Extension Bulletin E-1431 • Major Revision April 1988 85¢

# STORED GRAIN MANAGEMENT

**Roger C. Brook and Dennis G. Watson**
Department of Agricultural Engineering
Michigan State University

*Proper storage facilities and good management practices are important for successful short-term or year-round grain storage. Mold growth and insect infestation are the most common causes of spoilage in stored grain. The growth of these organisms is often the result of improper management of grain moisture content and temperature. This publication covers structural considerations in grain storage, grain aeration equipment, potential grain storage problems and proper stored grain management practices.*

## POTENTIAL GRAIN STORAGE PROBLEMS

A grain manager needs to understand potential grain storage problems and their causes. Mold growth and insect infestation are the causes of grain spoilage. Both these problems can be aggravated when moisture migration results in pockets of warm, moist grain.

### Mold growth and insect infestation

The starch in the grain kernel is a food source for grain storage molds and insects. Broken kernels are more susceptible to mold growth than whole, undamaged kernels. Grain storage molds grow rapidly in 80 to 90 degree F temperatures; temperatures below 55 degrees F substantially reduce mold growth. Most storage molds require the presence of moisture at greater than normal levels for storage (greater than 17 percent for corn, for example). An important exception is the mold responsible for blue-eye damage, which can grow on corn with moistures as low as 14 percent if the corn temperature is high enough. Other storage molds will generally not be a problem if the grain is properly dried and the grain moisture does not increase during storage because of moisture migration and/or water leaks.

Storage insects attack whole and broken kernels. Grain storage insects thrive in 80 to 85 degree F temperatures. Keeping grain temperatures at 55 degrees F or lower greatly reduces the rate of insect growth and the risk of insect infestation in stored grain. Low storage temperatures will not kill all insect adults and larvae in the stored grain but will force the insects into dormancy and prevent their reproduction.

Though the average moisture content of stored grain may be at a safe level, pockets of higher moisture grain will develop storage problems. These wet spots, often the result of moisture migration, can become sites of mold and insect activity. Mold activity raises grain temperature, which increases and spreads mold development and fosters insect infestation.

## Moisture migration

Moisture migration can occur in grain storage facilities when the temperature difference between the grain and the outside air is greater than 15 degrees F (see Fig. 1). As the outside air temperature drops in the fall, grain near the external wall of the storage facility cools. The cooled, dense air along the outside of the grain mass flows downward and warm air in the center rises. When the rising warm air encounters cold grain at the top of the grain mass, the air cools and moisture condenses on the grain. The moisture accumulation near the top center of the grain mass results in mold growth and insect infestation. Similar air currents occur if the grain is too cold during warm weather. Moisture migration is a slow process, becoming noticeable only after a period of weeks. The key to controlling moisture migration is to control grain temperature.

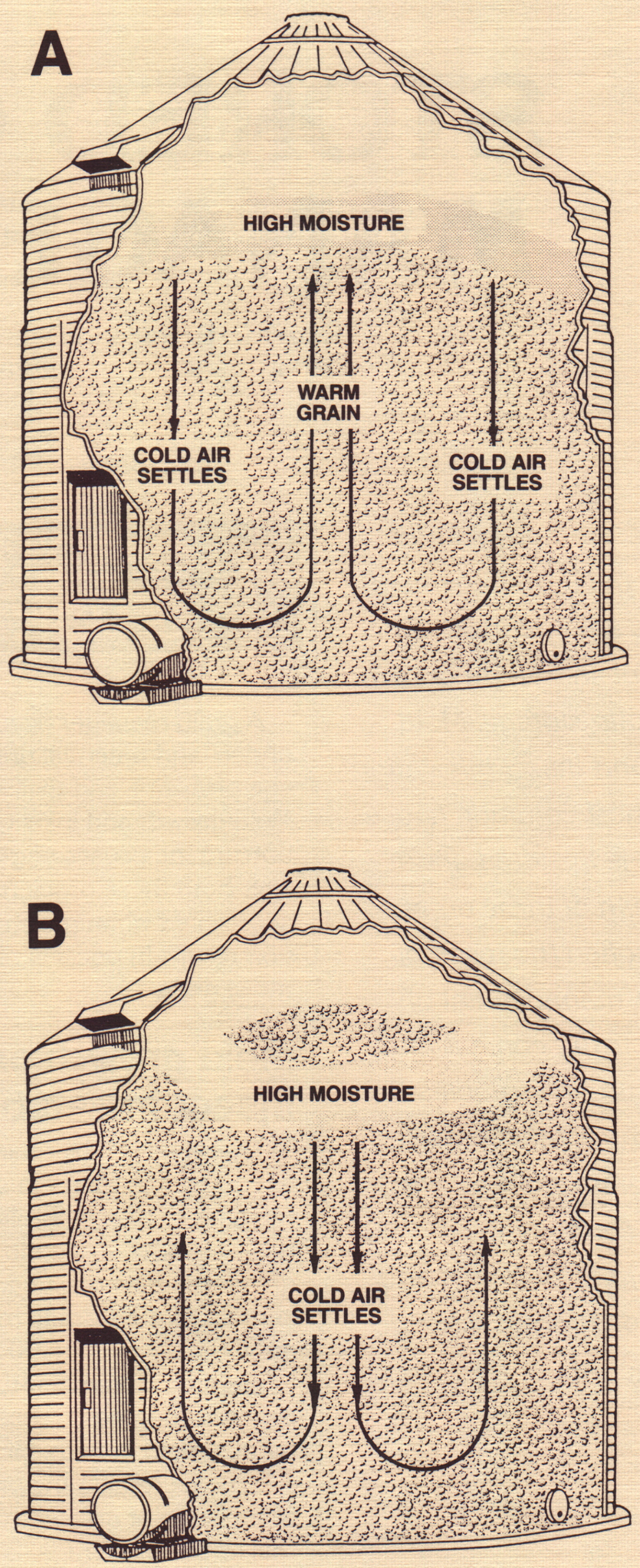



**FIG. 1. Sharp differences in outside air and grain temperatures cause air movement and moisture migration through grain. (A) In winter, cool air pushes warm air up through the center of the grain mass. When the warm air reaches the cool grain on top, moisture condenses and accumulates on grain just below the top of the grain mass. (B) In summer, a reverse air movement occurs. Proper grain aeration is essential to control moisture migration.**

# STRUCTURAL CONSIDERATIONS

Grain storage structures must be capable of holding the grain and protecting it from deterioration by weather, pests and other destructive agents. Locate storage structures on high ground with adequate drainage to avoid flooding.

Grain stores most easily in specially constructed grain bins (see Fig. 2). Silos or buildings used for grain storage will require some modification of the floor, sidewalls and/or roof. (Contact your local Extension office for copies of bulletins AEIS-258 and AEIS-478, which describe required modifications of silos and buildings, respectively.)

Install a temperature monitoring system for storage facilities containing over 30,000 bushels. A monitoring system consists of temperature-sensing cables and a conveniently located monitor for temperature display. The primary advantages of grain temperature monitors are convenience and the ability to measure temperatures where probing is difficult. Temperature monitoring systems are best used to determine the status of aeration cycles. They do not replace a grain inspection program during storage.

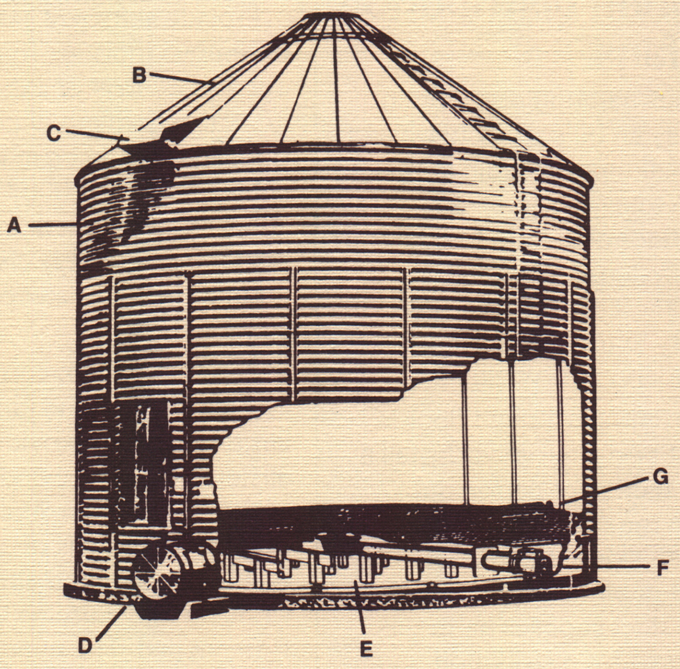



**FIG. 2. An adequate grain storage structure consists of: (A) sidewalls capable of withstanding grain pressure, (B) leak-proof roof, (C) exhaust vents, (D) aeration fan, (E) aeration distribution system, (F) unloading auger and (G) sweep auger.**

Provide sufficient airflow for proper grain temperature control. The common airflow designation is cubic feet of air per minute per bushel (CFM/bu) of grain in storage. Dry, farm-stored grains require a delivered airflow of 1/10 to 1/5 CFM/bu. Clean grain—grain with broken kernels and trash removed—at an acceptable storage moisture stores well with an airflow of 1/10 CFM/bu. Grain stored at higher than recommended moisture or poor quality grain requires an airflow of 1/5 CFM/bu for adequate temperature control.

## Aeration types

Aeration systems use either upward (pressure) or downward (suction) airflow. From a management perspective, the best airflow system uses upward airflow or pressure aeration. An upward airflow system exhausts air at the top of the storage where you can easily observe airflow patterns and cooling rates. The completion of cooling is easily monitored by measuring the temperature in the grain near the top. Another advantage is that heat from warm grain added to the storage will not warm previously cooled grain. Upward airflow is desirable during cooling because it conditions grain on the bottom, where inspection is difficult, the longest. Heat from the fan in an upward airflow system raises the temperature and lowers the relative humidity of the air, so aeration can proceed at times when air conditions would be too cool or humid. Upward airflow provides more uniform distribution of air through the shallow layers of grain served by long aeration ducts in flat storage.

A downward airflow or suction aeration system expels air outside the storage, where moisture cannot condense on cold surfaces. A downward airflow can be used in a ducted aeration system in partially filled storages if you cover the exposed ducts and shallow depths of grain with plastic sheets. A similar approach to airflow management can also help to direct aeration air to trouble areas or hot spots in the grain mass when using plastic covers over part of the grain surface.

## Aeration distribution and fans

Various aeration distribution systems can be successfully used to maintain proper grain temperatures. A totally perforated metal drying floor offers the best distribution system for flat-bottom grain bins. It also provides the flexibility to use the storage for in-bin drying or dryeration.

A partially perforated floor is the next best alternative. Install a square section of perforated metal in the center of the bin floor with side length equal to one-half of bin diameter. A below-surface duct supplies air to this center area for distribution throughout the grain.

Ducts are commonly used as distribution systems for aeration in buildings. Ducts set below floor level (flush-floor ducts) are not a hindrance during grain removal. Round or half-round ducts placed on the floor (on-floor ducts) hinder unloading of the storage.

Either axial or centrifugal fans will provide sufficient airflow in grain drying and aeration systems. An axial fan is suitable for static pressures of up to 4 inches of water. The primary advantage of axial fans is lower cost; the primary disadvantage is the high noise level. The primary advantages of centrifugal fans are their quiet operation and their ability to operate at static pressures above 4 inches of water; the primary disadvantage is the higher cost than axial flow fans for the same delivered airflow.

Provide sufficient exhaust area to remove moist air from the storage facility. Inlet or exhaust area is critical, regardless of airflow direction, and should be at least 1 square foot per 1,000 CFM of air supplied. The inlet or exhaust area must be evenly distributed around the perimeter of the storage.

Aeration system components, including ducts and fans, must be large enough to provide proper airflow for the type and condition of the stored grain. Multiply the number of bushels of grain in storage by the required airflow in CFM/bu to determine the total airflow needed. The condition of the grain and the size of the storage facility determines the number and size of ducts required. (Contact your local Extension office for more details on fan and duct sizing for grain storage.)

# GRAIN MANAGEMENT PRACTICES

Proper management practices are essential to successful storage of grain in bins, silos or other buildings. Grain should be clean, dry and cool to help prevent loss in quality during storage. Stored grain management responsibilities consist of storage preparation, grain aeration and grain inspection.

Table 1. Recommended moisture content for storage of good quality grain.

| | Through winter (Until April) | Through summer |
|---|---|---|
| Shelled corn | 15 | 14 |
| Soybeans | 14 | 12 |
| Edible beans | 18 | 16 |
| Wheat, rye, barley, oats | 14 | 13 |
| Sunflower seeds | 10 | 8 |

## Storage preparation

Start by thoroughly cleaning the storage and grain-handling equipment. Remove trash and debris from the storage and equipment (see Fig. 3). Take special care to clean under the aeration floor. A worthwhile preventive measure to deter insect development is to use an insect spray on the interior of the storage facility before filling it with grain. This is particularly important if you cannot thoroughly clean under the false floor or within the aeration ducts. Use a grain protectant for insect control on grain stored through the summer and for grain stored for more than one year. (Contact your local Extension office for copies of bulletin E-934, "Protecting Stored Grains from Insects," and USDA marketing bulletin 72, "Grain Protectants for Insect Control," for more information on insect control.)

Proper harvest is the first step in obtaining clean, high quality grain. Follow the manufacturer's recommendations for combine adjustments and check them regularly. Maintain the recommended ground speed to avoid overloading the combine and causing grain breakage. Broken grain is more susceptible to mold growth than whole grain and has greater resistance to airflow. The resulting decrease in airflow during aeration will increase the fan operating time for proper temperature management.

Grain must be of uniform moisture content and quality when loaded into storage. Table 1 shows recommended moisture contents for storage of good quality grain. Reduce moisture con-

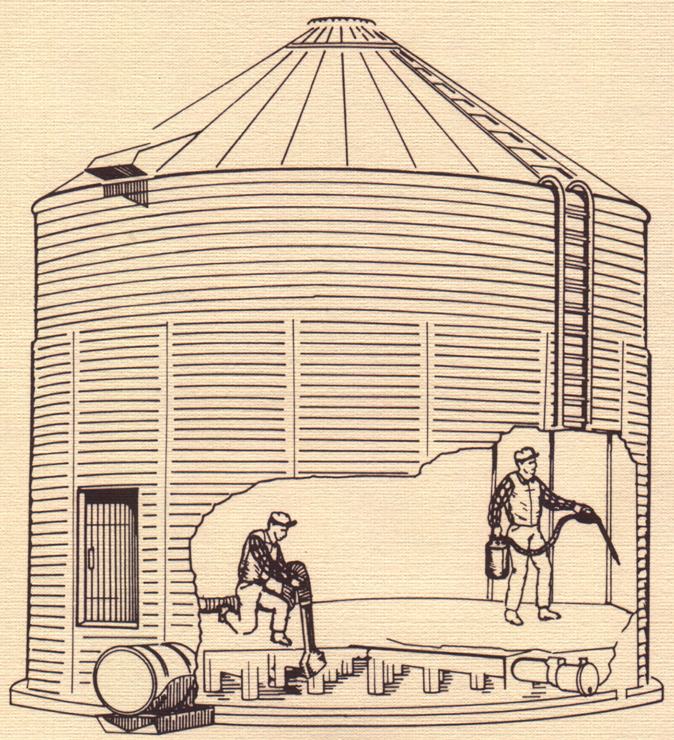


**FIG. 3. Storage facility and grain-handling equipment must be thoroughly cleaned before you place grain in storage. (A) Be sure to clean under the floor and within the sump. (B) Spray the interior of the facility with an approved insecticide to deter insect development.**

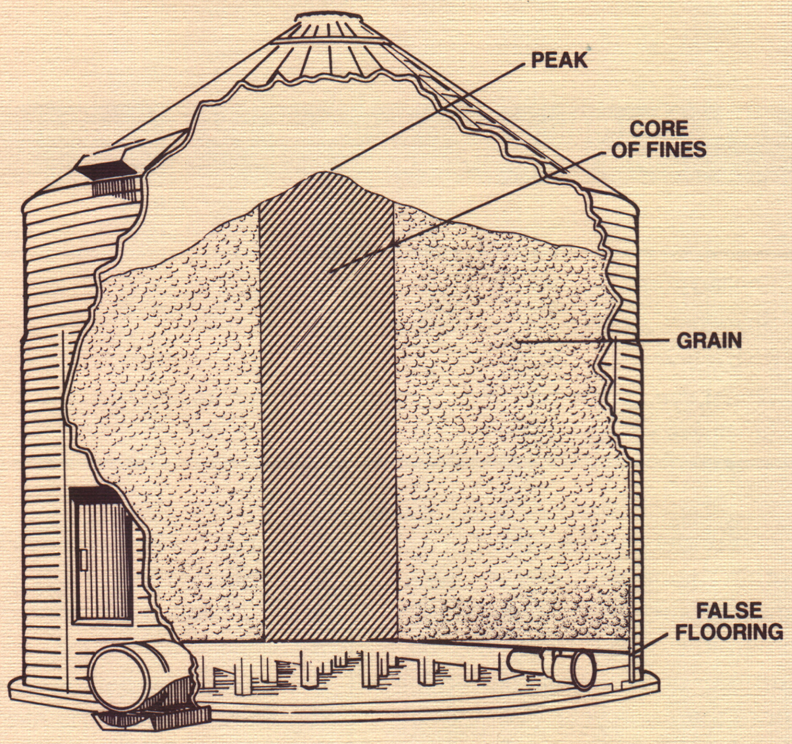



**FIG. 4. With center filling of a grain bin, fines accumulate in the center, forming a spoutline. Unload the spoutline and level the grain for even airflow through the grain.**

tent by 1 percent for any of the following conditions: poor grain quality (BCFM content over 5 percent); non-aerated storage facility; or flat storage facility. Do not determine the moisture content by averaging a wet load with dry loads of grain. The wet load, if placed in one location, may spoil and cause problems for the surrounding dry grain.

Use a grain cleaner to remove fines and foreign material before placing grain in storage. Use a center fill method when loading the grain into storage. The fines and small pieces will congregate in the center of the bin, forming a spoutline. Withdraw the spoutline and level the grain for even airflow distribution through all the grain (see Fig. 4). A level grain surface allows even airflow distribution through all the grain and reduces the surface area exposed to insect infestation.

Do not depend on a grain spreader as a tool for effectively dealing with grain containing fines and foreign material. A grain spreader will provide a level grain surface. However, a grain spreader often causes an accumulation of broken kernels somewhere other than at the center of the bin.

Cool grain to the desired storage temperature before loading a non-aerated structure. This may mean waiting to fill the non-aerated storage until late fall. Remember that grain from a dryer may be 10 degrees F warmer than the outside temperature. Grain storage in a non-aerated structure should not exceed 3,000 bushels or be stored more than three months.

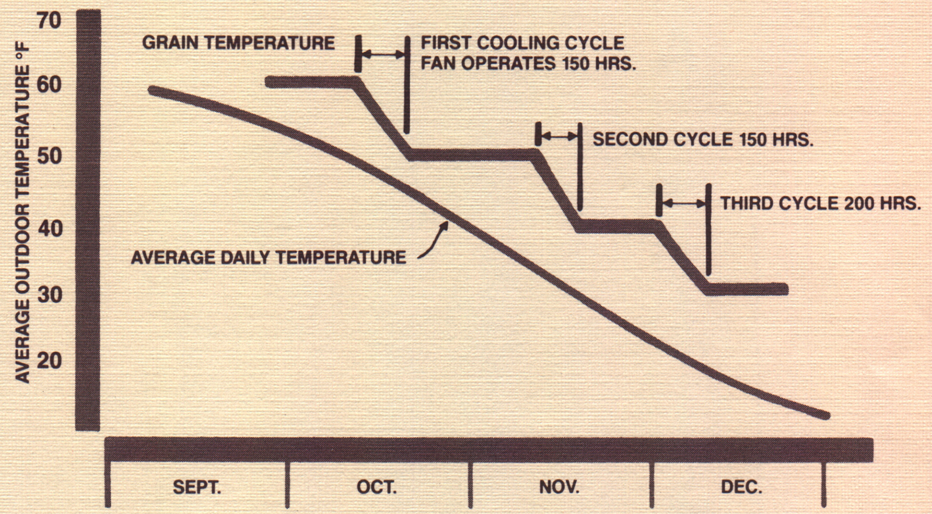
## Grain aeration

Proper temperature management is very important for successful grain storage and helps to prevent moisture migration. Storage molds and insects are dormant in cool grain.

After harvest or drying, cool grain to 50 to 60 degrees F. As the outdoor temperature decreases, cool grain to 30 to 35 degrees F for winter storage. Do not cool the grain below freezing because this will cause storage problems during warm periods in the winter.

Use two or three aeration cycles to cool grain to the desired temperature (see Fig. 5). The first aeration cycle should begin during, or immediately following, filling of the storage. Begin additional aeration cycles when the average of the daily high and low outdoor temperatures have become 15 degrees F cooler than the grain. Run the fan continuously during an aeration cycle. A fan providing 1/10 CFM/bu will cool grain in 5 to 8 days. It is very important to operate the fan long enough to sufficiently cool all the grain. See Table 2 for approximate fan operation hours required for a temperature change of 15 degrees F. Inadequate aeration time will result in sharp temperature differences within the grain mass, which will cause moisture migration and create the potential for mold growth (see Fig. 6).

**FIG. 5. Diagram of aeration cycle timing to cool grain as average daily temperature decreases in the fall.**




Grain removed from storage by late spring or early summer can be successfully held without warming. Grain held through the summer months requires special consideration during the spring. Grain stored at temperatures below 35 degrees F during the winter requires warming to no more than 45 to 50 degrees F during the spring. Grain stored at temperatures above 35 degrees F during the winter will store successfully during the summer. Watch closely for insect infestation, particularly during August. Do not warm the grain to high summer temperatures (80 to 90 degrees F).

During an aeration cycle, monitor the grain temperatures by holding a good thermometer in the exhaust airflow. The temperature change will be complete when the exhaust temperature is nearly equal to the outside temperature. For upward airflow, check grain temperatures about 6 inches down from the top surface of the grain. For downward airflow, check the air temperature as it leaves the fan. Be sure to check around the outside edge of the fan rather than near the center—the motor of an axial fan will slightly heat the air flowing over it.

Cover the mouth of the aeration fan when it is not running to prevent a chimney-effect draft back through the grain.

Table 2. Approximate grain cooling or warming times for fall, winter and spring aeration cycles of 10 to 15 degrees F temperature changes.

| Airflow rate (CFM/bu) | Fall cooling hours | Winter cooling hours | Spring warming hours |
|---|---|---|---|
| 1/20 | 300 | 400 | 240 |
| 1/10 | 150 | 200 | 120 |
| 1/5 | 75 | 100 | 60 |
| 1/4 | 60 | 80 | 48 |
| 1/3 | 45 | 61 | 36 |
| 1/2 | 30 | 40 | 24 |
| 3/4 | 20 | 27 | 16 |
| 1 | 15 | 20 | 12 |
| 1 1/4 | 12 | 16 | 10 |
| 1 1/2 | 10 | 13 | 8 |

Adapted from MWPS AED-20, "Managing Dry Grain in Storage."

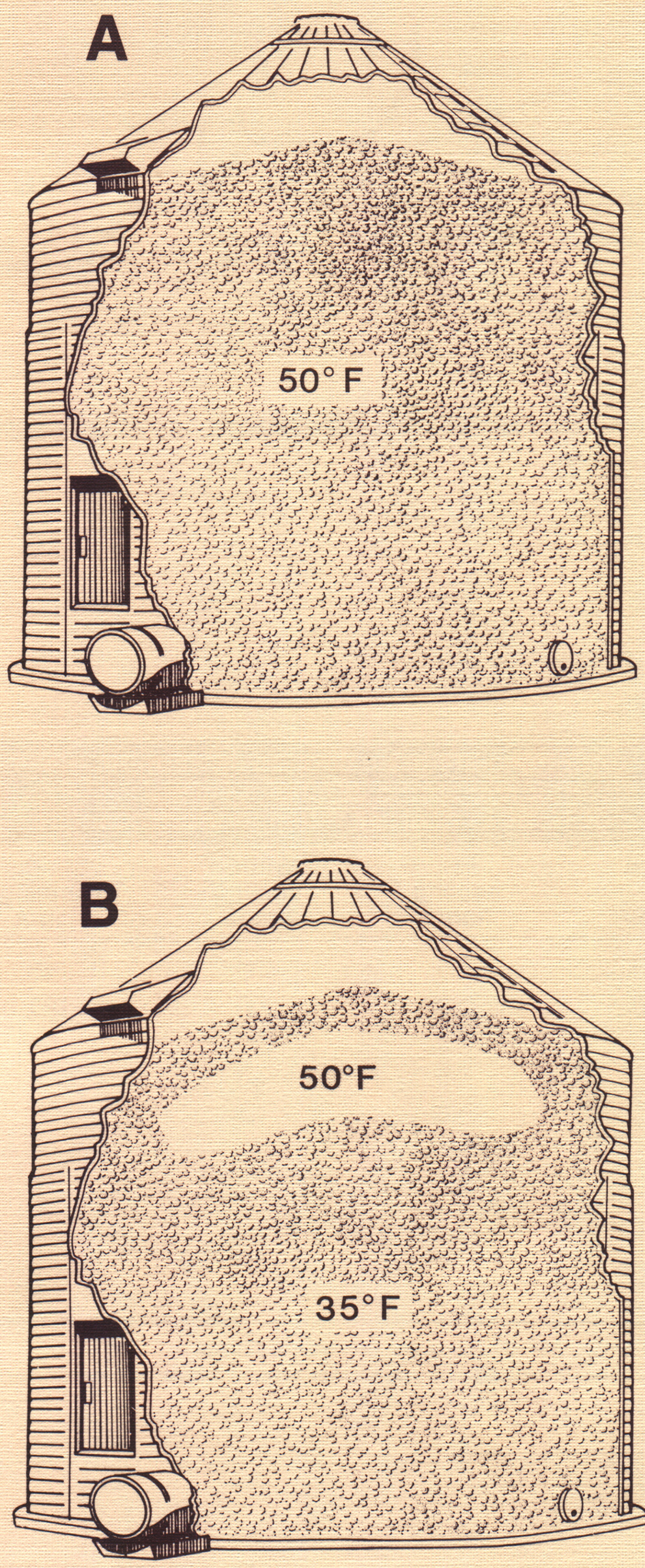



FIG. 6. Sufficient aeration time is critical to maintaining grain quality. (A) Start an aeration cycle to cool grain from 50 degrees F to 35 degrees F. (B) If the aeration fan is shut off just one day too early, a layer of grain will be left at 50 degrees F. This large temperature difference will lead to moisture migration and grain spoilage.

## Grain inspection

A key component of successful grain storage is regular inspection to help detect problems before they become serious. These inspection procedures are applicable regardless of the type of storage facility. Regular inspection is most critical for grain stored in a building because of the greater potential for non-uniform air distribution through the grain.

Weekly inspections of stored grain (see Fig. 7) are critical in the fall and spring when the outside temperature is changing rapidly. Check grain at least every two weeks during the winter and weekly during the summer. Establish a regular time of the week for inspection to avoid forgetting. Inspect grain from inside the stor-

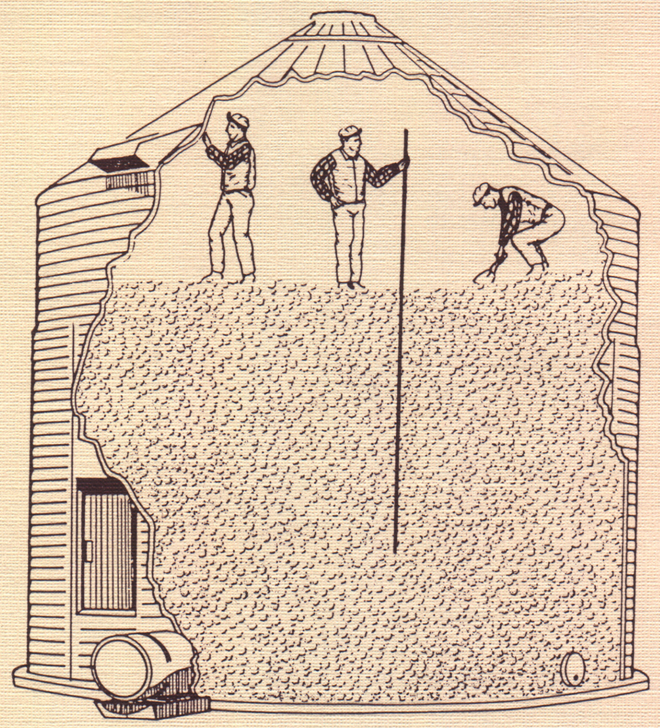


**FIG. 7. Conduct weekly grain inspections within the storage structure. (A) Look for signs of condensation and leakage on the roof. (B) Examine the grain for condensation, crusting, hot spots and odors. (C) Probe the grain to detect wet spots, measure grain temperature and collect samples for moisture tests.**

age facility, preferably while walking the grain surface.

LOOK at the grain, especially near the top surface where condensation and crusting are most likely to occur. Inspect the roof and grain surface for signs of condensation or leakage.

FEEL or probe for any hot spots that may be developing. Trouble spots are likely to be 1 to 3 feet beneath the surface and will normally be near the center of the storage. Use a steel rod or grain probe to check for wet spots. When the probe hits a wet spot, it will be much harder to push through the grain. Use a grain probe to measure grain temperature and collect moisture samples at various points in the grain bulk. Any consistent increase in temperature suggests a problem, unless the outdoor temperature is warmer than the crop. Check samples for signs of insect infestation, particularly in mid-August.

SMELL for any odors. Run the fan during the inspection and sniff the exhaust for any off-odors. This procedure helps detect any problems that may be developing in the center of the bin. Briefly running the fan during the inspection will not create any temperature-associated problems.

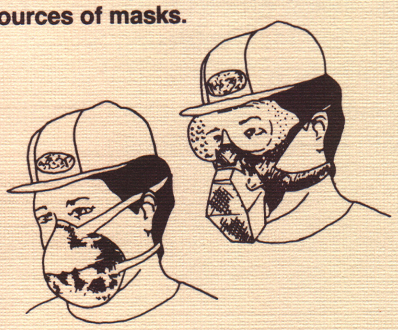
When a problem develops, prompt action can reduce the amount of grain spoilage. Use airflow supplied by the aeration system to correct minor wet or hot spots by cooling grain. Remove any grain with serious spoilage problems from the storage, dry it, if necessary, and clean it thoroughly. Table 3 summarizes problems observed during regular inspection, the probable causes and recommended actions or solutions. Use it as a guide for handling any problem that is developing. (Contact your local Extension office for a copy of bulletin E-934, "Protecting Stored Grains from Insects," for additional information about dealing with insect infestations.)

# SAFETY TIPS

Safety considerations are essential when working around a grain handling facility. Moldy grain can produce an allergic reaction and may cause respiratory problems. If you must work in or around moldy grain, wear a good, tight-fitting dust mask (see Fig. 8 and refer to AEIS-467, "Coping With Agricultural Molds and Dusts," for more information).

NEVER enter a bin of flowing grain (see Fig. 9). Flowing grain traps an adult in 5 seconds and completely covers him/her after 22 seconds. Flowing grain traps a child even quicker! Be aware of the hazards of flowing grain— YOUR LIFE MAY DEPEND ON IT!

**FIG. 8. Wear a tight-fitting dust mask when working in or around moldy grain. Moldy grain can cause an allergic reaction and respiratory problems. Check the Yellow Pages under "Safety Equipment" to find sources of masks.**



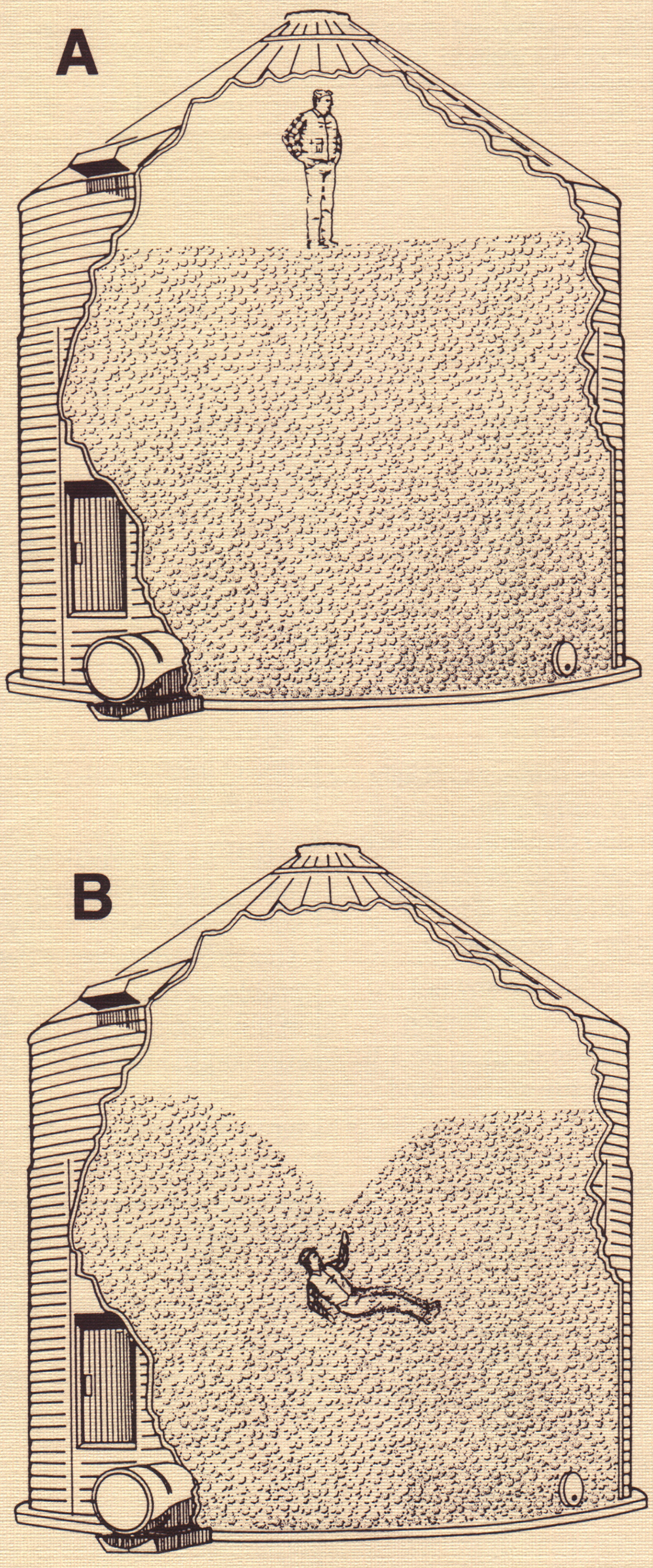
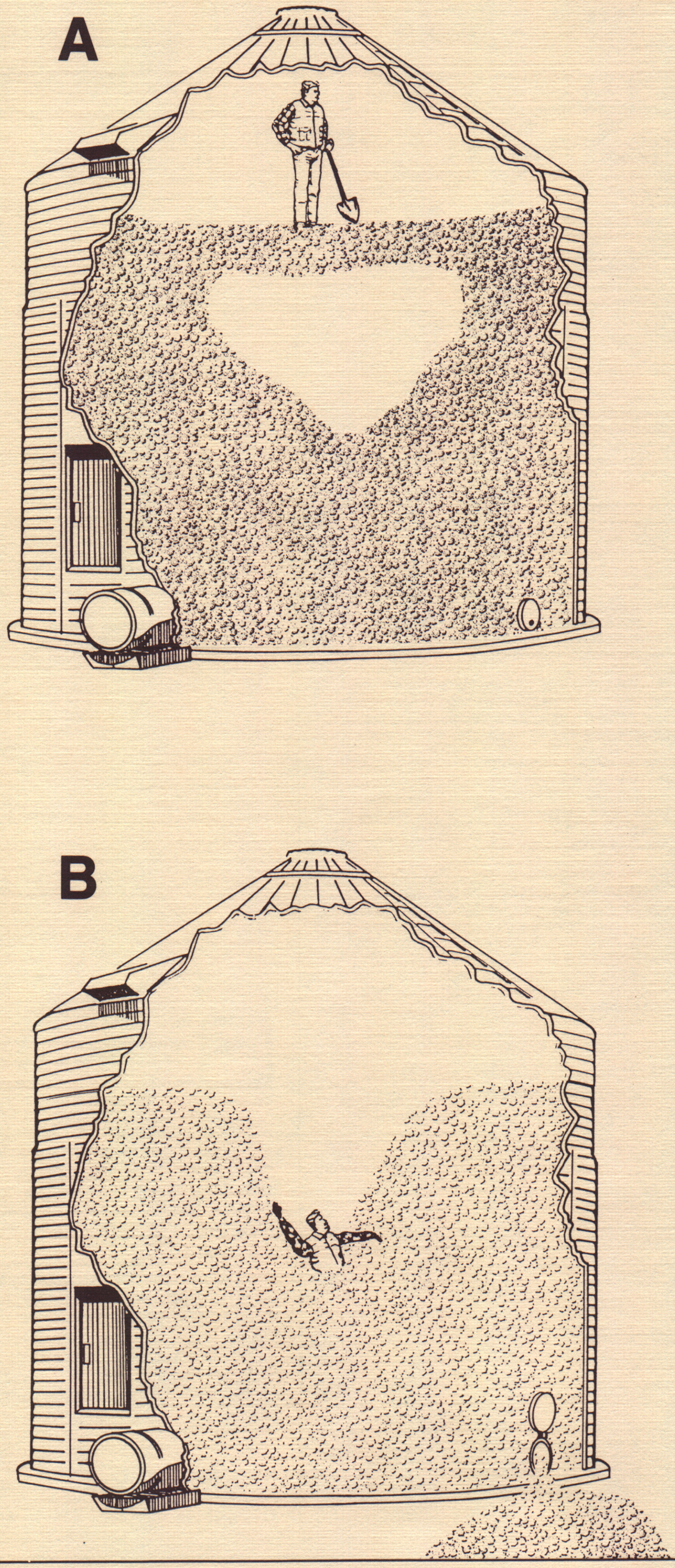



**FIG. 9. (A) Turn off and lock out the unloading equipment before walking on the grain surface. (B) Flowing grain traps an adult in 5 seconds and buries an adult in 22 seconds.**




DO NOT enter a bin without knowing its previous unloading history. Moldy grain can form a bridge at the top of the bin. Partial unloading of a bin can then result in an air pocket beneath the bridge. If you walk on the bridge, it will give way under you and you'll be trapped in the grain (see Fig. 10).

If you must enter a bin, the following safety measures can help protect you:

- Install safety ladders inside and outside of all bins.
- Lock out the unloading equipment control circuit.
- Use a rope and a safety harness when entering a potentially dangerous bin. Have two adults standing by to help you.
- If you should become trapped in a grain bin when unloading starts, stay near the outer wall and keep moving until the bin is empty and flow stops.
- In any rescue attempt, avoid becoming a second victim of the force of the flowing grain.

**FIG. 10. Always know a bin's previous unloading history before entering. Moldy grain can form a bridge. (A) Partial unloading creates a void under bridged grain. (B) A person can easily collapse the bridge by walking on or probing the grain and become trapped instantly.**

Table 3. Observations, probable causes and recommended actions for problems in dry stored corn.

| Observation | Probable cause | Solution/recommended action |
|---|---|---|
| Musty or spoiled grain odor. | Heating, moisture accumulation in one spot. | Run the fan, smell the exhaust while in the bin or in front of the exhaust fan. Run the fan to cool any hot spots. Severe damage: remove grain. |
| Hard layer or core below grain surface. | High moisture or spoiled, caked grain mass. | Run aeration or drying fan, check to see if caked or compacted mass blocks airflow. Cool out and dry if airflow is adequate; otherwise, unload to remove all spoiled grain. |
| Warm grain below the top surface. | Moisture content too high. | Run the fan, irrespective of weather conditions, until exhaust air temperature equals the desired grain temperature. |
| Slight skiffs of grain on bin surface sticking together, dragging on shoes. | Early signs of moisture migration, often noticeable only 1-2 weeks after binning. | Run aeration fan. Cool grain until exhaust temperatures equal desired grain temperature or outside air temperature. |
| Hard surface crust, caked and blocking airflow, possibly strong enough to support an adult. | Severe moisture migration and condensation in the top surface. | Remove the spoiled layer. Wear a dust mask to filter mold spores. Run the fan to cool grain when spoilage is removed. Sample grain with probe to determine condition throughout center mass below the crust. Consider marketing grain to arrest further spoilage. |
| Under-roof condensation, drip-back, surface wetting. | Warm grain in cold weather; severe convection circulation and moisture migration. | Run the aeration until exhaust air temperature equals desired grain temperature or approximate cooling air temperature at beginning of aeration cycle. |
| Wet or spoiled spots on grain surface outside center point. | Condensate drip from bolt end or under-roof fixture that funnels condensate flow; possible roof leak. | Check grain for heating. Check roof undersurface at night for condensation. Check for caulking around roof inlets, joints. |
| Wet or spoiled spot directly under fill cap. | Leaking roof cap. If gravity spout, condensate from spout. | Check bin cap seal, hold-down. Block or disconnect gravity spout so air from bin and grain cannot flow up tube. Marginal solution: hang bucket under spout inlet, check bucket for water accumulation. |
| No airflow through grain with aeration fan running. | Moldy, caked grain mass blocking flow; possible moldy grain layer immediately above perforated aeration duct or floor on pressure system. | Try to determine location and scope of spoilage. Unload storage and market, or re-bin good grain. |
| White dust visible whenever grain is stirred. | Mold on grain but in sufficient spoilage to seal top surface. | Evaluate grain condition throughout bin, if possible. Observe caution in continued storage because grain condition has deteriorated to some degree. |
| Cooling time required much longer than usual. | Increased fines in grain resisting and reducing airflow. Increased fines can cause airflow resistance 2-4 times as great as that in clean grain. | Run the fan longer; operate fan until grain and exhaust air temperature readings indicate grain is at desired temperature, irrespective of the fan time required. |
| Exhaust air temperatures in center of bin surface warmer than exhaust air temperatures away from center. | Fine material accumulation in storage center resisting airflow; airflow through center mass grossly reduced compared with relatively clean grain around outside of storage. | Run the fan sufficient time to cool the center, irrespective of the outside grain temperatures. Draw down the bin center to remove fines and decrease the grain depth for easier air passage in the center core. |
| Unknown grain conditions in the bin center. | Too deep to probe; bin too full to access; no temperature sensing cables installed. | Withdraw some grain from all bins and feed or market. Observe (look, feel, smell) first grain to flow in each withdrawal because it was resting in the center core. Withdraw any storage filled above level full as soon as possible following harvest to reduce moisture migration tendencies and permit access for observation and sampling. |

Adapted from MWPS AED-20, "Managing Dry Grain in Storage".

The Cooperative Extension Service has many other publications available on grain storage and other related subjects. Call or write your county Cooperative Extension Service office for a catalog of available publications, or write to: MSU Bulletin Office
P.O. Box 6640
Michigan State University
E. Lansing, MI 48826-6640

Following is a partial listing of some of the items available:

AM 50, **Deadly Gases: Danger Signs** ($3.00)
E 934, **Protecting Stored Grains from Insects**, 16 pp (70 cents)
E 1670, **How to Handle Moldy Feed Problems**, 4 pp (free)

These items are available from the Plan Service Secretary, 217 Farrall Hall, Agricultural Engineering Dept., MSU:

AEIS 258, **Using Silos for Grain Storage** (free)
AEIS 391, **Aeration Systems for Dry Grain** (free)
AEIS 467, **Coping with Agricultural Molds and Dusts** (free)
AEIS 478, **Using Buildings for Grain Storage** (free)
AEIS 558, **Temporary Corn Storage in Outdoor Piles** (free)
USDA Marketing Bull. 72, **Grain Protectants for Insect Control** (free)



Issued in furtherance of Cooperative Extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. W.J. Moline, Director, Cooperative Extension Service, Michigan State University, E. Lansing, MI 48824.



New-5:88-3M-KMF-SP, 85¢,For Sale Only

FILE: 18.15 or 22.07 (Field Crops-General)