Cornell Cooperative Extension
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NORTHEAST SARE
Sustainable Agriculture Research & Education

Farm Specific Grain Management Program

- Basic Steps to Store Grain
- Managing Dry Grain In Storage (Purdue)
- Maintaining Quality In On-Farm Stored Grain (SLAM, Univ of TN)
- Grain Bin Safety (Univ. of Illinois)
- Average Monthly Temperatures – Albany, NY
- Allowable Storage Times for Grains
- Fan Selection for Grain Bins, website address
- Grain Equilibrium Moisture Charts
- Tables: Grain Weights, Bin Capacities, Static Air Pressure & Flow
- Websites for Grain Safety
- Websites for Grain Storage
- Grain Grading Standards
- Grain beetle key and pictures
- Stored Grain Pests Identification

The purpose of this program is to train farmers in grain storage management and develop/refine the protocols and procedures needed for their grain facility. Along with the FSGM Records booklet, the cost of storing grain can be determined.

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November 2020

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Basic determinations made in grain storage management:

- What is the moisture content and temperature of the grain at harvest?
- How long can it be stored at that moisture and temperature?
- How will the grain initially be held (in what structure/bag) and what is the capacity of the system to deliver heat and air to dry it.
- Storage structure volume and fan capacity must be matched properly to deliver the need cubic feet per minute (CFM) of air.
- If heat is used to dry the grain, how will it be tempered and cooled before long-term storage.
- For long-term storage, how will the grain be cooled as the ambient temperature drops as winter progresses, to keep it within 15^{O} F of the average monthly temperature. The grain must be cooled down in steps as winter temperatures drop.
- How will grain be monitored periodically (bi-weekly, monthly) for temperature, moisture, and pests?

There are references to grain storage manuals that help you need to design storage, aeration, and drying systems:

- **Midwest Planning Service - https://www-mwps.sws.iastate.edu/catalog/grain-handling-storage**
- **North Dakota State University, https://www.ag.ndsu.edu/graindrying**
- **University of Nebraska, https://lancaster.unl.edu/ag/crops/storage.shtml**

AED-20

Purdue University

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MANAGING DRY GRAIN IN STORAGE

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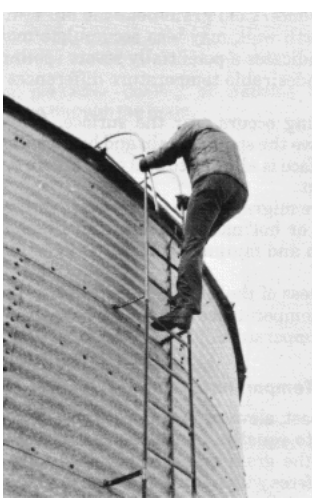
Contents



This publication can help you maintain the dollar value of a bin of dry grain. Although storage problems commonly occur during the bad harvest year, many also result from poor dry-grain management practices. Proper use of aeration and insect control, along with an adequate observation program minimize these dry grain problems.

Human safety around flowing and stored grain is included. Neither the design and selection of a system nor grain drying practices are included.

Storage Problem Causes

If grain has been dried correctly for the storage period intended, problems with grain condition usually result from:

*Improper grain cooling.

*Inadequate observation of the stored grain.

*Poor initial grain quality.

*Improper insect control.

Each of these problems can be minimized with good management.

See Table 1 for safe grain moisture contents for storage. Reduce the moisture 1% below table values for poor quality grain resulting from drought, frost, blight, harvest damage, etc.

Table 1. Maximum moisture contents for safe grain storage.

Values for good quality, clean grain and aerated storage: reduce 1% for poor quality grain, such as grain damaged by blight, drought. etc.

Grain type & storage time	**Maximum moisture content for safe storage, %**
Shelled corn and sorghum	
Sold as #2 grain by spring	15 1/2
Stored 6-12 mo	14
Stored more than 1 yr	13
Soybeans	
Sold by spring	14
Stored up to 1 yr	12
Stored more than 1 yr	11
Wheat, oats, barley	
Stored up to 6 mo	14
Stored more than 6 mo	13
Sunflower	
Stored up to 6 mo	10
Stored more than 6 mo	8
Flaxseed	
Stored up to 6 mo	9
Stored more than 6 mo	7
Edible beans	
Stored up to 6 mo	16
Stored more than 6 mo	14

Grain Temperature and Moisture Migration.

More dried grain goes out of condition because grain temperatures are not controlled than for any other reason. Improper control of temperature causes moisture to move or migrate from one part of the grain mass to another, where the moisture can accumulate and cause grain spoilage problems.

Although moisture migration problems can occur any time grain temperatures vary considerably in different parts of the bin, the most critical time occurs when warm grain is stored into cold winter temperatures. Grain is typically put into storage when the grain temperature is 50-80 F, and perhaps higher.

A bin of grain has 30%-60% air space within the grain mass, and this air surrounding the grain is at the same temperature as the grain.

By late fall or early winter, average outside temperatures fall to 20 F and colder in the Corn Belt, This drop in temperature causes the grain and air near the bin walls to cool. Because grain has fairly good insulating qualities, most of the large center mass of grain and air in the bin remains at about the same temperature as it was when placed in storage.

These temperature differences create a slow movement of both moisture and air. This natural air circulation is called convection currents.

Convection currents develop because the grain and air near the bin walls cool. Cooling causes the air to become heavier and settle toward the bin floor. As the air moves toward the floor and then into the center of the bin, it becomes warmer and less dense or lighter. This causes the air to rise through the warm grain where it continues to increase in temperature. As the air increases in temperature, its moisture-holding capacity increases and it begins to absorb small amounts of moisture.

The slowly moving air rises into the cooler grain mass in the upper portion of the bin where the air is cooled. Some of the moisture in the air is deposited in the grain by both moisture condensation onto the cold grain surfaces and by moisture diffusion into the cooler grain.

Fig 1 shows this natural movement of air and moisture, called moisture migration, which is the most common cause of problems in stored grain.

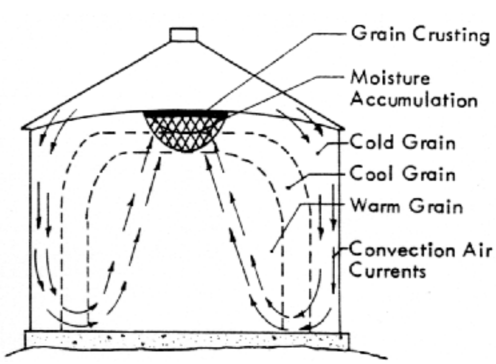


Fig 1. Winter grain temperatures and moisture migration

Often, minor moisture migration problems can result in severe spoilage. Check grain often for signs of moisture migration. Look for crusting, wet, slimy grain, ice or frost accumulation, and/or heating. Check for condensation or frost on the underside of roof surfaces, hatches, and vents on cold, crisp days before the sun warms the roof. This almost always indicates moisture migration and often indicates poor grain condition.

Increased moisture content and crusting usually occur at the top center of the grain surface, but can occur anywhere. Cold grain near the bin wall, often the cold north wall, may also accumulate moisture. Crusting indicates a potentially severe spoilage process and undesirable temperature differences in the grain.

If crusting occurs, stir the surface. In extreme cases, remove the spoiled grain and begin aerating. If the top surface is allowed to seal over, severe spoilage is imminent.

Moisture migration can occur in cold grain stored into warm or hot months. Aerate in the spring to warm grain and minimize moisture migration problems.

Regardless of the time of year it is best to maintain grain temperatures within 15-20 F of the average monthly temperature.

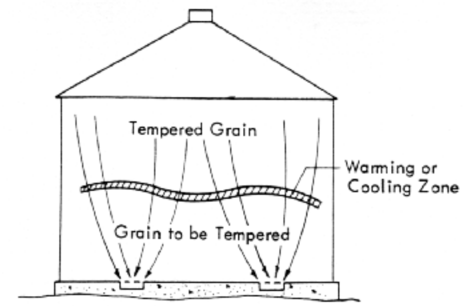
Aerate for Temperature Control

In the past, elevator operators turned grain from bin to bin to equalize temperatures, cool the grain and blend the grain mass. Although turning effectively interferes with natural moisture migration and breaks up hot spots, turning requires an empty bin, time and labor. It also tends to damage more grain.

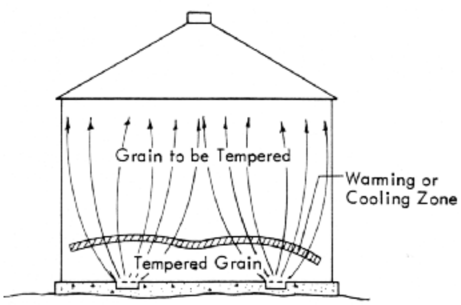
Modern grain management uses aeration to control grain temperature. Aeration forces air through the grain either continuously or intermittently. Aeration is **not** drying although small moisture changes do occur with a change in temperature. Aeration may be used to maintain quality in wet grain and to cool hot grain from a dryer, but these practices require special procedures that are not discussed in this publication.

Aerate to cool stored grain in the fall so there is no warm grain mass in the center of the storage. Aerate to warm the grain in the spring if storage is to be continued into the hot summer months.

Fig 2 shows how grain is tempered (cooled or warmed) by either negative or positive pressure aeration systems With either system, a tempering (cooling or warming) zone moves through the grain.



Negative pressure—cooling or warming zone moves down through the grain.



Positive pressure—cooling or warming zone moves up through the grain.

Fig. 2. Aerating to change grain temperature.

Grain behind the zone of cooling or warming has been tempered. Grain in the zone is changing and approaching outside air conditions. Grain in front of the zone has changed very little. One temperature change or cycle is the time needed to move the tempering zone completely through the stored grain mass.

The tempering zone starts at the top of the grain in a negative pressure or suction type aeration system and moves down. The last grain to cool or warm is normally next to the floor.

In a positive pressure system, the tempering zone starts at the bottom of the bin and moves up. The grain at the top is normally the last to cool or warm.

The movement of the tempering zone completely through the grain is one cooling or warming cycle. Once a cycle bas been started, operate the fan continuously until the zone moves completely through the grain. The time required to complete each cycle depends almost entirely on the aeration airflow rate, as shown in Table 2.

Table 2. Approximate times for one grain cooling or warming cycle.

Times are based on 60-lb bushels in the Midwest and 10-15 degree 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

Grain drying or rewetting is usually insignificant during grain aeration. Because the cooling (or warming) front moves through the grain about 50 times faster than a drying or wetting front, only a small fraction of the grain is rewetted during an aeration cycle, even with high humidities. As a precaution, operate the aeration fan only long enough to accomplish the grain cooling or warming cycle. This is particularly important with higher capacity aeration fans.

Although round bins are shown in all of the figures in this publication, the basic storage and aeration principles are the same for flat grain storage.

Aeration Airflow Rates

Successful aeration rates for farm-type storage usually range from 1/20 cfm/bushel (cfm = cubic feet of air per minute) to over 1 cfm/bushel in bins equipped for rapid grain cooling or drying. About 1/10 cfm/bushel is most common in farm bins, with higher rates more often selected for new bins. The aeration rate for a particular bin depends on the type of bin, air distribution system, desired storage moisture content, and the management procedures to be practiced.

The time for one cooling or warming cycle to completely pass through grain depends on the aeration rate (cfm/bushel) and the time of the year. The number of hours is estimated by:

$$\text{Hours} = \frac{15}{\text{cfm/bu}} \quad \text{(fall)}$$

$$\text{Hours} = \frac{20}{\text{cfm/bu}} \quad \text{(winter)}$$

$$\text{Hours} = \frac{12}{\text{cfm/bu}} \quad \text{(spring)}$$

Example: During the fall, 1/10 cfm (bushel moves one cooling cycle through the grain in approximately 150 hours, or about 6 1/4 days (150/24), or

$$\frac{15}{1/10 \text{ cfm/bu}} = 150 \text{ hours}$$

The hours for several aeration rates have been calculated for you in Table 2.

Usually two or three cooling cycles are needed to cool or warm the grain to the desired storage temperatures.

Cooling Grain tor Winter Storage

Aerate grain to cool to 35-40 F for winter storage in most of the Midwest. In the northern parts of the Midwest (South Dakota, North Dakota, Minnesota, and Wisconsin), cool stored grain to below 35 F because of colder average winter temperatures.

Start an aeration cycle when the average daily temperature, (high day temperature + low night temperature) / 2, is 10-15 F cooler than the grain. For example, if the high and low daily temperatures are 68 and 56 F, respectively, the average temperature is 62 F. For this example, if grain temperature is above 72 F, start the aeration cycle. Grain from a high temperature dryer is usually 10 F or more above air temperature, so start the aeration cycle immediately.

Operate aeration fans long enough to cool all grain or spoilage may occur. Table 2 estimates 150 hr. (nearly a week) are needed for each cycle to cool grain in the fall assuming a fan capacity of 1/10 a cfm/bu. However, about 2 weeks after the cycle is completed, outside temperatures will have dropped another 10-15 E Repeat the aeration cycle. A maximum of three cooling cycles are needed to properly cool grain for winter storage. Fig 3 shows how outside temperatures and grain temperatures typically lower during the fall with three 1/10 cfm/bu aeration cycles, totaling possibly 500 hr of fan operation (150 hr + 150 hr + 200 hr).

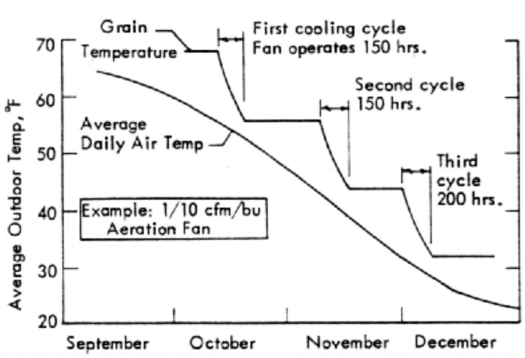


Fig 3. Example of aeration cooling cycles.

The number and length of cooling cycles depend on fan capacity, when and at what temperature grain was binned, and how fast average air temperatures cool during the fall. For example, 1 cfm/bu cools 10 times faster than 1An cfm/bu and requires only 15 hr for one cycle.

Some operators prefer only two cooling cycles to conserve energy. Cool grain to 50-60 F in the first cycle. Delay the second aeration cycle until outside temperatures will cool grain to 35-40 F.

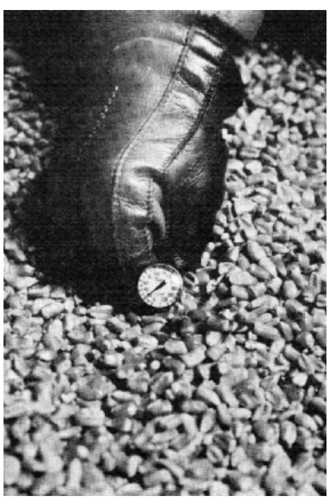
With low airflow rates (less than 1/5 cfm/bu), you can largely ignore outdoor humidity. Cooling the grain is important. Keep the fan running even if outdoor air has high humidity for a day or two. Any rewetting during these wet periods helps offset the unwanted drying during previous good weather periods. Many operators with airflow rates of 1/10th cfm/bu operate the fan continuously from the time the initial fill is placed in the bin at harvest, until outside air temperatures of 35-40 F have prevailed for at least 1-2 weeks. With higher airflow rates (more than 1/4 cfm/bu), each cooling cycle is short enough that aeration can be delayed a day or two to avoid warm, high humidity air conditions. **But if there are any signs of heating or hot spots, no matter what the season or the weather, run the fan continuously until no heating can be detected**.

Be sure to continue each aeration cycle until the cooling front has moved completely through the grain. This minimizes the chances for a moisture front within the grain mass that can cause spoilage.

You need to know how fast your aeration fan will move a cooling or warming cycle through a bin. If you don't know the aeration rate (cfm/bu), contact the dealer who furnished the fan.

To be sure the cooling or warming front has passed through the grain, check the grain or air temperature, Fig 4. On a negative pressure (suction) aeration system, check the temperature at the fan discharge. With positive pressure systems, where air is blown up through grain, check grain temperatures by placing a thermometer about 6"-12" into the grain. A sudden change in temperature indicates that the cooling or warming front has passed through the grain. The temperature will be about the average outdoor temperature when the aeration cycle was started.

4a. Suction (negative pressure) aeration.



4b.Positive pressure aeration.

Fig 4. Thermometer locations to monitor progress of aeration cycles.

Be aware that a thermometer in the airstream provides an average temperature. Air passes around pockets of fines and may not totally reflect temperature differences. Also, the tempering zone may not have completely passed through grain near the center if grain is peaked or contains more fines.

Making sure all grain has cooled is especially important during the last aeration cycle. With a suction system, unload some of the grain and check the temperature of the first few gallons to check the bottom grain. Check the next few gallons to check the critical center mass. If any temperatures are higher than the air temperature, run the aeration fan until all grain is cooled.

On pressure systems, check grain temperatures 6"-12" into the upper surface in several locations to confirm when the cooling or warming zone has passed through the grain.

Air does not pass through pockets of fines. These pockets can start heating and spoil. Although not completely reliable, taking temperatures, particularly numerous temperatures in a pressure aeration system, can help detect these hot spots.

Record grain temperature readings along with the date and the air temperature taken in the shade near the bin site. Cross check the time for a cooling or warming cycle with Table 2. If cooling or warming is taking much longer than expected, either your airflow is less than you thought (which is useful information for next year) or many fines may be blocking airflow. Once you establish this time for one aeration cycle, it will always take about the same time to move a temperature change through that depth of grain for the same bin and aeration equipment.

Freezing grain slightly decreases the potential for spoilage but is not needed for grain that is properly dried, aerated and managed. Because of possible problems, freezing grain is not encouraged.

Condensation during aeration can be a problem in grain cooled well below freezing. It may be difficult to warm grain in the spring without condensation immediately freezing into ice. Frozen chunks of grain block aeration warming cycles and grain unloading. In the winter, operate aeration fans in frozen grain only with relatively dry air that is as cold or colder than the grain.

In the spring, start warming grain as soon as the average daily air temperatures are about 10 F warmer than the grain to avoid excessive condensation and freezing. High airflow aeration for warming grain is advantageous because faster warming reduces the need for aerating in undesirable (particularly high humidity) weather.

Observation and Management of Stored Grain

Observe dry grain in storage weekly during the critical fall and spring months when outside air temperatures are changing rapidly, and during the summer. Check at least every 2 weeks during the winter. Establish a **regular** day of the week and time of the day to check grain to avoid forgetting.

Observe grain by climbing into the bin. If you have filled the bin to the roof, sell or feed enough grain so you can safely get onto the grain surface. You're searching for small changes, indicators of problems to come. Check the surface for indications of crusting-wet, sticky or frozen grain. Observe the roof for evidence of present or past condensation. Thrust your arm into the grain and see if you can detect any heating. Grasp a handful of grain from arm depth and the surface, and smell for musty, moldy odors. Run the fan to smell exhaust air. Keep a small diameter, stiff rod, such as a long endgate rod with a loop for a handle, in each bin. Poke the rod into the mass, down the center, outward toward the sides. Feel for any hard, compacted or moist masses. Leave the rod thrust into the grain when you leave. Tie it to the roof! Withdraw it quickly next time you check the grain to feel if you can detect warmth. See the appendix for a summary of observations and corrective actions in managing grain.

Once the grain has been cooled, run the aeration fan to smell the exhaust air for bad odors coming from grain that might be going out of condition and to dry condensation in the fan motor. When you run the fan, pick a clear, crisp day when the air and the grain are at about the same temperature. Because this day may not always occur on your chosen, regular inspection day, it may not be feasible to always run the fan when you check grain condition.

It is best to cover the fan intake when not aerating to block the air draft that is drawn in through the fan and up through the grain by the natural chimney effect of tall bins. Covering the fan also prevents rodent and pet access.

If additional aeration is needed to cool small hot spots, run the fan as long as outdoor air is not more than about 10 F above the grain temperature. If necessary, turn off the fan during the warm part of the day. If serious heating is occurring, run the fan day and night regardless of weather and temperature until the heating has stopped.

If the heating can't be stopped, the best action will likely be to remove the grain for drying, cleaning, breaking up hot spots, or for selling. Remember, it's better to sell grain with a minor storage problem, even at low grain prices, than to permit a bin to go completely out of condition.

Warming Grain In the Spring

Consider warming the grain with the aeration fan if:

*The grain will be stored into July and August.

*The grain was accidentally or intentionally frozen.

Spring warm-up prevents moisture migration with resulting high-moisture pockets that may spoil. Proper warming thaws any frozen grain that may interfere with aeration or handling.

Start the fan when the average outdoor temperature is 10-15 F above the grain temperature. Always run the fan continuously for a complete warming cycle; i.e., until the warming front has moved completely through the grain and the average grain temperature has been raised 10-15 F. Stopping midway almost guarantees a deposit of condensed moisture that will encourage spoilage. Repeat the warming cycles as needed to bring the average grain temperature up to 50-60 F.

Conduct weekly grain inspections. Warmer weather and warmer grain temperatures encourage mold and insect activity.

Summer Management

Do not warm the grain to high summer temperatures (80-90 F). Aerate as needed if heating occurs, but stop spring warm-up at about 50-60 F.

Although some good grain managers are storing corn at 15 1/2% into summer in the colder areas of the Corn Belt, the grain should be down to the moisture contents in Table 1 to minimize risk. All of the grain in the storage must be at or below the maximum. Pockets of higher moisture grain will likely spoil.

Other Aeration Tips

Do not operate suction aeration systems until several feet of grain are in the bin to avoid pulling fines toward the duct. Also, perforated floors and metal perforated ducts get cold while the fan is off. When the fans start, warm, moist air from the grain can condense on the floor and in grain near the floor. Wet grain can spoil and plug the aeration system.

Cover aeration fans when they are not being used. Warm, moist air can be drawn through uncovered aeration fans and condense on cold metal ducts and perforated floors.

Check stored grain weekly during critical fall and spring months and at least every two weeks during winter. Check for odors by turning on the fan and smelling the exhaust air. A foul or musty odor is an early indicator of a problem. Also, check and record the air temperature. An increase in temperature also indicates a problem. When in a bin feel and probe the grain to check for insects and other problems.

Commercial automatic aeration control systems are available that use humidity and temperature to control fans according to preset conditions. Controls can be incorporated with a computer to monitor, control, and record fan operation. Automatic controls are useful and can relieve you of some management tasks, but regular monitoring is important to make sure the system is working properly. The grain value is worth the effort. Do not use automatic controls during spring warm-up because continuous fan operation is essential.

Aeration Costs

Operating a grain aeration system is very inexpensive. Operating cost hours x kilowatts (kW) x cents/kilowatt-hour (kWh). For estimating, assume that 1 hp = 1 kilowatt. Therefore, operating cost is approximately equal to fan horsepower x hr x cents/kWh. To properly cool or warm a bin of grain seldom exceeds 1/10 cents per bushel for electricity-a very small cost compared with the benefits!

Peaking Grain in Storage

Most dry grain peaks at an angle of 18-28 degrees for center filling without a distributor. Estimate the volume of corn in bushels stored in the peak of a round bin with Eq 1. Eq 1 is based on a filling angle of 23 degrees. Capacities for other grains will vary, but Eq 1 provides a suitable estimate.

```
Peak capacity = 0.044 x D x D x D          Eq 1.
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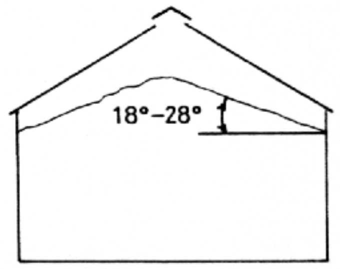
For example, the estimated capacity of the peak in a 24' diameter round bin of corn is 608 bu (0.044 x 24 x 24 x 24). Although it is tempting to store those extra bushels, peaked grain is more difficult to uniformly aerate which can cause moisture migration problems.



Natural filling angle for most dry grains

Peaking also makes it difficult and dangerous to enter the bin for observation. Because of dust and high temperatures during the summer, entering a small space between roof and grain should be prohibited. Shifting grain may block the exit.

If the grain is peaked during harvest, withdraw the peak immediately after harvest. Lowering the center core of the bin improves airflow through the center of the bin, and probing and sampling are made easier and safer. Some fines are also removed.

Managing Fines in Storage

Broken grain and foreign material, or fines, can create two problems in stored grain, particularly when they accumulate in pockets. First, broken kernels are more susceptible to spoilage than unbroken ones. Second, airflow from aeration fans tends to go around pockets of fines so they cool more slowly. These pockets often develop into hot spots that result in spoiled grain.

Strive to minimize the fines produced from harvesting, drying, and handling, rather than later trying to solve resulting storage problems. Consider three grain storage management techniques that avoid problems from fines that do go into the storage:

> *The most common technique is to use a grain spreader to minimize concentration of fines.
>
> *Grain can also be cleaned before binning to improve storability. Unfortunately, cleaned grain may have no greater market value. Fines do have value, both as livestock feed and as added weight in market grain. It makes sense for livestock farmers to clean all their feed grain because they can feed the fines. Unless fines are causing serious storage problems or grade reduction, cash grain farmers may lose money by cleaning grain unless they can sell the gleanings to a livestock farmer or grain elevator.
>
> When planning a new grain storage and drying system, plan for a way to include grain cleaning now or in the future. The grain grading rules may change to make on-farm grain cleaning profitable.
>
> *Another possibility is no grain spreading coupled with frequent withdrawal of the center core of grain to remove accumulated fines. Direct the flow of grain toward the exact center of the storage. The grain drops onto the grain pile and rolls down toward the outside wall. Remove grain at regular intervals (daily or more often) during filling to remove the peak. The goal is to draw the surface daily to an inverted cone with a diameter of 4' to 10'. Repeated withdrawals remove many of the fines that accumulate in the center core. See Fig 5.

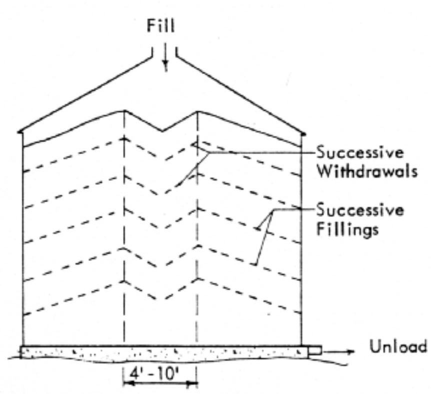


Fig 5. Withdrawals during tilling remove most fines from the 4-10' core.

A secondary benefit of nondistributed filling is that the grain rolling down the cone of grain results in a looser fill than when using a grain distributor. This loose fill reduces the resistance to airflow through the grain. However, with nondistributed fines not removed by withdrawal, the aeration airflow patterns in the bin may not be uniform

Temperature Sensing

Consider installing temperature sensing units in large grain storages. Fig 6 illustrates locating four cables with temperature sensors 4'-5' apart along each cable. Suspend the cables from the roof. Mount the center cable to one side of the center of the bin to reduce the drag on the cable when unloading grain. Check with the bin manufacturer to be sure the cables, supports and roof can withstand the drag from grain filling and unloading. Anchor the bottom of the cables to assure alignment but allow for a sweep unloader. Bring the circuits from the top of the cables to a central point for attaching to the read-out device.

Temperature sensors accurately trace the progress of aeration cooling or heating cycles. They help identify hot spots within the grain mass. They also indicate overall heating and approximate average grain temperature.

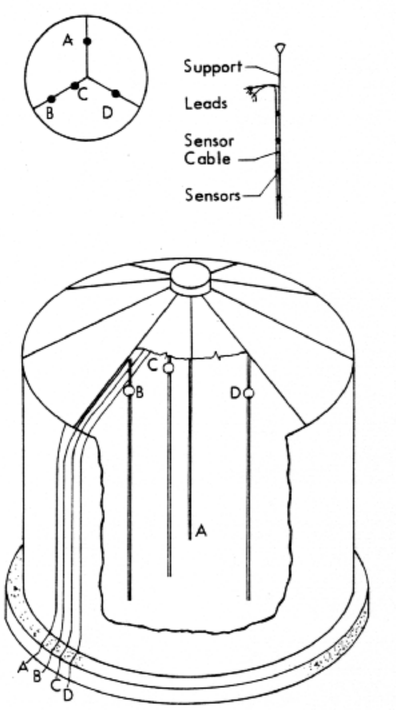


Fig 6. Bin temperature sensing system.

Four sensing cables are suspended from the roof: 3 are half way from wall to bin center, one is close to the center.

Temperatures may change only 1-2 F per week so read and record them accurately. A continual increase in temperature is a warning that must be heeded, especially if one spot in the bin is heating faster than the bin as a whole. Experience indicates that once heating starts, it continues to increase at an increasing rate until cooling is applied.

Insect Control in Stored Grain

Insect infestations in storage can come from grain residues in combines, handling equipment, and old grain left in storage. Correctly drying, aerating and managing stored grain minimizes the risks of insect infestation and damage. Insect activity goes with moisture accumulation and grain heating. Whenever grain will be held during the warm part of the year, practice regular preventive treatment. Where infestations are more often found with poor quality grain, or where there is an occasional slip in overall management, emphasize observation and control. Look for insect activity during every storage visit. Follow this preharvest checklist:

1.Clean all debris from harvesting. handling and drying equipment (trucks, augers, elevators).

2.Sweep old grain, grain particles and dust from inside the bin. If possible, remove debris under perforated floors and dispose of the sweepings by burning, burying, etc. or saturate this debris with malathion, Actellic or Reldan.

3.Repair bin if any signs of water leakage are found (spoiled grain on the floor holes in the roof, etc.).

4.Apply malathion, Actellic or Reldan to all surfaces of clean, empty bins.

5.Remove piles of boards, spilled grain, and vegetation from around the bin that attract rodents. If there is no chance of runoff to adjacent fields, gardens, etc., spray a 2 band of soil sterilant around the foundation so vegetation will not grow.

6.Do not put new grain on top of old grain. Just a few insects in the old grain can contaminate the entire bin.

Preventive Insect Control

For frequent insect problems, apply a grain protectant in addition to using a residual insecticide spray.

*Spray grain being augered or elevated into the bin with a protectant--1 pint 57% malathion in 3 to 5 gallons water per 1,000 bushels of grain. After the bin is full, apply a cap-out Actellic spray-3 oz Actellic in 2-3 gal water/1,000 ft^2.

* Apply one-half of the product and incorporate to a depth of 4-5 inches. Apply the other half without incorporation. Cap-out treatments are not effective in controlling large infestations late in the summer. Cap-out treatments should be applied in spring, before grain temperatures are warmed above 50 F. The cap-out spray is a barrier against insects entering or feeding on the grain surface.

Controlling an infestation

You have two alternatives for controlling a stored grain infestation:

*Fumigate with a liquid, solid, or gas grain fumigant in storage or as the grain is being turned. **Fumigants arc toxic and must be applied with proper safety precautions and equipment**. Each fumigation job is different; hire a commercial applicator.

*If rice weevil is not present and the grain can be turned into a nearby empty bin, apply an actellic or malathion grain protectant. Also, passing grain over a screen removes many insects and debris.

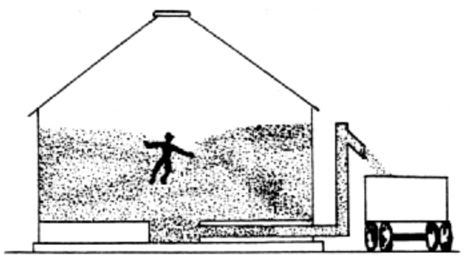
Safety Practices

Take time to review safety measures with workers and all family members. "Better safe than sorry" is very real around grain and hazardous machinery.

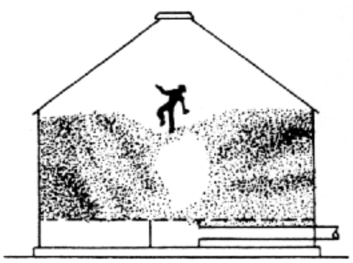
Absolutely forbid entry into a bin or gravity unload vehicle when grain is flowing. It is a major cause of accidental death when handling and unloading grain.

With modest flow rates of a 6" auger, you are helpless only two to four seconds after stepping into the cone of flowing grain. You are totally submerged within 20 seconds at a grain flow rate of only 1,000 bu/hr.

A child submerges even more quickly. Even in gravity-unload vehicles not as deep as the child's height, the massive outflow rate drags him down into the discharge cone, folding his legs and shortening the height necessary for complete submergence and suffocation.



Flowing grain can trap and suffocate you In seconds.



Crusted or bridged grain can collapse and bury you.

Safety Precautions

* Don't enter a bin of flowing grain.

* Don't enter a bin to break a crust or remove a blockage when unloading equipment is running, whether or not grain is flowing. Restarted flow can trap you.

* Before entering a bin or cleaning or repairing conveyors:

    * Lock out the control circuit on automatic unloading equipment, as on a wet holding bin.

    * Flag the switch on manual equipment so someone else doesn't start it.

* Don't enter a bin unless you know the nature of previous grain removal, especially if any crusting is evident.

* Beware of walking on any surface crust.

* Don't depend on a second person--on the bin roof, on the ground, or at some remote point-to start or stop equipment on your shouted instructions.

    * Equipment noise can block out shouts for action or assistance.

    * That person may fall or over-exert in the panic and haste of getting off the bin or running to the control point.

* Be wary and alert while working with grain that has gone out of condition--there may be molds, blocked flow, cavities, cave-ins or crusting.

* When entering a questionable bin or storage, have two outside and one inside workers. Attach a safety rope to the man in the bin with the two men outside capable of lifting him out without entering the bin. One man outside cannot do this and cannot go for help while giving first aid.

* Always wear a respirator capable of filtering fine dust to work in obviously dusty-moldy grain. Never work in such conditions, even with protection, without a second person on safety standby.

* Parents, watch your children.

* Keep them away from bins and vehicles with flowing grain.

* Small hands and feet can penetrate even properly shielded augers, belts and PTOs.

* If a grain bin is peaked close to the roof, be extremely cautious. Crawling between roof and peak can cave grain and block the exit.

* Maintain proper and effective shields and guards on hazardous equipment.

Appendix-Observations and Actions in Management of Dry Stored Grain

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. If damage is severe, remove the grain.
Hard layer or core below grain surface.	High moisture or spoiled, caked grain mass.	Run the aeration or drying fan. Check to see if caked or compacted mass blocks airflow. Cool 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 regardless of weather conditions until the exhaust air temperature equals the desired grain temperature.
Surface grain wet or slimy. Perhaps grain sticking or frozen together.	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 temperatures.
Hard surface crust, caked, and blocking airflow. Possibly strong enough to support a man.	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 after 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 dripping onto surface.	Warm grain in cold weather, severe convection circulation and moisture migration.	Aerate until exhaust air temperature equals outdoor 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 under surface at night. Check for caulking around roof inlets and joints.
Wet, spoiled spot directly under fill cap.	Leaking roof cap or condensed water from gravity spout.	Check bin cap seal and hold down. Block or disconnect gravity spout so air from bin and grain cannot flow up tube. Marginal solution: hang bucket under spout inlet and check bucket for water accumulation.
No Air flow through grain with aeration fan running.	Moldy, caked grain mass blocking flow; possible moldy grain layer immediately above aeration duct or perforated floor on suction 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 not sufficient spoilage to seal top surface.	Wear dust mask in working grain. Evaluate grain condition throughout bin where 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 to increase as much as 2-4 times over that of clean grain.	Run the fan longer time. Operate fan until grain and exhaust air temperature readings indicate grain is at desired temperature, regardless of the fan time required.
Exhaust air temperatures in center of bin surface warmer than those away from center.	Fine material accumulation in storage center resisting airflow; airflow through center mass grossly reduced compared to relatively clean grain around outside of storage.	Run the fan sufficient time to cool the center irrespective of th 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 to feed or market. Observe (look, feel, smell) first grain to flow with each withdrawal, since it was 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.

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The University of Tennessee
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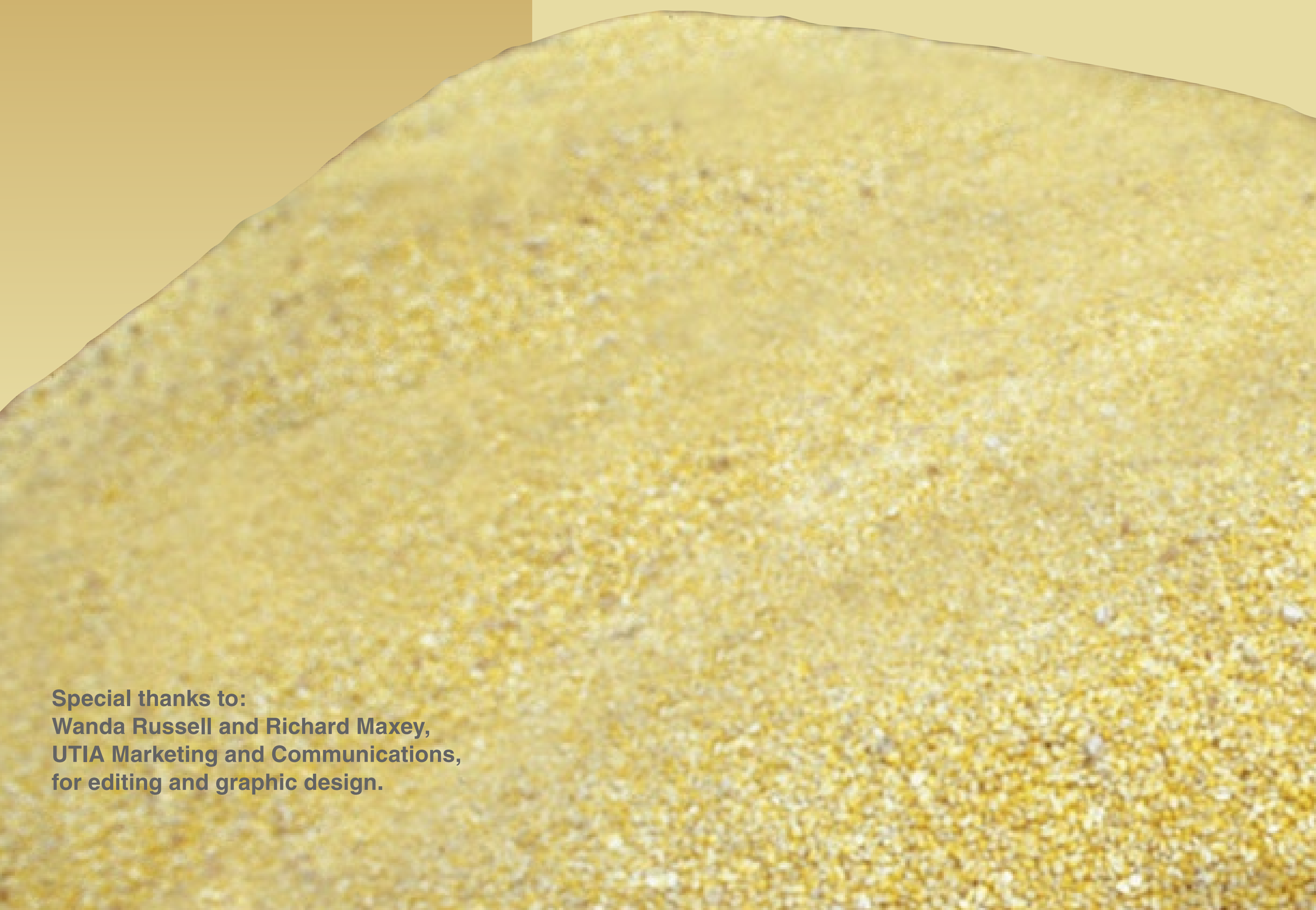
PB1724

Maintaining Quality in On-Farm Stored Grain

Contents



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Maintaining Quality in On-Farm Stored Grain

Michael J. Buschermohle, Professor; Lester O. Pordesimo, Associate Professor; and Luther R. Wilhelm, Professor; Biosystems Engineering and Environmental Science

Introduction

Industry concerns over grain quality, along with increased production of specialty, identity-preserved and food-grade crops, have placed increased focus on grain quality and storage issues. Most damage that occurs during storage is caused by molds and insects. Grain spoilage occurs as microorganisms feed on the nutrients in the grain. As they grow and develop, these microorganisms produce heat, which increases the temperature of the surrounding grain. This heating may result in hot spots. If the temperature and moisture in the grain are just right, the major mold species Apergillus, Fusarium and Pencillum may produce mycotoxins such as aflatoxin, fumonisin, DON and zearalenone. These mycotoxins can cause serious illness and even death when consumed by humans or livestock. The presence of mold does not mean that mycotoxins will be present, but rather the potential exists for their development with the right combination of temperature, grain moisture content and storage time. Even more frustrating is the fact that the absence of mold does not guarantee that mycotoxins are not present.

This is because the growth of the mold may not be extensive enough to cause visible damage, but nevertheless, it can still produce toxins.

Economic losses caused by stored grain insects can be measured in several ways. When the grain is sold, costly discounts are levied for insect damage. More importantly, infested grain results in dissatisfied customers and a poor reputation in marketing channels. Left untreated, insect infestations will eventually lead to other storage problems. Insects give off moisture that can cause grain moisture contents to increase enough to create a mold problem. Mold activity will in turn raise temperatures and result in an increased rate of insect reproduction. Greater numbers of insects create more moisture, and the cycle is repeated at an ever-increasing rate. Management of field insect pests often receives more attention than storage pests. However, storage losses are often equal to or greater than field losses due to dockage and contamination of the grain.

Grain quality will not improve during storage. At best, the initial quality can only be maintained. Once grain is stored, the quality depends on your control and management of the storage system. Molds and insects need adequate food, moisture and temperature to survive and reproduce. Since food is always available in stored grain, grain moisture and temperature must be maintained at levels that are detrimental to mold and insect growth.

Grain Moisture and Temperature

Grain moisture content and temperature interact to affect storage risks. Even the best management practices will not keep grain from spoiling if the moisture content and temperature are too high. For example, grain that is held continuously at 75 degrees F and 25 percent moisture content will deteriorate more in four days than 15 percent moisture grain held at 60 degrees F will in 250 days. As little as a 0.5 percent moisture increase can mean the difference between safe storage and a damaging invasion by storage fungi.

Favorable moisture and temperature levels must exist for fungi to grow. Recommended storage moisture contents depend on the length of time that grain will be stored, and are given in Table 1. These recommendations refer to the wettest grain in the bin, not the average moisture content. These moisture contents may be too high if the grain is poorly managed in storage. Reduce the recommended moisture contents by 1 percentage point when storing low-quality grain. This includes immature grain, severely cracked and damaged grain, and grain subject to previous insect or mold activity. The influence of grain temperature and moisture become especially important in long-term storage.

Grain moisture content and temperature also influence insect population growth and reproduction. At low moisture levels, insects that feed on stored grain have a more difficult time obtaining the water necessary for growth and development. Optimum feeding and reproduction for most insect species typically occur between 70–90 degrees F. As grain temperatures drop below 50 degrees F, most visible insect activity, including feeding, ceases. Most insects do not enter hibernation at these low temperatures, but do become less active. Insects that don't feed at these lower temperatures will use up stored energy reserves and eventually die of starvation. Since the insects are not reproducing, their numbers will begin to slowly decline.

To reduce the incidence of molds and insects, cool and dry the grain immediately after harvesting. It is important to monitor the moisture content both before and during drying. Take samples from several locations within the bin to be sure the moisture content in all locations is at safe levels.

S.L.A.M.

Appropriate actions taken as the crop goes into storage and during the storage period will minimize the chance of problems. Maintaining the quality of grain in storage requires an integrated approach that incorporates a number of tools and practices rather than relying on a single "big gun" approach to treat a problem after it occurs. Relying on a single tool to take care of a problem is an approach that simply will not work. The S. L. A. M. management strategy is an integrated approach that producers can use to maintain the quality of grain in storage. S.L.A.M. stands for Sanitation, Loading, Aeration and Monitoring.

	Moisture Content % Wet Basis		
Storage Period	Corn	Wheat	Soybeans
Sept. - Oct.	14	13.5	12
Nov. - Mar.	15	14	13
Apr. - May	14	13	12
June - Aug.	13	12.5	11

Table 1. Recommended grain moisture content for safe storage.

Sanitation

Grain crops stored on the farm have a limited storage life due to molds, insects, rodents and other pests. Proper sanitation before the harvest season begins will help minimize the chance of problems occurring during storage. Some good sanitation practices include the following:

- Remove old grain from combines, truck beds, grain carts, augers and any other equipment that is used for harvesting, transporting or handling grain. Even small amounts of insect-infested or moldy grain left over from a previous harvest can contaminate a bin of newly-harvested grain.
- Remove any spilled grain, weeds, tall grass or other vegetation around the bins to reduce the likelihood of rodent or insect infestations.
- Inspect the bin roof and sides, inside and out, for cracks, loose or missing bolts, and rust or other corrosion. Repair all leaks and holes to prevent water and rodent damage. Place a light inside the bin and inspect from the outside at night to help you find any cracks or holes that may have been missed.
- Clean grain storage facilities thoroughly before filling to eliminate existing insect and mold infestations. Remove all old grain, sweep walls, floors and ledges and remove and clean augers and boots.
- Remove all debris from fans, exhaust vents and aeration ducts. If possible, clean under perforated floors to remove any accumulation of dust and fine materials that can harbor insects and rodents.
- After cleaning and repairing bins, sanitize the walls, floors, underfloor and roof areas inside and out with an approved residual spray. Pesticide applications without adequate cleaning are generally a waste of money and time. See Extension PB1395 ***Insects in Farm-Stored Grain - Prevention and Control*** for more details on grain bin sanitation.

Loading

Good-quality, clean, sound grain is much easier to store and market than cracked and broken grain. Broken grain and foreign material, or fines, create two problems in stored grain, especially when they accumulate in pockets in the bin. First, broken kernels and trash create a haven for molds and insects. Broken kernels will mold three to four times faster than whole kernels.

Broken grain is also more susceptible to insect attack, because many of the common grain insects are secondary feeders and only feed on broken or cracked kernels and other materials, not sound kernels. Second, accumulations of fine grain particles, weed seeds and other foreign material form dense pockets in the center of the bin (Figure 1). Airflow from drying or aeration fans tends to go around these dense pockets of fines so they dry and cool more slowly. These pockets often develop into hot spots that result in spoiled grain. Good management practices can

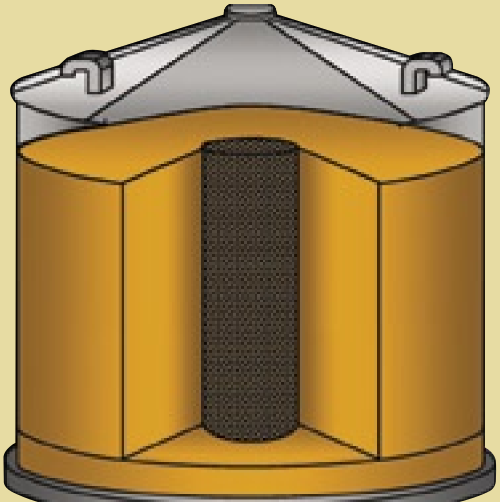

Figure 1.
Trash and fines form dense pockets in the center of the bin.

Weeds and tall grass around the bin can harbor insects.

Don't overfill the bin.

reduce storage risks from accumulations of trash and fines.

To help assure that only high-quality grain goes into storage, the following management practices are recommended:

Before Loading the Storage Bin

- Properly adjust your combine to the manufacturer's specifications to minimize grain damage during harvest and to maximize the removal of trash and fines.
- Operate augers at full capacity to reduce wear and grain breakage. With variable incoming flowrates, reducing auger speed can keep the auger operating at full capacity. Another option is to add a hopper over the auger intake, keeping it full. Be sure that all safety shields and auger intake grates are kept in place and in good working order.

Loading the Storage Bin

- Do not mix new grain with old grain, because this will be a potential source of mold and insect infestation of the new grain.
- Cleaning grain before loading into storage bins reduces the amount of foreign material and greatly improves its storability. Unfortunately, cleaned grain may have no greater market value. Fines add weight to the marketable grain. Unless fines are causing lower grades or serious storage problems, cash-grain farmers may lose money by cleaning grain unless the cleanings can be sold to a livestock producer or grain elevator.
- A good management practice in bins equipped with center unloading augers is to periodically unload some of the grain to remove any trash and fines accumulated in the center of the bin. This is often referred to as "coring." During filling, run the unloading auger at least daily or more often if needed to remove the peaked grain (Figure 2). The goal is to form an inverted cone with a diameter in the range of 5 to 10 feet. The grain that is removed can be mixed with other grain and put back into the bin.

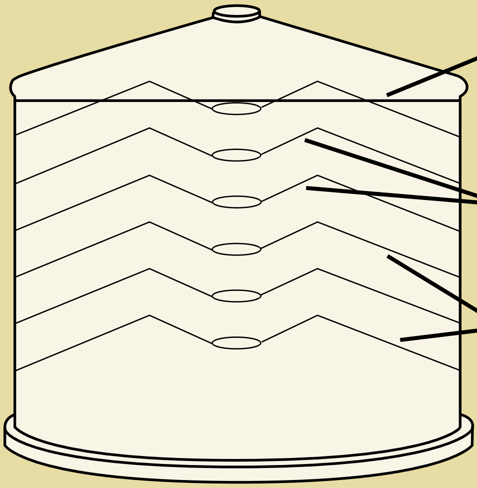

Figure 2.
Coring a bin of grain to redistribute the trash and fines.

Coring does not remove the trash and fines, but repeated unloadings help redistribute much of this material that normally would accumulate in the center of the bin. After the bin is full, the grain surface should be leveled.

Leveling the Grain Surface

Most dry grain peaks at an angle of 18 to 20 degrees when filling the bin from the center. Although peaking adds more storage capacity, these peaked areas increase airflow resistence.

Air follows the path of least resistance and tends to flow around the grain located in the peak (Figure 3). You will have to operate a fan about 50 percent longer to cool an overfilled bin compared to a similar bin with the grain leveled and only filled to the eave. Peaking the grain also makes it more difficult and dangerous to monitor during storage.

Managing the grain during storage is much easier when the grain is leveled after the bin is filled (Figure 4). Three methods are commonly used to level the grain. The first is unloading the center core immediately after filling. By unloading 200 to 300 bushels, the overfilled portion of the bin, as well as some of the trash and fines in the center core, is removed. The second method is using a gravity or mechanical grain spreader. A properly adjusted and operated grain spreader can leave the top surface of the grain

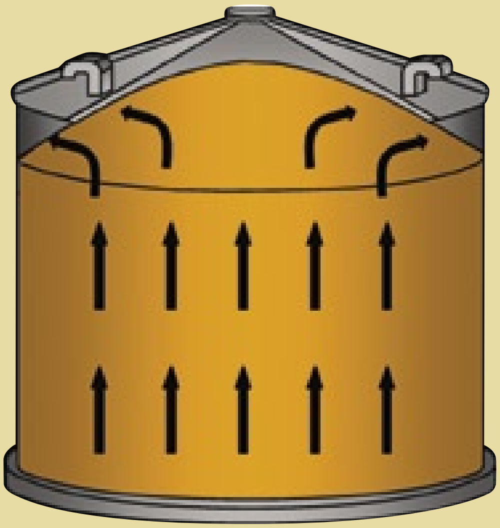

Figure 3.
Peaked grain causes uneven airflow through the grain.

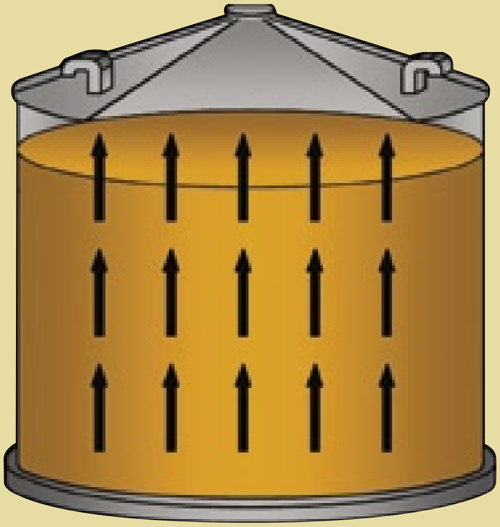

Figure 4. A level grain surface is easier to manage.

Peaked grain is harder to manage.

level and evenly distribute the fine material throughout the bin. One problem with using a grain spreader is that the grain tends to be packed tighter in the bin. Although this might seem a plus, since more grain can be stored in the bin, packing increases airflow resistence, which reduces airflow. When using grain spreaders, the depth of grain may need to be adjusted to ensure that you have adequate airflow when running aeration fans.

The last method is leveling the grain by hand. This method is seldom used because it is often very hot and dusty inside a grain bin. If you level a bin by hand, you need to take some precautions. Never enter a grain bin alone. Have at least two people at the bin to assist in case problems arise. Do not enter a grain bin without stopping the auger first and then using "lock-out/tag-out" procedures to secure it. Use a key-type padlock to securely lock the switch for the auger in the off position. Attach a tag to the locked switch so that other people involved can positively identify it. Always wear a respirator capable of filtering fine dust particles.

Aeration

Moisture Migration

Millions of bushels of dry grain spoil each year because grain temperatures are not controlled. When grain is stored at safe moisture levels but is not aerated, moisture movement, commonly called moisture migration, can develop from one part of the grain mass to another. Moisture migration is caused by significant temperature differences that develop within the grain mass. Grain is a good insulator, which means that heat loss from grain is relatively slow compared to other materials. For this reason, when grain is placed in a bin in the fall, the grain near the center of the bin tends to maintain the temperature at which it came from the dryer or field. On the other hand, the grain along the bin wall and along the top and bottom of the bin tends to cool near the average outside temperature. As the outside temperatures get colder, the differences in temperature between the grain in the center of the bin and along the outside walls become more pronounced.

Air currents develop as the grain and air near the bin walls cool. Cooling causes the air along the outer walls to become heavier and settle very slowly toward the bin floor (Figure 5).

The air moves along the floor to the center area of the bin, then rises slowly through the warm center grain mass. Since warmer air can hold more moisture, it absorbs moisture from the grain as it rises. When the warm, moist air rises through the top layer of cooler grain, the air is cooled, loses its water-holding capacity and begins condensing moisture on the colder grain near the surface. The grain along the surface absorbs this water, which causes

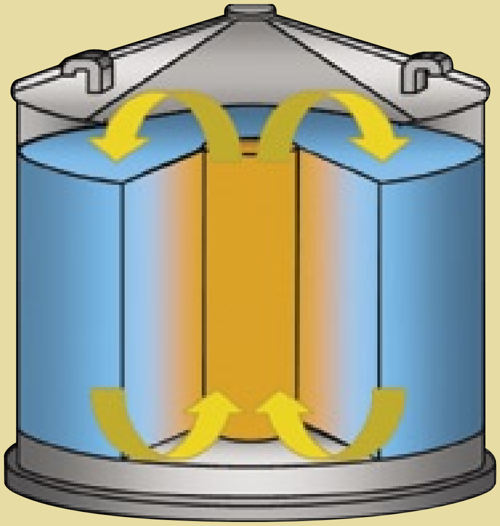

Figure 5.
Natural air currents developed during winter conditions in non-aerated bins.

the moisture content to increase. This increase in grain moisture content, coupled with warmer air temperatures in the headspace, creates an environment that enhances mold and insect growth. This surface moisture change can occur even though the grain was initially stored at safe moisture contents. The reverse situation occurs during the summer months, when the grain along the bin walls warms faster than in the center. As the air along the bin wall rises, it pulls air down through the center of the bin. In this case, moisture is redistributed to the bottom center of the grain mass.

Problems caused by winter moisture migration often become obvious in the spring when outside air temperatures begin to warm. Often, minor moisture migration problems develop into severe spoilage if allowed to continue developing for several months during late winter or early spring. The first indication of trouble is usually damp or tacky-feeling kernels at the grain surface, followed by the formation of a crust. As the center of the bin seals over, the rising air moves farther away from the center and continues to condense moisture near the surface on the cold grain. If the problem is not corrected, the entire top surface of the bin can crust over, as shown in Figure 6.

Aeration greatly improves the "storability" of grain by changing the temperature of the grain in response to seasonal temperature changes. Aeration is not a grain-drying system, but a management tool that can be used to reduce mold development and insect activity and to prevent moisture migration. Aeration involves moving low volumes of air through the grain to control and maintain uniform temperatures throughout the grain mass. Begin aeration in the fall when the average monthly outdoor temperature is about 10 - 15 degrees F lower than the grain temperature. Proper aeration will require several cooling cycles. If the crop is put into storage at 85 degrees F, the first cooling

Aeration is a management tool that greatly improves the storability of grain.

cycle will cool the grain to 55 - 65 degrees F, the second to 40 - 50 degrees F and the third to 35 - 40 degrees F (Table 2). Grain held through the winter should be warmed in the spring and held at about 60 degrees F through the summer.

Figure 6. Grain spoilage caused by moisture migration.

Table 2. Target storage temperatures.

Months	*Temperature (°F)*
Sept.	55 - 65
Oct	55 - 65
Nov	40 - 50
Dec - Feb.	35 - 45
April	60

An aeration cycle moves a cooling or warming front through the grain in the same direction as the airflow. A common question is whether the airflow should be upwards (pressure system) or downwards (suction system) through the grain mass. From the standpoint of aeration system performance, the effect of airflow direction is negligible. However, from a management standpoint, upward airflow is preferred, since the top of the grain mass will be the last region to change temperature when a cooling or warming front is moved through the bin. This makes it easier to determine if the front has moved completely through the grain.

How fast the cooling or warming front moves completely through the grain depends on the airflow rate (cfm/bu), the number of hours the fans are operated and the time of year. A rule of thumb is that it takes 150 hours of aeration in the fall at an airflow rate of 0.1 cfm/bu to completely move a cooling front through the grain mass (Table 3). At 1 cfm/bu it takes only 20 hours. When changing grain temperatures, run the fan continuously until the cooling or warming front has been moved completely through the grain. A commonly expressed concern is running aeration fans during rainy or humid weather. The cooling front moves through the crop about 50 times faster than a wetting or drying front, so only a small fraction of the crop is rewetted during an aeration cycle, even when the humidity of the air is very high. However, if several days of foggy or high humidity weather are expected, aeration can normally be delayed until the weather improves. The effects of operating the fan during damp conditions usually are more than offset by the time the fan is operated under more favorable conditions.

Table 3.
Estimated aeration cooling and warming cycles (hours).

Airflow cfm/bu	*Aeration Cycles (hours)*		
	Fall	*Winter*	*Spring*
1/10	150	200	120
1/4	60	80	48
1/2	30	40	24
3/4	20	27	16
1	15	20	12

You can estimate when a cooling front has passed through the crop by measuring the temperature. Place a thermometer 6 to 12 inches into the grain at the top of the bin. When the cooling front has passed through the grain mass, the temperature reading will drop. Check the temperature at several locations. Automatic controllers are now available that will run aeration fans as necessary to cool or warm the grain to the desired temperature.

Aeration Management

Learn to use aeration in terms of grain temperature control, not grain moisture control. The following aeration management tips will help you maintain the quality of your grain in storage.

- The most common mistake is to stop running the aeration fan before the cooling or warming front has moved through the entire grain mass. This can lead to condensation and crusted layers of spoiled grain in the bin.
- As soon as cooling or warming is complete, stop aerating. Otherwise, significant changes in moisture content can occur if substantially more air is moved through the grain than is required for a temperature change.
- Cover the fan when not operating. This limits excessive cooling in winter, rapid warming in the spring and excessive warming in the summer. Moisture may condense on the aeration ducts if warm moist air is allowed to contact the cold grain near the ducts. Also, covering the fan helps keep water, debris and rodents out of the aeration system.
- If "top crusting" occurs, the surface should be stirred to break up the crust or, in extreme cases, the crust should be removed. Aeration should be started immediately.

Monitoring

Failing to monitor grain conditions throughout the entire storage period is a mistake that many producers make. Regular inspections are essential if mold and insect activity are to be detected early. A small area that starts to heat or otherwise go out of condition can quickly get out of control and spread within the bin.

How often you need to check the grain in storage will vary with the time of year, the initial condition of the grain and how often the grain is aerated. Generally, grain should be inspected at least once a month during the winter and every two weeks during the spring, summer and fall. Grain checking is extremely important during the summer, because grain is being held at higher temperatures and aeration conditions are less favorable than during the rest of the

Grain probes and insect traps are useful monitoring tools.

year. Grain temperatures should be checked and recorded during each inspection. Without temperature records, it is difficult to tell whether elevated grain temperatures are caused by normally occurring outside temperatures or by heating due to mold activity. Use a deep bin probe to obtain samples at different locations in the bin to determine the moisture content, the amount of trash and fines and the general condition of the grain. An accurate moisture tester is required to determine actual moisture contents. Inexpensive moisture meters or one that has been in use for many years can give inaccurate readings under many conditions. You can check the accuracy of your tester by checking readings with your local elevator.

When checking your bins, look for:

- Condensation on the grain surface, crusting, wet areas, molds and insects.
- Leaks or condensation on the bin roof.
- Non-uniform temperatures in the grain mass, pockets or layers of high-moisture grain, molds and insects.
- Musty or sour odors. Spoiled grain gives off a detectable odor, but in most cases, the spoiling grain must be near the surface of the grain and the grain must have undergone considerable spoilage before you can detect any odor. Generally, if you can smell a musty odor, a problem is already well underway.

Any problems that are found need to be evaluated and corrected as soon as possible. This may include cooling with aeration, further drying or fumigation for insect control.

Summary

Maintaining the quality of grain in storage requires an integrated approach that incorporates a number of tools and practices. Storing only clean grain at the proper moisture content and temperature, sanitizing the bin before loading, checking the grain condition regularly and correcting problems before they get out of hand are critical management strategies that must be implemented to prevent grain deterioration and possible economic loss.

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PB1724-2.5M-6/03
E12-4315-00-004-03

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Agricultural Extension Service, Charles L. Norman, Dean

Grain Bin Safety

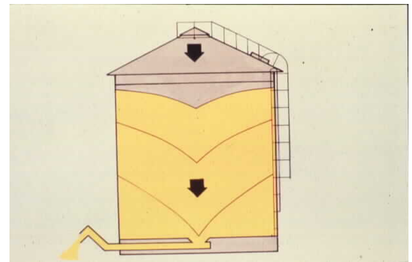
Safety Precautions

Whenever possible, don't enter a grain bin. If you must enter the bin, as a farm owner/operator you should:

- Break up crusted grain from the outside of the bin with a long pole. When using a pole, check to see that it doesn't come into contact with electric lines.
- Wear a harness attached to a properly secured rope.
- Stay near the outer wall of the bin and keep walking if the grain should start to flow. Get to the bin ladder or safety rope as quickly as possible.
- Have another person, preferably two people, outside the bin who can help if you become entrapped. These people should be trained in rescue procedures and should know and follow safety procedures for entering the confined space.
- Grain fines and dust may cause difficulty in breathing. Anyone working in a grain bin, especially for the purpose of cleaning the bin, should wear an appropriate dust filter or filter respirator.
- Stay out of grain bins, wagons and grain trucks when unloading equipment is running.
- If it is necessary to enter the bin, remember to shut off the power to augers and fans. It is a good idea to lock out any unloading equipment before you enter a bin to prevent someone from unintentionally starting the equipment while you are in the bin.
- Children should not be allowed to play in or around grain bins, wagons or truck beds.
- Where possible, ladders should be installed inside grain bins to for an emergency exit. Ladders are easier to locate inside a dusty bin if there are brightly painted stripes just above or behind the ladder.

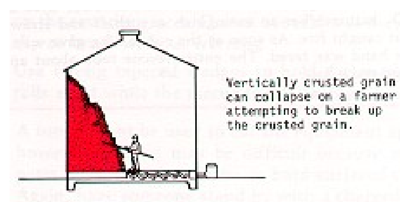
Grain bins are commonly found on Illinois farms. These bins are used to store grain such as corn, soybeans, wheat, oats, and grain sorghum.

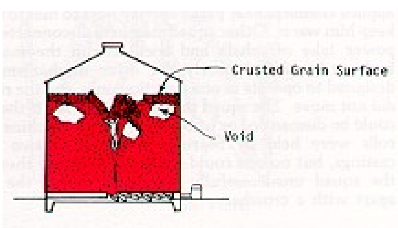
Grain being stored is removed through an opening in the center of the bin. As you can see, this process pulls the grain down and toward the center of the bin. You can see how a depression in the middle of the grain is formed.



Grain wagons can be a hazard, particularly to youngsters. The grain in a grain wagon acts just like the grain in a bin when moving. It pulling down on whatever might be in the grain and children are not strong enough to pull themselves out of the moving grain.

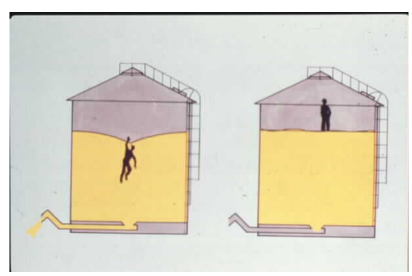
Vertically crusted grain can collapse on a farmer attempting to break it up while in the bin.

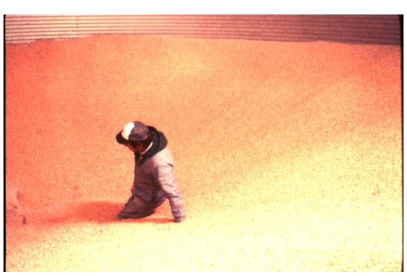




Grain crusted on the surface can be over voids (open spaces) and a person's weight can cause the grain to collapse and the person can be covered with grain.

If someone is in the bin when the grain is removed, they, too, will be pulled down and toward the center of the bin. If grain continues to be removed the person will be covered with grain in a matter of seconds!





As you can see, this person has been pulled down into the grain and pulled toward the center of the bin. Once the person as been pulled into the grain above their knees, they cannot get out of it by themselves. The pressure of the grain on their legs and the grain flowing down as they try to move gives them no place to go.

This is a sweep auger. It helps to collect grain when the bin is almost empty. Because it goes slowly in a circle on the floor, it can be an entanglement hazard to someone in the bin when it is operating.

From: http://www.albany-ny.climatemps.com/temperatures.php

Average Temperatures Table for Albany, New York

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max Temperature °C (°F)	-1 (30.2)	0.7 (33.3)	6.7 (44.1)	14.2 (57.6)	20.9 (69.6)	26.1 (79)	28.9 (84)	27.4 (81.3)	22.9 (73.2)	16.6 (61.9)	9.3 (48.7)	1.6 (34.9)	14.5 (58.1)
Average Temperature °C (°F)	-6.3 (20.7)	-4.7 (23.5)	1.3 (34.3)	8 (46.4)	14.2 (57.6)	19.4 (66.9)	22.1 (71.8)	20.9 (69.6)	16.3 (61.3)	10.1 (50.2)	4.3 (39.7)	-3.1 (26.4)	8.5 (47.3)
Average Min Temperature °C (°F)	-11.7 (10.9)	-10.1 (13.8)	-4.2 (24.4)	1.7 (35.1)	7.4 (45.3)	12.6 (54.7)	15.3 (59.5)	14.3 (57.7)	9.7 (49.5)	3.7 (38.7)	-0.7 (30.7)	-7.7 (18.1)	2.5 (36.5)

To prevent moisture migration inside grain storage containers, keep the grain mass within 15^{O}F of the average monthly temperature.

Table 2. Shelled corn storage time for 0.5% dry matter loss (days).

This is the approximate amount of time that corn can be stored before fungi (molds) consume 0.5% of the initial corn dry matter. After 0.5% dry matter loss, there is usually enough mold damage that corn drops at least one U.S. grade. (From ASAE Standard X535.)

Temperature	Corn moisture (% wet basis)							
(F)	16	18	20	22	24	26	28	30
	days							
35	1,144	437	216	128	86	63	50	41
40	763	291	144	85	57	42	33	27
50	339	130	64	38	26	19	15	12
60	151	58	29	17	11	8	7	5
70	85	32	16	10	7	5	4	4
80	47	18	9	6	4	3	3	2

difficult to dry or cool with forced air. The combination of high moisture, high airflow resistance, and high availability to molds and insects makes concentrated areas of fines and foreign material very likely places for grain spoilage problems to develop.

Uneven grain temperatures

Large differences in temperature between different areas within a storage bin can lead to grain spoilage problems. In most regions where grain is produced in the U.S., outdoor temperatures are warmer at harvest than they are several months after harvest. For example, in many parts of the Corn Belt, corn is harvested during 50 to 70F fall weather. Because corn is usually cooled with outside air at the time of storage, the initial corn temperature in storage is approximately equal to the outdoor temperature. By winter, the temperature outside the storage bin often drops to 10 to 30F, and grain near the outer edges of the bin cools to the winter temperature. Because grain is a poor conductor of heat, though, it takes a long time for heat to move from the center to the outer edges of the grain mass.

As an illustration of the poor thermal conductivity of grain, consider that the insulating or R-value for bulk shelled corn is about 1 per inch. For an 18-foot diameter bin, the distance between the wall and the center of the bin is 108 inches, so the equivalent R-value for the grain is about 108. In comparison, the wall of a typical home in northern climates is insulated to an R-value of about 20. For a typical round storage bin, the larger the bin, the longer it takes for the center of the grain mass to respond to changes in the outdoor temperature (assuming for the minute that the grain is not aerated).

During times when the center of a grain mass is warm and the outer edges are cool, air currents, called "convection currents," move down through the outer parts of the grain mass and up through the center, Figure 2. The convection currents are caused by differences in density between the cold and warm air in different parts of the bin. As warm air moves up through the center of the grain mass, it picks up small amounts of moisture from the grain. Then, when the warm air contacts cold grain at the top of the bin and the cold bin roof, moisture condenses on the cold surfaces. Some moisture also transfers between warm grain and cold grain due to a process called diffusion. The combined effects of convection currents and diffusion lead to gradual wetting of grain at the top center of the bin. This moisture transfer is called "moisture migration." Eventually, moisture levels can get high enough that when the surface grain warms due to increasing outdoor temperatures or due to the sun heating the bin roof and headspace, the grain becomes infested by molds and insects. Moisture migration can occur in any size of grain mass, but it is much more likely in bins that have a capacity of more than about 1,500 bushels of grain.

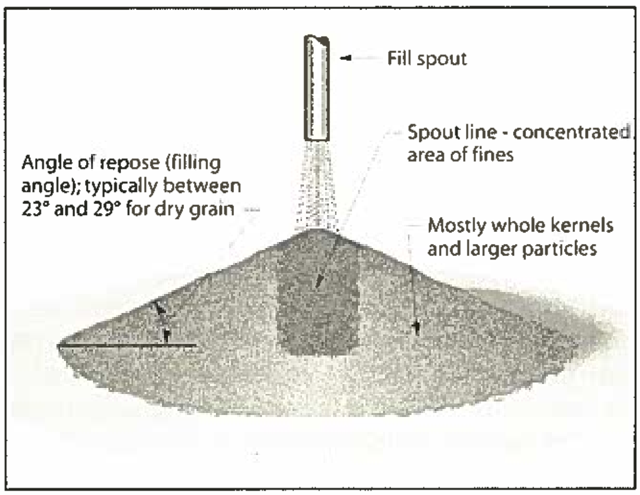


Figure 1. Fines concentration under a fill spout.

“Approximate” Allowable Storage Time for Cereal Grains

Moisture Content (%)	**--- Grain Temperature (°F) ---**					
	30°	**40°**	**50°**	**60°**	**70°**	**80°**
	Approximate Allowable Storage Time (Days)					
14	*****	*****	*****	*****	**200**	**140**
15	*****	*****	*****	**240**	**125**	**70**
16	*****	*****	**230**	**120**	**70**	**40**
17	*****	**280**	**130**	**75**	**45**	**20**
18	*****	**200**	**90**	**50**	**30**	**15**
19	*****	**140**	**70**	**35**	**20**	**10**
20	*****	**90**	**50**	**25**	**14**	**7**
22	**190**	**60**	**30**	**15**	**8**	**3**
24	**130**	**40**	**15**	**10**	**6**	**2**
26	**90**	**35**	**12**	**8**	**5**	**2**
28	**70**	**30**	**10**	**7**	**4**	**2**
30	**60**	**25**	**5**	**5**	**3**	**1**

* Allowable storage time exceeds 300 days

- Allowable storage time is the storage period before quality loss is expected to affect grain quality.
- Airflow through the grain permits maintaining the grain temperature, but does not extend the allowable storage time beyond that listed in the table.
- Allowable storage time is cumulative. If 20% moisture corn were stored for 25 days at 50°F, one-half of the storage life has been used. If the corn is cooled to 40 degrees, the allowable storage time at 40 degrees is only 45 days.

Estimated Allowable Storage Time for Malting Barley (days)

(Criterion: Germinability)

	11%	12%	13%	14%	15%	16%	17%	18%	19%
80 F	230	175	115	70	40	20	11	9	6
70 F	560	420	270	175	100	50	30	20	15
60 F	*	*	660	430	260	130	65	45	25
50 F	*	*	*	*	630	350	140	100	60

* Allowable storage time exceeds 700 days.

Source: Drying Cereal Grains by Brooker, Bakker-Arkema and Hall

"Approximate" Allowable Storage Time for Soybeans

Moisture Content (%)	--- Grain Temperature (°F) ---					
	30°	40°	50°	60°	70°	80°
	Approximate Allowable Storage Time (Days)					
11	*	*	*	*	200	140
12	*	*	*	240	125	70
13	*	*	230	120	70	40
14	*	280	130	75	45	20
15	*	200	90	50	30	15
16	*	140	70	35	20	10
17	*	90	50	25	14	7
19	190	60	30	15	8	3
21	130	40	15	10	6	2
23	90	35	12	8	5	2
25	70	30	10	7	4	2
27	60	25	5	5	3	1

* Allowable storage time exceeds 300 days

- Allowable storage time is the storage period before quality loss is expected to affect grain quality.
- Airflow through the grain permits maintaining the grain temperature, but does not extend the allowable storage time beyond that listed in the table.
- Allowable storage time is cumulative. If 16% moisture soybeans were stored for 35 days at 50°F, one-half of the storage life has been used. If the soybeans are cooled to 40 degrees, the allowable storage time at 40 degrees is only 70 days.

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University of Minnesota Fan Selection for Grain Bins Link - https://extension.umn.edu/corn-harvest/selecting-fans-and-determining-airflow-grain-bins

Background

Show Background

Settings

Print

Bin and Crop Inputs

Select a crop: Barley

Bin Diameter, feet: 21

Floor Type: (•) Full ( ) Duct

Grain Depth, feet: 20

Desired airflow (cfm/bu): 1

Estimated Fan Requirements

Show Table

(to get desired airflow when bin is full)

Bin capacity (bushels):	5,542
Total airflow (cfm):	5,542
Estimated static pressure (inches of water):	7.12
Estimated fan power needed (hp):	10.34

Fan Selection

Show Fan Data

Select a fan: 0.33 hp AEROVENT 1240-DW | 12" (Axial) Add a New Fan

Fan arrangement: (•) Parallel ( ) Series

Number of fans on bin: 1

Results

Airflow vs Depth Table | Airflow Graph | System Graph

Print

Crop : Barley; Bin Diameter, feet: 21
Floor: Full
Airflow, cfm/bu: 1
Fan: 1 - 0.33 hp AEROVENT 1240-DW | 12" (Axial) arranged in Parallel

* Actual airflow differs from desired airflow by more than 5% at the desired depth.
Try using a shallower depth or a different fan.

Airflow and Pressure with Different Quantities of Grain in a Bin

Depth (ft)	Bushels	Airflow (cfm)	Airflow (cfm/bu)	S.P. (in. H2O)
2	554	2,008	3.62	0.21
4	1,108	1,882	1.70	0.39

6	1,663	1,753	1.05	0.53
8	2,217	1,600	0.72	0.64
10	2,771	1,473	0.53	0.73
12	3,325	1,366	0.41	0.81
14	3,879	1,274	0.33	0.87
16	4,433	1,194	0.27	0.93
18	4,988	1,124	0.23	0.98
20	5,542	1,068	0.19	1.03

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Last modified on May 24, 2013

BARLEY EQUILIBRIUM MOISTURE CONTENT

	TEMPERATURE (°F)																
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	100°
R.H.	MOISTURE CONTENT (% W.B.)																
5%	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0
10%	4.7	4.6	4.6	4.6	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.3	4.3	4.3	4.3	4.2	4.2
15%	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.2
20%	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.3	6.2	6.2	6.1	6.1	6.1	6.0	6.0
25%	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	7.0	6.9	6.9	6.8	6.8	6.8
30%	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.5
35%	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1
40%	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.8	8.8
45%	10.4	10.3	10.2	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.8	9.7	9.7	9.6	9.5	9.5	9.4
50%	11.1	11.0	10.9	10.9	10.8	10.7	10.7	10.6	10.6	10.5	10.4	10.4	10.3	10.3	10.2	10.1	10.1
55%	11.8	11.7	11.6	11.6	11.5	11.4	11.4	11.3	11.2	11.2	11.1	11.0	11.0	10.9	10.9	10.8	10.7
60%	12.5	12.4	12.4	12.3	12.2	12.1	12.1	12.0	11.9	11.9	11.8	11.7	11.7	11.6	11.5	11.5	11.4
65%	13.3	13.2	13.1	13.0	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.5	12.4	12.3	12.3	12.2	12.1
70%	14.1	14.0	13.9	13.8	13.8	13.7	13.6	13.5	13.4	13.4	13.3	13.2	13.1	13.1	13.0	12.9	12.9
75%	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.4	14.3	14.2	14.1	14.0	14.0	13.9	13.8	13.7	13.7
80%	15.9	15.8	15.7	15.6	15.6	15.5	15.4	15.3	15.2	15.1	15.0	15.0	14.9	14.8	14.7	14.6	14.6
85%	17.1	17.0	16.9	16.8	16.7	16.6	16.5	16.4	16.3	16.2	16.1	16.0	15.9	15.9	15.8	15.7	15.6
90%	18.5	18.4	18.2	18.1	18.0	17.9	17.8	17.7	17.6	17.5	17.5	17.4	17.3	17.2	17.1	17.0	16.9
95%	20.5	20.4	20.3	20.2	20.1	19.9	19.8	19.7	19.6	19.5	19.4	19.3	19.2	19.1	19.0	18.9	18.9

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Source: ASAE D245.4 Modified Henderson Equation

CORN EQUILIBRIUM MOISTURE CONTENT																	
	TEMPERATURE (°F)																
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	100°
R.H.	MOISTURE CONTENT (% W.B.)																
5%	3.9	3.8	3.7	3.6	3.5	3.4	3.3	3.2	3.2	3.1	3.0	3.0	2.9	2.9	2.8	2.8	2.7
10%	5.7	5.5	5.3	5.2	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.2	4.1	4.0	3.9
15%	7.0	6.8	6.6	6.4	6.3	6.1	6.0	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9
20%	8.2	8.0	7.8	7.6	7.4	7.2	7.0	6.9	6.7	6.6	6.4	6.3	6.2	6.1	6.0	5.9	5.8
25%	9.3	9.1	8.8	8.6	8.3	8.1	8.0	7.8	7.6	7.5	7.3	7.2	7.0	6.9	6.8	6.7	6.6
30%	10.4	10.0	9.8	9.5	9.3	9.0	8.8	8.6	8.5	8.3	8.1	8.0	7.8	7.7	7.6	7.4	7.3
35%	11.3	11.0	10.7	10.4	10.2	9.9	9.7	9.5	9.3	9.1	8.9	8.8	8.6	8.4	8.3	8.2	8.0
40%	12.3	11.9	11.6	11.3	11.0	10.8	10.5	10.3	10.1	9.9	9.7	9.5	9.3	9.2	9.0	8.9	8.7
45%	13.2	12.8	12.5	12.2	11.9	11.6	11.3	11.1	10.9	10.7	10.5	10.3	10.1	9.9	9.7	9.6	9.4
50%	14.2	13.8	13.4	13.0	12.7	12.4	12.2	11.9	11.7	11.4	11.2	11.0	10.8	10.6	10.5	10.3	10.1
55%	15.1	14.7	14.3	13.9	13.6	13.3	13.0	12.7	12.5	12.2	12.0	11.8	11.6	11.4	11.2	11.0	10.9
60%	16.1	15.6	15.2	14.8	14.5	14.2	13.9	13.6	13.3	13.0	12.8	12.6	12.4	12.1	12.0	11.8	11.6
65%	17.1	16.6	16.2	15.8	15.4	15.1	14.8	14.4	14.2	13.9	13.6	13.4	13.2	13.0	12.7	12.5	12.4
70%	18.2	17.7	17.2	16.8	16.4	16.0	15.7	15.4	15.1	14.8	14.5	14.3	14.0	13.8	13.6	13.4	13.2
75%	19.3	18.8	18.3	17.9	17.5	17.1	16.7	16.4	16.1	15.8	15.5	15.2	15.0	14.7	14.5	14.3	14.1
80%	20.6	20.0	19.5	19.1	18.7	18.3	17.9	17.5	17.2	16.9	16.6	16.3	16.0	15.8	15.5	15.3	15.1
85%	22.1	21.5	21.0	20.5	20.0	19.6	19.2	18.8	18.5	18.1	17.8	17.5	17.2	17.0	16.7	16.5	16.2
90%	23.9	23.3	22.7	22.2	21.7	21.3	20.9	20.5	20.1	19.7	19.4	19.1	18.8	18.5	18.2	17.9	17.7
95%	26.6	25.9	25.3	24.8	24.2	23.8	23.3	22.9	22.5	22.1	21.7	21.4	21.0	20.7	20.4	20.1	19.8

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Source: ASAE D245.4 Modified Henderson Equation

EDIBLE BEANS EQUILIBRIUM MOISTURE CONTENT

	TEMPERATURE (^{O}F)																
	20^{O}	25^{O}	30^{O}	35^{O}	40^{O}	45^{O}	50^{O}	55^{O}	60^{O}	65^{O}	70^{O}	75^{O}	80^{O}	85^{O}	90^{O}	95^{O}	100^{O}
R.H.	MOISTURE CONTENT (% W.B.)																
5%	3.3	3.3	3.2	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0
10%	4.7	4.7	4.7	4.6	4.6	4.6	4.6	4.6	4.5	4.5	4.5	4.5	4.4	4.4	4.4	4.4	4.3
15%	5.9	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.5	5.4	5.4
20%	6.9	6.8	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.4	6.3
25%	7.8	7.8	7.7	7.7	7.6	7.6	7.6	7.5	7.5	7.4	7.4	7.4	7.3	7.3	7.3	7.2	7.2
30%	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.4	8.3	8.3	8.2	8.2	8.2	8.1	8.1	8.0	8.0
35%	9.5	9.4	9.4	9.3	9.3	9.2	9.2	9.2	9.1	9.1	9.0	9.0	8.9	8.9	8.8	8.8	8.8
40%	10.3	10.2	10.2	10.1	10.1	10.0	10.0	9.9	9.9	9.8	9.8	9.7	9.7	9.7	9.6	9.6	9.5
45%	11.1	11.0	11.0	10.9	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5	10.5	10.4	10.4	10.3	10.3
50%	11.9	11.8	11.8	11.7	11.7	11.6	11.5	11.5	11.4	11.4	11.3	11.3	11.2	11.2	11.1	11.1	11.0
55%	12.7	12.6	12.6	12.5	12.5	12.4	12.3	12.3	12.2	12.2	12.1	12.0	12.0	11.9	11.9	11.8	11.8
60%	13.5	13.5	13.4	13.3	13.3	13.2	13.1	13.1	13.0	13.0	12.9	12.8	12.8	12.7	12.7	12.6	12.6
65%	14.4	14.3	14.3	14.2	14.1	14.1	14.0	13.9	13.9	13.8	13.7	13.7	13.6	13.5	13.5	13.4	13.4
70%	15.3	15.3	15.2	15.1	15.0	15.0	14.9	14.8	14.8	14.7	14.6	14.6	14.5	14.4	14.4	14.3	14.2
75%	16.3	16.3	16.2	16.1	16.0	15.9	15.9	15.8	15.7	15.7	15.6	15.5	15.4	15.4	15.3	15.2	15.2
80%	17.5	17.4	17.3	17.2	17.1	17.0	17.0	16.9	16.8	16.7	16.7	16.6	16.5	16.4	16.4	16.3	16.2
85%	18.7	18.7	18.6	18.5	18.4	18.3	18.2	18.1	18.1	18.0	17.9	17.8	17.7	17.7	17.6	17.5	17.4
90%	20.4	20.2	20.2	20.1	20.0	19.9	19.8	19.7	19.6	19.5	19.5	19.4	19.3	19.2	19.1	19.1	19.0
95%	22.7	22.6	22.5	22.4	22.3	22.2	22.1	22.0	21.9	21.8	21.8	21.7	21.6	21.5	21.4	21.3	21.2

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Source: ASAE D245.4 Modified Henderson Equation

SOYBEAN EQUILIBRIUM MOISTURE CONTENT																	
	TEMPERATURE (°F)																
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	100°
R.H.	MOISTURE CONTENT (% W.B.)																
5%	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
10%	2.2	2.2	2.1	2.1	2.1	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.7
15%	3.1	3.1	3.0	3.0	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.6	2.6	2.6	2.5	2.5	2.5
20%	4.0	4.0	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.4	3.4	3.3	3.3	3.2	3.2
25%	4.9	4.8	4.8	4.7	4.6	4.5	4.5	4.4	4.3	4.3	4.2	4.2	4.1	4.0	4.0	3.9	3.9
30%	5.8	5.7	5.6	5.5	5.5	5.4	5.3	5.2	5.1	5.1	5.0	4.9	4.9	4.8	4.7	4.7	4.6
35%	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.9	5.8	5.7	5.6	5.6	5.5	5.4	5.3
40%	7.7	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.3	6.3	6.2	6.1
45%	8.6	8.5	8.4	8.2	8.1	8.0	7.9	7.8	7.6	7.5	7.4	7.3	7.2	7.1	7.1	7.0	6.9
50%	9.6	9.5	9.3	9.2	9.1	8.9	8.8	8.7	8.6	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7
55%	10.7	10.5	10.4	10.2	10.1	9.9	9.8	9.6	9.5	9.4	9.3	9.1	9.0	8.9	8.7	8.7	8.6
60%	11.8	11.6	11.5	11.3	11.1	11.0	10.8	10.7	10.5	10.4	10.2	10.1	10.0	9.9	9.6	9.6	9.5
65%	13.1	12.9	12.7	12.5	12.3	12.1	11.9	11.8	11.6	11.5	11.3	11.2	11.0	10.9	10.6	10.6	10.5
70%	14.4	14.2	14.0	13.8	13.6	13.4	13.2	13.0	12.8	12.7	12.5	12.3	12.2	12.0	11.7	11.7	11.6
75%	15.9	15.6	15.4	15.2	15.0	14.8	14.6	14.4	14.2	14.0	13.8	13.7	13.5	13.3	13.0	13.0	12.9
80%	17.6	17.3	17.1	16.8	16.6	16.4	16.2	16.0	15.7	15.5	15.4	15.2	15.0	14.8	14.5	14.5	14.3
85%	19.6	19.3	19.1	18.8	18.6	18.3	18.1	17.8	17.6	17.4	17.2	17.0	16.8	16.6	16.2	16.2	16.0
90%	22.3	22.0	21.7	21.4	21.1	20.8	20.6	20.3	20.1	19.8	19.6	19.3	19.1	18.9	18.5	18.5	18.3
95%	26.2	25.9	25.5	25.2	24.9	24.6	24.3	24.0	23.7	23.5	23.2	23.0	22.7	22.5	22.0	22.0	21.7

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Fargo, ND

Source: ASAE D245.4 Modified Henderson Equation

CONFECTIONERY SUNFLOWER EQUILIBRIUM MOISTURE CONTENT

	TEMPERATURE (°F)																
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	100°
R.H.	MOISTURE CONTENT (% W.B.)																
5%	2.8	2.7	2.6	2.6	2.5	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1	2.0	2.0	2.0	1.9
10%	4.1	4.0	3.8	3.7	3.6	3.5	3.5	3.4	3.3	3.2	3.2	3.1	3.0	3.0	2.9	2.9	2.8
15%	5.1	5.0	4.8	4.7	4.6	4.5	4.3	4.2	4.2	4.1	4.0	3.9	3.8	3.8	3.7	3.6	3.6
20%	6.0	5.9	5.7	5.5	5.4	5.3	5.1	5.0	4.9	4.8	4.7	4.6	4.5	4.4	4.4	4.3	4.2
25%	6.9	6.7	6.5	6.3	6.1	6.0	5.8	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	4.9	4.8
30%	7.7	7.4	7.2	7.0	6.9	6.7	6.5	6.4	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4
35%	8.4	8.2	7.9	7.7	7.5	7.4	7.2	7.0	6.9	6.7	6.6	6.5	6.4	6.2	6.1	6.0	5.9
40%	9.2	8.9	8.7	8.4	8.2	8.0	7.8	7.7	7.5	7.3	7.2	7.1	6.9	6.8	6.7	6.6	6.5
45%	9.9	9.6	9.4	9.1	8.9	8.7	8.5	8.3	8.1	7.9	7.8	7.6	7.5	7.4	7.2	7.1	7.0
50%	10.7	10.4	10.1	9.8	9.6	9.3	9.1	8.9	8.7	8.6	8.4	8.2	8.1	7.9	7.8	7.7	7.6
55%	11.4	11.1	10.8	10.5	10.2	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.7	8.5	8.4	8.2	8.1
60%	12.2	11.9	11.5	11.2	11.0	10.7	10.5	10.2	10.0	9.8	9.6	9.5	9.3	9.1	9.0	8.8	8.7
65%	13.0	12.7	12.3	12.0	11.7	11.4	11.2	10.9	10.7	10.5	10.3	10.1	9.9	9.8	9.6	9.5	9.3
70%	13.9	13.5	13.1	12.8	12.5	12.2	11.9	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.3	10.1	10.0
75%	14.8	14.4	14.0	13.7	13.4	13.1	12.8	12.5	12.3	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.7
80%	15.9	15.5	15.1	14.7	14.3	14.0	13.7	13.4	13.2	12.9	12.7	12.4	12.2	12.0	11.8	11.6	11.5
85%	17.1	16.7	16.2	15.8	15.5	15.1	14.8	14.5	14.2	14.0	13.7	13.5	13.2	13.0	12.8	12.6	12.4
90%	18.7	18.2	17.7	17.3	16.9	16.5	16.2	15.9	15.6	15.3	15.0	14.7	14.5	14.3	14.0	13.8	13.6
95%	21.0	20.4	19.9	19.5	19.0	18.6	18.2	17.9	17.5	17.2	16.9	16.6	16.4	16.1	15.8	15.6	15.4

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Source: ASAE Paper 74-3534

OIL SUNFLOWER EQUILIBRIUM MOISTURE CONTENT																	
	TEMPERATURE (^{O}F)																
	20^{O}	25^{O}	30^{O}	35^{O}	40^{O}	45^{O}	50^{O}	55^{O}	60^{O}	65^{O}	70^{O}	75^{O}	80^{O}	85^{O}	90^{O}	95^{O}	100^{O}
R.H.	MOISTURE CONTENT (% W.B.)																
5%	2.7	2.7	2.6	2.5	2.5	2.4	2.4	2.3	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.1	2.0
10%	3.7	3.6	3.5	3.5	3.4	3.3	3.2	3.2	3.1	3.1	3.0	3.0	2.9	2.9	2.8	2.8	2.8
15%	4.5	4.3	4.2	4.1	4.1	4.0	3.9	3.8	3.8	3.7	3.6	3.6	3.5	3.5	3.4	3.4	3.3
20%	5.1	5.0	4.8	4.7	4.6	4.5	4.5	4.4	4.3	4.2	4.2	4.1	4.0	4.0	3.9	3.9	3.8
25%	5.6	5.5	5.4	5.3	5.1	5.0	4.9	4.9	4.8	4.7	4.6	4.5	4.5	4.4	4.3	4.3	4.2
30%	6.2	6.0	5.9	5.7	5.6	5.5	5.4	5.3	5.2	5.1	5.0	5.0	4.9	4.8	4.8	4.7	4.6
35%	6.7	6.5	6.4	6.2	6.1	6.0	5.8	5.7	5.6	5.5	5.5	5.4	5.3	5.2	5.1	5.1	5.0
40%	7.1	7.0	6.8	6.7	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.4
45%	7.6	7.4	7.3	7.1	7.0	6.8	6.7	6.6	6.5	6.3	6.2	6.2	6.1	6.0	5.9	5.8	5.7
50%	8.1	7.9	7.7	7.5	7.4	7.2	7.1	7.0	6.9	6.7	6.6	6.5	6.4	6.3	6.3	6.2	6.1
55%	8.6	8.3	8.2	8.0	7.8	7.7	7.5	7.4	7.3	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.5
60%	9.0	8.8	8.6	8.4	8.3	8.1	8.0	7.8	7.7	7.6	7.4	7.3	7.2	7.1	7.0	6.9	6.8
65%	9.5	9.3	9.1	8.9	8.7	8.6	8.4	8.3	8.1	8.0	7.9	7.7	7.6	7.5	7.4	7.3	7.2
70%	10.1	9.8	9.6	9.4	9.2	9.0	8.9	8.7	8.6	8.4	8.3	8.2	8.1	7.9	7.8	7.7	7.6
75%	10.6	10.4	10.2	9.9	9.7	9.6	9.4	9.2	9.1	8.9	8.8	8.7	8.5	8.4	8.3	8.2	8.1
80%	11.3	11.0	10.8	10.5	10.3	10.1	10.0	9.8	9.6	9.5	9.3	9.2	9.0	8.9	8.8	8.7	8.6
85%	12.0	11.7	11.5	11.2	11.0	10.8	10.6	10.4	10.3	10.1	9.9	9.8	9.7	9.5	9.4	9.3	9.2
90%	12.9	12.6	12.4	12.1	11.9	11.7	11.5	11.3	11.1	10.9	10.7	10.6	10.4	10.3	10.1	10.0	9.9
95%	14.3	14.0	13.7	13.4	13.1	12.9	12.7	12.5	12.3	12.1	11.9	11.7	11.5	11.4	11.2	11.1	11.0

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Source: ASAE Paper 74-3534

DURUM WHEAT EQUILIBRIUM MOISTURE CONTENT																	
	TEMPERATURE (^{O}F)																
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	100°
R.H.	MOISTURE CONTENT (% W.B.)																
5%	4.5	4.4	4.4	4.3	4.2	4.2	4.1	4.0	4.0	3.9	3.9	3.8	3.8	3.7	3.7	3.6	3.6
10%	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.4	5.3	5.2	5.2	5.1	5.0	5.0	4.9
15%	7.4	7.3	7.2	7.0	6.9	6.8	6.7	6.6	6.5	6.4	6.4	6.3	6.2	6.1	6.1	6.0	5.9
20%	8.5	8.3	8.2	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.8
25%	9.4	9.2	9.1	8.9	8.8	8.7	8.5	8.4	8.3	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5
30%	10.2	10.1	9.9	9.7	9.6	9.5	9.3	9.2	9.1	8.9	8.8	8.7	8.6	8.5	8.4	8.3	8.2
35%	11.1	10.9	10.7	10.5	10.4	10.2	10.1	9.9	9.8	9.7	9.5	9.4	9.3	9.2	9.1	9.0	8.9
40%	11.8	11.6	11.4	11.3	11.1	10.9	10.8	10.6	10.5	10.4	10.2	10.1	10.0	9.9	9.8	9.7	9.6
45%	12.6	12.4	12.2	12.0	11.8	11.6	11.5	11.3	11.2	11.0	10.9	10.8	10.6	10.5	10.4	10.3	10.2
50%	13.4	13.1	12.9	12.7	12.5	12.4	12.2	12.0	11.9	11.7	11.6	11.4	11.3	11.2	11.1	10.9	10.8
55%	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.4	12.2	12.1	12.0	11.8	11.7	11.6	11.5
60%	14.9	14.6	14.4	14.2	14.0	13.8	13.6	13.4	13.2	13.1	12.9	12.8	12.6	12.5	12.4	12.2	12.1
65%	15.7	15.4	15.2	15.0	14.7	14.5	14.3	14.2	14.0	13.8	13.6	13.5	13.3	13.2	13.0	12.9	12.8
70%	16.5	16.3	16.0	15.8	15.5	15.3	15.1	14.9	14.7	14.6	14.4	14.2	14.1	13.9	13.8	13.6	13.5
75%	17.4	17.1	16.9	16.6	16.4	16.2	16.0	15.7	15.6	15.4	15.2	15.0	14.8	14.7	14.5	14.4	14.2
80%	18.4	18.1	17.8	17.6	17.3	17.1	16.9	16.7	16.5	16.3	16.1	15.9	15.7	15.5	15.4	15.2	15.1
85%	19.6	19.2	19.0	18.7	18.4	18.2	17.9	17.7	17.5	17.3	17.1	16.9	16.7	16.6	16.4	16.2	16.1
90%	21.0	20.6	20.3	20.1	19.8	19.5	19.3	19.0	18.8	18.6	18.4	18.2	18.0	17.8	17.6	17.4	17.3
95%	23.0	22.7	22.3	22.0	21.7	21.5	21.2	20.9	20.7	20.5	20.2	20.0	19.8	19.6	19.4	19.2	19.0

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Source: ASAE D245.4 Modified Henderson Equation

HARD WHEAT EQUILIBRIUM MOISTURE CONTENT																	
	TEMPERATURE (°F)																
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	100°
R.H.	MOISTURE CONTENT (% W.B.)																
5%	5.0	4.9	4.8	4.7	4.6	4.5	4.5	4.4	4.3	4.2	4.2	4.1	4.1	4.0	3.9	3.9	3.8
10%	6.8	6.6	6.5	6.4	6.2	6.1	6.0	5.9	5.8	5.7	5.6	5.6	5.5	5.4	5.3	5.3	5.2
15%	8.1	7.9	7.7	7.6	7.4	7.3	7.2	7.1	6.9	6.8	6.7	6.6	6.5	6.5	6.4	6.3	6.2
20%	9.2	9.0	8.8	8.6	8.5	8.3	8.2	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1
25%	10.1	9.9	9.7	9.5	9.4	9.2	9.0	8.9	8.7	8.6	8.5	8.4	8.3	8.1	8.0	7.9	7.8
30%	11.0	10.8	10.6	10.4	10.2	10.0	9.8	9.7	9.5	9.4	9.2	9.1	9.0	8.9	8.8	8.7	8.6
35%	11.9	11.6	11.4	11.2	11.0	10.8	10.6	10.4	10.3	10.1	10.0	9.8	9.7	9.6	9.4	9.3	9.2
40%	12.7	12.4	12.2	11.9	11.7	11.5	11.3	11.1	11.0	10.8	10.7	10.5	10.4	10.2	10.1	10.0	9.9
45%	13.4	13.2	12.9	12.7	12.4	12.2	12.0	11.8	11.7	11.5	11.3	11.2	11.0	10.9	10.7	10.6	10.5
50%	14.2	13.9	13.7	13.4	13.2	12.9	12.7	12.5	12.3	12.2	12.0	11.8	11.7	11.5	11.4	11.2	11.1
55%	15.0	14.7	14.4	14.1	13.9	13.7	13.4	13.2	13.0	12.8	12.7	12.5	12.3	12.2	12.0	11.9	11.7
60%	15.8	15.5	15.2	14.9	14.6	14.4	14.2	13.9	13.7	13.5	13.3	13.2	13.0	12.8	12.7	12.5	12.4
65%	16.6	16.3	15.9	15.7	15.4	15.1	14.9	14.7	14.4	14.2	14.0	13.9	13.7	13.5	13.3	13.2	13.0
70%	17.4	17.1	16.8	16.5	16.2	15.9	15.7	15.4	15.2	15.0	14.8	14.6	14.4	14.2	14.1	13.9	13.7
75%	18.3	18.0	17.6	17.3	17.0	16.8	16.5	16.3	16.0	15.8	15.6	15.4	15.2	15.0	14.8	14.6	14.5
80%	19.3	19.0	18.6	18.3	18.0	17.7	17.4	17.2	16.9	16.7	16.5	16.2	16.0	15.8	15.7	15.5	15.3
85%	20.5	20.1	19.7	19.4	19.1	18.8	18.5	18.2	17.9	17.7	17.5	17.2	17.0	16.8	16.6	16.4	16.3
90%	21.9	21.5	21.1	20.7	20.4	20.1	19.8	19.5	19.2	19.0	18.7	18.5	18.3	18.1	17.8	17.6	17.5
95%	23.9	23.5	23.1	22.7	22.3	22.0	21.7	21.4	21.1	20.8	20.5	20.3	20.0	19.8	19.6	19.4	19.2

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Source: ASAE D245.4 Modified Henderson Equation

SOFT WHEAT EQUILIBRIUM MOISTURE CONTENT

	TEMPERATURE (°F)																
	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°	95°	100°
R.H.	MOISTURE CONTENT (% W.B.)																
5%	5.1	5.0	4.9	4.8	4.7	4.7	4.6	4.5	4.5	4.4	4.4	4.3	4.3	4.2	4.2	4.1	4.1
10%	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.9	5.8	5.7	5.7	5.6	5.5	5.5	5.4	5.4
15%	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6	6.6	6.5	6.4	6.3	6.3
20%	8.7	8.5	8.4	8.3	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.4	7.3	7.2	7.1	7.1
25%	9.5	9.3	9.2	9.0	8.9	8.8	8.7	8.6	8.4	8.3	8.2	8.2	8.1	8.0	7.9	7.8	7.7
30%	10.2	10.1	9.9	9.8	9.6	9.5	9.4	9.2	9.1	9.0	8.9	8.8	8.7	8.6	8.5	8.4	8.4
35%	10.9	10.8	10.6	10.4	10.3	10.1	10.0	9.9	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9
40%	11.6	11.4	11.2	11.1	10.9	10.8	10.6	10.5	10.4	10.2	10.1	10.0	9.9	9.8	9.7	9.6	9.5
45%	12.2	12.0	11.9	11.7	11.5	11.4	11.2	11.1	10.9	10.8	10.7	10.6	10.5	10.3	10.2	10.1	10.0
50%	12.9	12.7	12.5	12.3	12.1	12.0	11.8	11.7	11.5	11.4	11.3	11.1	11.0	10.9	10.8	10.7	10.6
55%	13.5	13.3	13.1	12.9	12.7	12.6	12.4	12.2	12.1	12.0	11.8	11.7	11.6	11.4	11.3	11.2	11.1
60%	14.2	13.9	13.7	13.5	13.3	13.2	13.0	12.8	12.7	12.5	12.4	12.3	12.1	12.0	11.9	11.8	11.7
65%	14.8	14.6	14.4	14.2	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.8	12.7	12.6	12.4	12.3	12.2
70%	15.5	15.3	15.0	14.8	14.6	14.4	14.2	14.1	13.9	13.7	13.6	13.4	13.3	13.2	13.0	12.9	12.8
75%	16.2	16.0	15.8	15.5	15.3	15.1	14.9	14.8	14.6	14.4	14.3	14.1	14.0	13.8	13.7	13.6	13.4
80%	17.1	16.8	16.6	16.3	16.1	15.9	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4	14.3	14.1
85%	18.0	17.7	17.5	17.2	17.0	16.8	16.6	16.4	16.2	16.0	15.8	15.7	15.5	15.3	15.2	15.1	14.9
90%	19.1	18.8	18.6	18.3	18.1	17.9	17.6	17.4	17.2	17.0	16.9	16.7	16.5	16.4	16.2	16.1	15.9
95%	20.8	20.5	20.2	19.9	19.7	19.4	19.2	19.0	18.8	18.5	18.4	18.2	18.0	17.8	17.6	17.5	17.3

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Source: ASAE D245.4 Modified Henderson Equation

Grain Storage Safety

Purdue University, https://extension.entm.purdue.edu/grainsafety/index.php

"Show Me Farm Safety", https://farmsafety.mo.gov/grain/

Training Materials:
Grain Handling Safety Coalition, http://grainsafety.org/
National Grain and Feed Association (combustible grain dust video), https://imis.ngfa.org/safety

Factsheet:
Hazards of Flowing Grain, https://extension.psu.edu/hazards-of-flowing-grain

Youtube has grain bin safety videos. Here are three:

https://vimeo.com/366552299 grain bin safety video 6 minutes

https://www.youtube.com/watch?v=zqbUubNAVE0

https://www.youtube.com/watch?v=FhIq87HPkT0&list=PLY7XQBihZRNukpxj7Q4ltHFpxXW34f6CX

Deborah Dalton, Information Specialist
Northeast Center for Occupational Health and Safety
Agriculture | Forestry | Fishing
One Atwell Rd.
Cooperstown , NY 13326
800-343-7527 / 607-547-6023
https://www.necenter.org/

Websites About Grain Storage And IPM

Managing Grain in Storage:

University of Minnesota (Scroll down to your specific crop and follow links to storage information.) https://extension.umn.edu/crop-production

University of Nebraska (List of many articles. Some links are invalid but the article may still be on the internet. Do an internet search for the specific title.) https://lancaster.unl.edu/ag/crops/storage.shtml

North Dakota State University (Select your crop and follow the links to the storage information articles.) https://www.ag.ndsu.edu/extension/crops

Purdue University (incl article on converting silos to grain storage) https://extension.entm.purdue.edu/grainlab/index.php?page=pubs/storage.php

Fan size calculator: https://bbefans.cfans.umn.edu/

S.L.A.M. based Quality Grain Management Practices: https://extension.entm.purdue.edu/publications/ID-207.pdf

https://extension.tennessee.edu/publications/Documents/PB1724.pdf

(Organic) Stored Grain Pest Management, ATTRA - https://attra.ncat.org/attra-pub/summaries/summary.php?pub=140

Grain Pests:

USDA - https://www.gipsa.usda.gov/fgis/publication/ref/Stored%20Grain%20Insects_2015-03-04.pdf

Canada – https://www.grainscanada.gc.ca/en/grain-quality/manage/identify-an-insect/primary-insect-pests/

Presentation, U of Wisc, https://www.youtube.com/watch?v=vy6WH76HxEA

Using Insecticides for Insect Control

Controlling Insects in Stored Grain (UKY) https://entomology.ca.uky.edu/ef145

Insecticides
2019 Stored Grain Insecticides Registered in New York State - http://blogs.cornell.edu/capitalareaagandhortprogram/2020/08/04/2019-stored-grain-insecticides-registered-for-nys/

Grain Storage Safety:
General Overview, U of Maine: http://umaine.edu/publications/2291e/
Kansas State Univ. (incl respiratory safety), https://bookstore.ksre.ksu.edu/pubs/AF170.pdf

Rescue demos: https://www.youtube.com/watch?v=stEYwHmnXzk

https://www.youtube.com/watch?v=FraV05EHyW0

Why bin safety? https://vimeo.com/231083105/61c3be86ea

Federal Grain Inspection Service, image library, grade standards, & much more- https://www.gipsa.usda.gov/fgis/fgis.aspx

Grain Standards: https://www.gipsa.usda.gov/fgis/usstandards.aspx

VIDEOS
Wisconsin Conference 1 hr, https://attra.ncat.org/video-focuses-on-developing-artisan-grain-markets/?utm_source=WH&utm_medium=PM&utm_campaign=news

University Webpages with resources:
Purdue, https://extension.entm.purdue.edu/grainlab/index.php?page=pubs/storage.php

Grain Grading Standards and Resources

Grain Grading Standards
https://www.gipsa.usda.gov/fgis/usstandards.aspx

Presentation "Wheat Grading" (Given as part of an online tour of Ardent Mills. The basic grading steps outlined are used for all grains. The standards will be different for each grain.)
https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/e/1628/files/2020/08/Wheat-Wheat-Grading-Varieties-Aug-2020-w-notes.pdf

Chapter 4 US Grain Council - Importer Manual, chapt 4
https://grains.org/wp-content/uploads/2018/02/chapter4.pdf

"Understanding Grain Quality", https://extension.umn.edu/small-grains-crop-and-variety-selection/understanding-grain-quality

Federal Grain Inspection Service,
https://www.ams.usda.gov/about-ams/programs-offices/federal-grain-inspection-service
Headquarters
Stop 3614
1400 Independence Ave., SW
Washington, D.C. 20250-3601
Telephone: (202) 720-9170
Fax: (202) 690-2333
fgis.oda@usda.gov
National Grain Center
USDA, AMS, FGIS
10383 N Ambassador Dr
Kansas City, MO 64153
Telephone: 816-891-0401
Fax: 816-872-1253
Domestic Inspection Operations Office
USDA, AMS, FGIS
10383 N Ambassador Dr
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Fax: 816-872-1258

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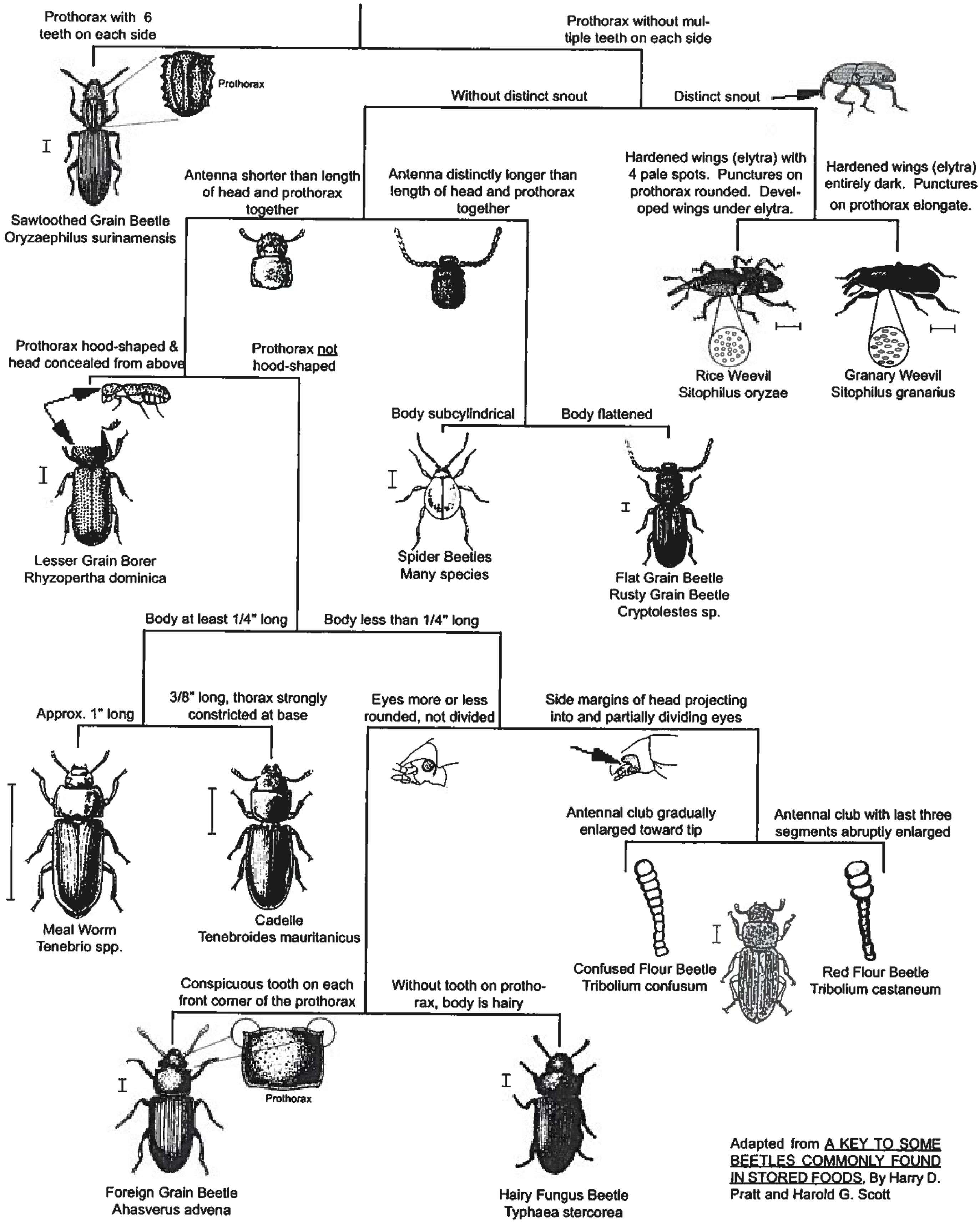
A PICTORIAL KEY TO BEETLE PESTS OF STORED GRAIN COMMONLY FOUND IN INDIANA



Adapted from A KEY TO SOME BEETLES COMMONLY FOUND IN STORED FOODS, By Harry D. Pratt and Harold G. Scott

"The Dirty Dozen"

Indianmeal Moth
(Plodia interpunctella)

Mediterranean Flour Moth
(Ephestia kuehniella)

Cigarette Beetle
(Lasioderma serricorne)

Drugstore Beetle
(Stegobium paniceum)

Red Flour Beetle
(Tribolium castaneum)

Confused Flour Beetle
(Tribolium confusum)

Saw-toothed Grain Beetle
(Oryzaephilus surinamensis)

Merchant Grain Beetle
(Oryzaephilus mercator)

Granary Weevil
(Sitophilus granarius)

Rice Weevil
(Sitophilus oryzae)

Lesser Grain Borer
(Rhyzopertha dominica)

Warehouse Beetle
(Trogoderma variabile)

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