INTRODUCTION

Losses of grain in storage due to insects are the final components of the struggle to limit insect losses in agricultural production. These losses can exceed those incurred while growing the crop. Losses caused by insects include not only the direct consumption of kernels, but also include accumulations of frass, exuviae, webbing, and insect cadavers. High levels of this insect detritus may result in grain that is unfit for human consumption. Insect-induced changes in the storage environment may cause warm, moist ‘hotspots’ that are suitable for the development of storage fungi that cause further losses. Worldwide losses in stored products, caused by insects, have been estimated to be between five and ten percent. Heavier losses occurring in the tropics may reach 30%, and the net value of losses in storage in the United States has been placed at over $200 million annually.

Limiting insect infestation in grain storage must be a primary consideration beginning at the time of harvest. Economically speaking, storage insects and, to a lesser degree, fungi reduce the quality and value of grain, while losses due to rodents and birds are typically quite infrequent and minor. Infestation on-farm may further proliferate to devastating losses throughout the grain storage and marketing ecosystem. It is essential that on-farm storage should limit the infestation of grain from the onset of storage, to ensure the acceptance and marketability of grain in domestic and foreign channels. In Montana, the majority of grain storage is on-farm, a situation that is quite different from other major wheat-producing states.

Cold Montana winters are an asset in the management of stored-product pests, but do not in any way guarantee that the stored product will be pest-free. While greater than thirty species of storage pests can attack grain stored in the northwest of the United States, seldom do more than a few species reach economic levels in Montana. This manual will help the producer storing grain on-farm and the commercial elevator operator become familiar with the available methods for managing these pests in Montana.

While several procedures to manage pests are used at storage facilities before storage, those that minimize pest invasion into storage structures include:

- Cleaning bins, harvest and loading equipment prior to harvest and after bin emptying,
- Applying “empty-bin” insecticides to the inside of the structures,
- Sealing structures,
- Cleaning up grain spills on the grounds,
- Removing weeds close to structures.
Since higher moisture can encourage mold and insect development, additional management techniques also include:
- Storing sufficiently dry wheat (less than 13%),
- Aerating the stored grain with fans to cool the wheat thus slowing insect development,
- Close monitoring of grain temperature and insect populations.

There are limited options for managing insects in the grain itself. Grain protectants are expensive, and thus used infrequently. In Montana, diatomaceous earth (Insecto®) can be used effectively for on-farm storage due to low ambient humidity and the relatively small sizes of bins.

Diatomaceous earth (DE) is the remains of microscopic one-celled plants (diatoms) that lived in the oceans that once covered the western part of the United States and other parts of the world. Huge deposits were left behind when the water receded. The insecticidal quality of DE is due to the razor sharp edges of the diatom remains. As the insects crawl through treated grain and dusted bins, the DE comes in contact with the insects and the sharp edges punctures the insects exoskeleton. The powdery DE then absorbs the body fluids causing death from dehydration.

Biological control agents, such as predatory and parasitic insects, have limited use in stored wheat management. This is mainly due to inadequate availability and restrictions on the presence of all live insects in the wheat when it is sold. Fumigants are a frequently-used type of insecticide for stored grain insects in Montana and include chloropicrin and phosphine. Chloropicrin has limited use in empty bins only. Phosphine is highly effective, remedial, relatively inexpensive, leaves no residual product, and when used correctly, is safe around workers and the environment. However, environmental factors and a revised label make the use of this product more exacting than in the past.

In general, warm grain temperatures at harvest and during storage, combined with grain moisture content of 12-13%, are favorable to growth of insect populations. Insect populations increase during the autumn, peak during late fall or early winter, with reproduction declining through the remainder of winter. The following spring, population growth resumes as the grain warms once again. However, very large bins do not cool down significantly over the winter, because of the thermal inertia of the large grain mass.

Wheat is tested and graded when it is sold. The price received for the grain is dependant upon the standards of the buyer. In the United States, government standards are set by the Grain Inspection, Packers and Stockyard Administration (GIPSA). Grain contaminated with high levels of insect-damaged-kernels (IDK), mycotoxins, pesticides, or commodities contaminated with animal or insect filth or fragments above established tolerances can be condemned.

Grain is assigned a U.S. Grade from No. 1 to 5. The premium grade is U.S. No. 1, and requires that a bushel of wheat weigh a minimum of 58 pounds and have less than two percent damaged kernels. There can also be no more than one live insect injurious to grain in a 1-kilogram sample (32.57 dry ounces). Some buyers set a no-live insect standard. Wheat that contains 32 or more insect-damaged-kernels (IDK) per 100 gram sample (3.5 dry ounces) is classified as sample grade and cannot be sold for human
consumption. Sample-grade wheat is difficult to sell and will suffer a considerable price
discount. Flour millers strive to minimize insect fragments in their finished product and
thus have high quality standards for grain purchased. Millers will typically not accept
grain with any live insects, and prefer grain with few or no insect-damaged-kernels (IDK)
per sample. They may pay more for grain that meets these high quality standards.
For export contracts, some countries may specify a specific grain treatment to eliminate
insect pests, whereas another country will not accept grain on which any pesticide was
used. Much of the wheat stored on-farm in Montana will end up in an overseas market.
All pest management decisions made for on-farm and commercial storage situations are
based on minimizing discounts or penalties at the time of sale.

INSECT CLASSIFICATION AND IDENTIFICATION

Classification

All living things are classified into groups known as taxonomic groups. The highest level
of all taxonomic groups is the kingdom. There are five kingdoms: (1) plant, (2) fungi, (3)
bacteria, (4) protists (amoebas and algae), and (5) animal. Each kingdom is then further
divided into increasingly smaller groups based on similarities.

Insects are classified into the animal kingdom. Using the honey bee (Apis mellifera) and
humans (Homo sapien) as examples, the standard groups in a typical complete
classification of this species are:

<table>
<thead>
<tr>
<th>Taxonomic Level</th>
<th>Honey Bee</th>
<th>Humans</th>
</tr>
</thead>
<tbody>
<tr>
<td>KINGDOM</td>
<td>Animal</td>
<td>Animal</td>
</tr>
<tr>
<td>PHYLUM</td>
<td>Arthropoda</td>
<td>Chordata</td>
</tr>
<tr>
<td>CLASS</td>
<td>Insecta</td>
<td>Mammals</td>
</tr>
<tr>
<td>ORDER</td>
<td>Hymenoptera</td>
<td>Primates</td>
</tr>
<tr>
<td>FAMILY</td>
<td>Apidae</td>
<td>Hominid</td>
</tr>
<tr>
<td>GENUS</td>
<td>Apis</td>
<td>Homo</td>
</tr>
<tr>
<td>SPECIES</td>
<td>mellifera</td>
<td>sapien</td>
</tr>
</tbody>
</table>

Of the 31 insect orders, there are 9 that contain most of the destructive insects.

- Coleoptera – Beetles, weevils
- Diptera – Flies, mosquitoes
- Hemiptera – True bugs, assassin bugs, stink bugs, bed bugs, lygus bugs
- Homoptera – Aphids, leafhoppers
- Hymenoptera – Wasps, bees, ants, sawflies
- Lepidoptera – Butterflies and moths
- Orthoptera – Grasshoppers
- Siphonaptera – Fleas
• Thysanoptera - Thrips
Identification

All adult insects have two physical characteristics in common. They have three pairs of jointed legs, and they have three body regions -- the head, thorax, and abdomen (Figure 1.1).

Head - The head includes the antennae, eyes, and mouthparts. Antennae vary in size and shape and can aid in identifying some pest insects. Insects have compound eyes made up of many individual eyes. These compound eyes enable insects to detect motion, but they probably cannot see clear images. Mouthparts are also used to identify insects. The four general types of mouthparts are:
Chewing - Cockroaches, ants, beetles, caterpillars, and grasshoppers,
Piercing/sucking - stable flies, sucking lice, bed bugs, mosquitoes, true bugs, and aphids
Sponging - flesh flies, blow flies, and house flies
Siphoning - butterflies and moths

Thorax - The thorax contains the three pairs of legs and (if present) the wings. The various sizes, shapes, and textures of wings and the pattern of the veins are also used to
identify insect species. The forewings take many forms. In the beetles, they are hard and shell-like; in the grasshoppers, they are leathery. The fore-wings of flies are membranous; those of true bugs are part membranous and part hardened.

Abdomen - The abdomen is usually composed of 11 segments, but 8 or fewer segments may be visible. Along each side of most of the segments are openings (called spiracles) through which the insect breathes. In some insects, the tip end of the abdomen has a tail-like appendage.

Insects, unlike some other types of animals, have no backbones. They have an outer supporting structure called an exoskeleton. Therefore they are called invertebrates. Organisms with an internal support structure (endoskeleton) which is characteristic of most large animals, are termed vertebrates.

Stored Grain Insects

In addition to obvious identifying characteristics, the feeding habits of storage insect pests are used to separate them into two classes: Primary pests and secondary invaders. Primary pests are those that are capable of penetrating and infesting intact kernels of grain, and have immature stages that can readily develop within a kernel of grain. Secondary invaders cannot infest sound grain but feed on broken kernels, debris, higher moisture weed seeds, and grain damaged by primary insect pests. In general, the immature stages of these species are found external to the grain. It is often thought that secondary invaders cannot initiate an infestation. This is untrue as in almost any storage situation there will be adequate amounts of broken grains and debris to support an infestation by secondary invaders. Moreover, secondary invaders contribute directly to grain spoilage after establishment, just as primary pests do. However, the most damaging insect types are those that feed within the kernel itself, causing insect-damaged-kernels (IDK). Wheat is discounted based on the number of insect-damaged-kernels (IDK) as well as the presence of live insects, and other grain quality factors, when samples are graded at the time of sale.

In Montana, almost all stored-grain insects are beetles and weevils in the Order Coleoptera. There are rare occurrences of moth pests (Lepidoptera). Members of seven other insect Orders are also found in grain storage throughout the world, but the major pests are still primarily from the Coleoptera and the Lepidoptera.

Insects from these two groups develop by complete metamorphosis; meaning they have (1) an egg stage, (2) multiple larval stages, (3) a pupal stage and , (4) the adult stage (Figure 1.2). Insects such as grass-hoppers and aphids pass through incomplete metamorphosis with three stages: (1) egg, (2) nymph, and (3) adult. The immature stages resemble and feed on the same food as adults (Figure 1.2). By con-trast, larval and adult beetles that develop using complete metamorphosis feed on grain, while only the immature forms of the moth pests feed on the grain. Beetle pests are relatively common
in Montana, even in unheated facilities, while moth pests are seldom able to overwinter in unheated facilities.

Before applying any treatment, it is a good practice to have pests positively identified by an expert. But with magnification, a little practice, and a good reference guide, it is possible to identify most stored product insects; especially in Montana where there are comparatively few species.

CRITICAL IPM ISSUES

The integrated pest management (IPM) approach that protects stored grain includes:

- Sanitation
- Frequent monitoring
- Aeration
- Biological control
- Pesticide treatments

IPM techniques should be considered as tools in a toolbox; not all of them are needed every time, such as pesticides, but still need to be available.

SANITATION AND GRAIN LEVELING

The key to preventing insect infestations is to continually clean and properly maintain the storage structure. Stored grain insects breed readily in residual grain. They also live and feed on cracked grain, grain trash, or left over grain from previous crop. Both birds and rodents are also attracted to spilled grain. Rodents and pest insects find harborage and food in mature weeds surrounding the facility. The following are standard sanitation practices used for empty storage facilities.

- Clean harvest and transportation equipment before the harvest.
- Storage structures are emptied of old grain. Never store a new crop on top of old grain.
- Floors and walls inside empty bins are swept of old grain and debris.
- Weeds around the bins are removed.
- Remove spilled grain outside the storage structure.
- All grain handling equipment is repaired and kept in good condition before harvest.

For additional protection, the inside and outside surfaces, foundations and floor of a storage facility should be treated with a residual insecticide, four to six weeks prior to harvest. This will kill any insects that were not removed during cleaning and those that migrate into the bin.
A serious problem for Montana producers is a tendency to overfill the bins, peaking the grain to the very top of the bin roof. The proper procedure is to fill the bins and level the surface of the grain at the top of the bin walls. This allows for a uniform dissipation of heat and moisture into a large airspace, which allows for the movement of warm moist air out of the storage structure (Figure 1.14).

Improper storage results in moisture wicking up the peaked grain and accumulating in the grain mass in this peak. Storage fungi can readily establish in this area, leading to spoilage, the development of hot-spots, and providing a very favorable environment for a large population of storage insects.
The process of leveling the grain requires the judicious use of the grain auger and a brief period of physical labor using a grain shovel. The level surface is well suited for monitoring with pitfall traps, and for the proper application of fumigants.

**MONITORING**

Pest monitoring is an important component in the IPM post-harvest practice for stored grain. Inspections should be done frequently, especially after first storage. Initially, grain is inspected for insects weekly until the baseline insect numbers are known. Then the
grain is monitored every 2-3 weeks during throughout the autumn until the grain is cooled to 50-55°F or below, and monitored monthly for the remainder of the storage period.

Grain managers should carefully monitor the following:
- Grain quality
- Grain temperature
- Insects and insect density
- Hot spots
- Mold growth
- Any “off odor”
Temperatures below 60°F prevent insect activities, while higher temperatures allow for increased insect growth and breeding. Many storage structures are equipped with temperature sensors that provide the temperature of the grain through the grain mass. The sensors are placed on permanent cables that are suspended from the roof of the storage bin. Three are midway between the center and the wall, and one is very near the center (Figure 1.16).

Information is transmitted for each thermocouple to a reading device that helps grain managers record temperature over time. More than a five-degree rise (>5°F) recorded by one of the thermocouples over a two-week period indicates a pest or moisture problem exists in that location. Monitoring also detects changes in grain temperature during aeration or seasonal temperature fluctuations. Temperature of the stored grain in bins without temperature monitoring devices can be monitored by a thermometer mounted on a probe and inserted into the grain mass, or simply by inserting one's arm into the top layer of the grain mass.

Frequent grain sampling from several locations throughout the storage structure provides grain managers with the status of insects and grain quality. Initial sampling should be done at least weekly until the history of the grain has been clarified. In many warmer locations, samples are collected from standing grain using either a deep bin cup or a grain trier (Figure 1.17).
An alternative that works quite well is to use pitfall probe traps that remain in the grain (Figure 1.18). These traps are placed just below the grain surface or probed into the grain. With Montana’s, comparatively low insect numbers, these traps can be serviced weekly to readily provide similar information to sampling. Note that the traps are more sensitive than sampling, so the numbers will appear greater than from sampling. Nonetheless, the basic approach remains the same. Numbers and species of insects are recorded to assess a monthly pattern. The presence of insects in dry whole grain is an indication of future economic loss (in terms of live insects at time of sale). The presence of IDK-causing insects will result in discounts at the time of sale. A moldy appearance, dampness, off-odor, presence of IDK, and high moisture levels can also indicate insect problems. Consistent findings of internal feeders and IDK call for fumigation to protect grain value.

**AERATION**
Aeration is used to dry and cool newly-stored grain. It is also used to prevent moisture migration when ambient temperatures drop below that of the grain temperature.

Moisture migration occurs when outdoor temperatures decline during the fall and winter. Grain and air temperatures near the bin walls also drop. The insulating characteristics of grain prevent temperatures in the center of the grain mass from falling as rapidly. Cooling air near the bin wall makes this air more denser (heavier), and it settles toward the bin floor. At the same time, warmer air near the center of the bin floor is less dense (lighter). This air, which is displaced by the cooler air, rises through the center of the bin, absorbing small amounts of moisture from the surrounding grain as it rises. Grain near the top of the grain mass, like that near the outer walls, is cooler than the rising air. As the warm air rises through the cooler grain and is cooled by it, moisture condenses from the air onto the grain. This moisture migration produces wetting and crusting of surface grain (Figure 1.19).

Prevention of moisture migration by maintaining a uniform temperature throughout the grain mass greatly reduces the possibility of mold development as well as insect feeding and reproduction. Aeration will not kill insects, but will slow their growth and development. Aerated bins contain lower insect populations than non-aerated bins through the winter, thus aeration greatly reduces the requirement for fumigation. In Montana, running aeration fans continuously for up to one week, and then running them only at night will rapidly cool grain stored to temperatures that inhibit insect feeding and reproduction in smaller bins.

Aeration fans at the base of the bin move cool air through the mass, with warm air exhausting through vents in the roof. Airflow rates of 0.1 to 0.5 cfm/bu are historically recommended for wheat at normal moisture levels. However, higher airflow, night aeration is most effective during late summer and fall, when the air temperature is below 60°F. In Montana, the nighttime air temperatures conducive for cooling occur from the time of first storage onwards. The number of aeration hours required to cool the grain to less than 50°F depends on the volume of wheat, the depth of the grain in the bin, airflow rates, and the difference between grain and ambient air temperatures. Automatic controllers turn the aeration fans on when the ambient air temperature drops a set interval (5°F for example) below the grain temperature to cool the grain. The controllers turn the fan off when the air temperature exceeds the set point.

**BIOLOGICAL CONTROL**

There are a number of insect predators and parasitic wasps that attack insect pests of stored grain. All are effective if used in overwhelming numbers. However, biologicals are generally not used because the Food and Drug Administration (FDA) and food processors do not accept live insects or insect parts in raw grain. This inductive approach is simply the addition of very large numbers of beneficial insects.

Biological agents have limited commercial availability and are cost prohibitive, except perhaps for organic production. Specific species that attack the different groups of pests
are listed below. It is important to note that there are limited numbers of naturally occurring biological control agents:

Primary Pests
Parasitic wasp of grain
   - *Anisopteromalus calandrae*
Choetospila elegans
Lariophagus distinguendus

Predaceous mites
Warehouse pirate bug - *Xylocoris flavipes*

Secondary Pests
Predaceous mites
Warehouse pirate bug - *Xylocoris flavipes*

Indianmeal moth
Habrobracon hebetor

Predaceous mites
Trichogramma pretiosum
Warehouse pirate bug - *Xylocoris flavipes*
INSECTICIDE TREATMENTS

Empty bin treatments include residual insecticides applied in and around the fan, aeration ducts, auger, door openings, and hatch covers, or fumigants, before bins are filled at harvest. Commercial facilities must comply with the Occupational Safety and Health Administration (OSHA) bin entry permits. Following are pesticides available for treating empty bins:

<table>
<thead>
<tr>
<th>Insecticides Labeled for Use as Empty Bin Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active Ingredient (a.i.)</strong></td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Cyfluthrin</td>
</tr>
<tr>
<td>Chlorpyrifos-methyl</td>
</tr>
<tr>
<td>Diatomaceous earth (DE)</td>
</tr>
<tr>
<td>Malathion</td>
</tr>
<tr>
<td>Chlorpyrifos-methyl + cyfluthrin</td>
</tr>
<tr>
<td>Chloropicrin</td>
</tr>
<tr>
<td>Methyl bromide</td>
</tr>
</tbody>
</table>
Grain protectants are insecticides applied directly onto grain going into the storage or already in storage. Grain protectants do not kill insects inside the kernels. Following are insecticides labeled as protectants.

In Montana, the use of protectants should be limited to high-value commodities that need protection during storage for several months, and for which it is cost effective to use them. For direct application on wheat at first storage, there are limited circumstances where the use of a protectant is necessary.

### Liquid Insecticides Labeled for Use as Grain Protectants

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Example Brands</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorpyrifos-methyl</td>
<td>Reldan 4E®</td>
<td>Reldan does not control lesser grain borer. Can only be applied to the grain stream as it is moved (augered) into the bin. Use limited to existing stocks.</td>
</tr>
<tr>
<td>Malathion</td>
<td>Malathion 5EC</td>
<td>Existing stocks are available but label has been withdrawn. Most stored grain insects are resistant.</td>
</tr>
<tr>
<td>DDVP</td>
<td>Vapona®</td>
<td>Also as strips. Used in the head space against Indianmeal moth.</td>
</tr>
<tr>
<td>Methoprene</td>
<td>Gentrol, Diacon II®</td>
<td>Kills developing insects only, slow kill of larvae, no kill of adults though causes sterility. High cost and must use other products before sale. Newly marketed.</td>
</tr>
<tr>
<td>Chlorpyrifos-methyl + cyfluthrin</td>
<td>Storcide®</td>
<td>Can only be applied to the grain stream as it is moved (augered) into the bin. It is not recommended for grain intended for export.</td>
</tr>
<tr>
<td>Pyrethrins</td>
<td>Pyrenone®</td>
<td>Expensive, short residual life.</td>
</tr>
</tbody>
</table>

### Dust Insecticides Labeled for Use as Grain Protectants

<table>
<thead>
<tr>
<th>Active Ingredient</th>
<th>Example Brands</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malathion</td>
<td>Big 6 Grain Protector®,</td>
<td>Top-dress treatment. Insects are resistant in many areas. Millers resist purchasing grain with strong malathion odor.</td>
</tr>
<tr>
<td></td>
<td>Agrisolutions 6% Malathion Grain Dust</td>
<td></td>
</tr>
<tr>
<td>Diatomaceous earth (DE)</td>
<td>Protect-It™, Insecto®</td>
<td>Can lower the test</td>
</tr>
</tbody>
</table>
FUMIGANTS

Properly conducted fumigation will stop insect infestation and grain degradation from getting progressively worse. When fumigation is effectively conducted in late fall, pest populations can be drastically reduced.

Fumigation is recommended if:

- Grain samples reveal the presence of insect-damaged-kernals (IDK).
- Samples or traps capture harmful insects (lesser grain borer, granary weevil).
- Trapping or sampling indicates that a population of secondary pests like the rusty grain beetle is expanding rapidly.

Fumigants registered for use are phosphine, either released from aluminum or magnesium phosphide or directly as a gas, methyl bromide, and chloro-picrin (used for empty bin treatment only). Tablets or pellets of aluminum or magnesium phosphide are sold under Weevilcide®, Fumitoxin®, and Phos-toxin® trade names. Phosphine gas mixed with carbon dioxide is sold in gas cylinders as ECO2.Fume®. Methyl bromide is expensive, difficult to use properly on raw grain, kills the germ, and is not recommended for stored grain, especially seed wheat. In addition, methyl bromide use is being phased out due to its status as an ozone depleter under the Montreal protocol. The phosphide pellets or tablets release phosphine gas as they are exposed to moisture in the air. In a large storage facility, phosphide pellets or tablets are often added to infested grain as it is moved from one silo to another silo, bin, railcar, or truck.

NOTE: The treatment of mobile units must be in isolation as per label standards and the units can not be moved until the fumigation is over and the residue has been properly aerated!

For fixed facilities with a significant infestation, pellets or tablets are probed deeply into the mass and also similarly distributed near the top surface. The released gas is more effectively distributed through the mass using an air-circulation system known as closed-loop fumigation (CLF). For an effective fumigation, the facility must be well sealed to prevent gas leakage to maintain a high enough dosage for sufficient time to kill all life...
stages of the infesting insects. This requirement to prevent leaks is now a label requirement for the use of phosphine products.

In Montana, phosphine can only be sold to and used by pesticide applicators that are certified in its use. Phosphine is used because it has good cost-benefit factors, is safe for workers when used properly, is environmentally safe, has no residue, is highly effective, and is remedial when large insect populations are found. Phosphine can be corrosive to copper and precious metals, such as those found in electronic equipment (computers, aeration fan motors, etc.), which limits its use in buildings. Fumigation is more effective when sanitation, grain leveling, removal of fines, and thorough bin sealing has been done in advance. It is essential that the level of phosphine remain adequate (greater than 200 ppm) for as long as possible, with a minimum of 100 hours recommended to kill all life stages of the pest insects at optimal temperatures. Many of the regulations stressed in this manual were recently established. The label and applicators manual are considered part of the revised label, and the label requirements are far more stringent than for the previous label and includes:

- a stricter restricted use statement requiring the physical presence of a certified applicator when the product is used,
- a requirement that two trained applicators be present whenever fumigation or gas monitoring requires work or reentry within confined spaces which reinforces the common sense approach that fumigators should always work in pairs,
- language that fumigant use must be in strict accordance with the label.

In addition, certified applicators must:

- ensure that the fumigated facility is secure and placarded before leaving,
- be physically present and responsible for all workers when the fumigation exposure is complete,
- ensure that the structure is opened for aeration.

The certified applicator is also responsible for the monitoring of exposure levels during the application, fumigation, and aeration process. For this reason, the new label has strict sealing guidelines to prevent exposure to phosphine gas escaping from leaky storage structures. The new label also sets on maximum dosage levels and gives recommended dosage ranges for specific applications, whereas the preceding label only set minimum and maximum dosage levels.

Also, the entire label must be physically present when the product is used, and if an incident with adverse effects on human health or the environment occurs, the product registrant must be informed.

There are also requirements for weatherproof placarding, with name of the applicator and the product EPA registration number affixed.
There are requirements for the reporting of product theft to local police, and for DOT transportation labels when the product is transported.

**FUMIGATION MANAGEMENT PLAN**

A fumigation management plan (FMP) must be prepared by the certified applicator for each structure to be fumigated (See Appendix 1 and 2). This plan is designed to ensure a safe and effective fumigation, and must fully characterize the area to be fumigated, and include all appropriate monitoring and notification requirements. The development of a fumigation management plan is quite involved so we will spend some time on this.

In order to develop an effective Fumigation Management Plan, the following procedures need to be followed:

The certified applicator must inspect the structure and surroundings to determine suitability for fumigation. If sealing is required, review records to determine if structural changes may have resulted in new potential leaks.

- Seal all leaks and test the seal, plus monitor phosphine levels in adjacent occupied buildings to ensure safety.
- Review existing Fumigation Management Plans, Material Data Safety Sheets, the label/applicator’s manual, and safety procedures before fumigating.
- Develop procedures and safety measures for other workers that will be in and around the fumigation area during application and aeration.
- Develop a monitoring plan that confirms that workers and bystanders are not exposed to levels above the allowed limits during application, fumigation, and aeration. This monitoring plan must also demonstrate that nearby residents are not exposed to unacceptable levels, as well. The levels for exposure are an 8 hour time-weighted average of 0.3 ppm or a 15 minute time-weighted short term exposure limit of 1.0 ppm.
- Develop a procedure with local authorities to notify nearby residents in the event of an emergency.
- Confirm the placement of placards to secure all entrances to any structure under fumigation.
- Ensure that the required safety and monitoring equipment and adequate manpower is available to conduct a safe fumigation. More recent respiratory protection guidelines for workers and certified applicators, require the use of monitoring equipment to establish airborne concentrations. Between 0 and 0.3 ppm, no respiratory protection is required. At concentrations from 0.3-15 ppm, a NIOSH/MSHA approved full – face canister respirator is required (Figure 1.21). If the phosphine concentration is above 15 ppm or if it is not known, a self-contained breathing apparatus (SCBA) is required (Figure 1.22).
Application of fumigant material and post-fumigation aerations must be by two persons, with at least one person being a certified applicator. The second individual may be a worker under the direct supervision of the certified applicator, and the certified applicator is responsible for the safety of this worker.

GAS DETECTION AND MONITORING DEVICES

Revised labels for fumigants require the use of sensitive gas monitoring devices during fumigant application and before warning placards can be removed from fumigated storages. Devices that provide adequate sensitivity include gas detector tubes and matching pumps manufactured by Auer, Draeger, Matheson Kitagawa, MSA, and Sensidyne.
Detector tubes are sealed glass tubes filled with a specific reactive solid. Both ends of a tube are broken off just before use, and one end is attached to a calibrated pump. Available pumps use a bellows, bulb, or piston-type syringe to draw a precise volume of air through the detector tube (Figure 1.23). Discoloration of the solid material within the tube indicates fumigant presence, and the gas concentration, can be read directly from the scale on the glass tube. A reading of 2 ppm is shown in Figure 1.24. Although tubes and pumps manufactured by different companies may be very similar, accurate readings require matching detector tubes and pumps from the same manufacturer. Do not mix separate brands of equipment.

Detector tubes are specific for a single fumigant. Auer, Draeger, Matheson-Kitagawa, MSA, and Sensidyne manufacture detectors that offer adequate sensitivity for label-required monitoring of hydrogen phosphide and methyl bromide.

**Resistance Management Issues**

Grain storage facilities lend themselves to the development of insecticide resistance by virtue of the enclosed, protected structures, limited immigration and emigration of insects, and the repeated use of the same chemicals without rotation between chemical
classes and modes of action. Of particular concern are the organophosphate and pyrethroid protectants.

The same fumigant, phosphine, is used with no rotation with other chemical classes. Methyl bromide is to be phased out entirely in 2005, leaving phosphine as the only registered fumigant for application directly to stored wheat. Resistance to phosphine can occur in locations where it is used frequently, but thus far there have been no real control failures in Montana. Investigation of unsuccessful fumigation has shown that improper application has been the cause of the reduced efficacy in every circumstance scrutinized. However, proper use of phosphine is essential to prevent resistance development, including correct bin sealing and dosage to maintain phosphine concentration at high levels for a sufficient amount of time. As stated above, these are now label requirements, and will ensure that improper application does not speed the development of resistance through exposure to a less than optimal concentration, or by shortening of the exposure interval.

**Consumer Education Issues**

Pesticide residues are an ever-growing concern to consumers, and many of the grain protectants can be detected in the final milled product. However, phosphine fumigant does not leave any residues once the grain is ventilated.

Insect fragments and parts, rodent and bird droppings and hairs are all undesirable components in foodstuffs. The standard for the acceptable amount of insect fragments and/or animal droppings in a milled product is regulated by the Food and Drug Administration (FDA). Flour mills will not accept grain with live insects or animal droppings, and strive to strictly limit the amount of insect fragments. Millers also note that these fragments are not just of pest insects, but of beneficial (e.g., predators, parasites) insects as well, thus limiting their use. Consumers are largely unaware of the balance between the use of pesticides and those standards that pertain to fragment and animal dropping in grain. Perhaps a critical education issue is to stress that good storage practices limit the use of pesticides to prevent contamination of foodstuff by either the pesticide residue or unacceptable levels of the end products from infestation.

As a related issue, the Food and Agriculture Organization and the World Health Organization have established the Codex Alimentarius, which sets international residue limits. Insect-infested grain is not acceptable, and only those pesticides that are on the Codex can be exported unless accepted by the receiving country. Given that most of Montana’s wheat is exported, this further limits insecticides that can be used on stored grain. For example, the product Storicide® contains cyfluthrin as one of its active ingredients, but since there is no Codex Maximum Residue Limit (MRL) for this chemical, wheat destined for export cannot be treated with the product.