?*
24. *How does temperature affect the action of fumigants on insects?*
25. *Why might the immediate after effect of fumigants such as methyl bromide or ethylene dibromide be disappointing to an inexperienced person?*

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