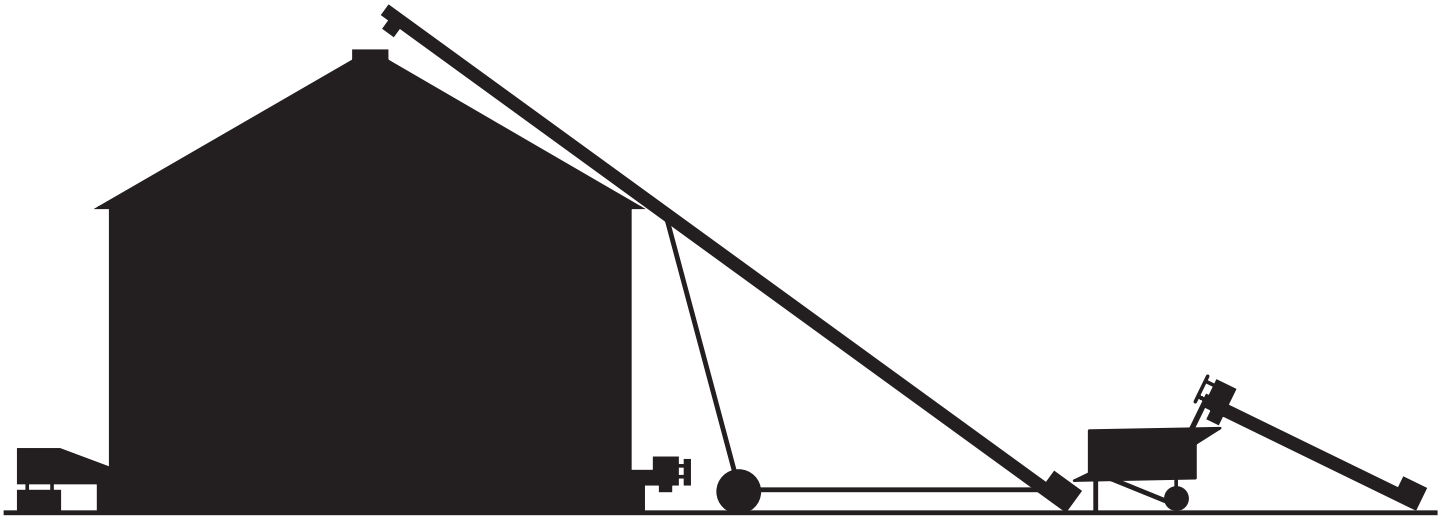
Low-Temperature Drying Systems in Iowa



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This publication discusses many of the most important decisions you need to make to successfully develop and use low-temperature grain drying systems in Iowa. The information about selecting the equipment and operating the bin is appropriate only for corn, and similar for grain sorghum. Do not consider the information to be accurate for other grains such as soybeans, wheat, or oats.

Low-temperature drying includes drying with natural or unheated air or with air that has been heated as much as an additional 10°F.

This publication does not provide a complete discussion about low-temperature drying. Midwest Plan Service publication MWPS-22, "Low-Temperature and Solar Grain Drying," is available from your local Iowa county extension office, and contains a very complete 18-page discussion about low-temperature grain drying. The publication here highlights the specific points that are most important about low-temperature corn drying for Iowa conditions and discusses other subjects, such as locating drying bins, that are not included in MWPS-22.

One of the primary limitations for low-temperature drying is the moisture content of corn that can be dried without spoilage. The maximum moisture content depends upon several factors such as the specific way the drying bin is filled. For example, the *maximum* practical moisture content is about 22 percent for filling a low-temperature drying bin in one day. Because of this limitation, there are two general categories of Iowa corn producers who most commonly use low-temperature drying bins.

1. The producers who can store their entire crop in one or two bins. Such producers usually have a maximum annual production of around 20,000 bushels of corn. They may need to harvest their corn over a 2-3 week period.

2. The larger corn producer who has a combination high-temperature/low-temperature drying system. If the corn is sufficiently dry, usually 22 percent or less, it can be dried in a low-temperature drying bin. If it is wetter, the corn is first dried in some type of high-temperature dryer to 20-22 percent; the corn is then moved to the low-temperature drying bin to complete the drying. Combination drying systems are appropriate for very large corn producers.

Selecting the Equipment

Low-temperature drying systems are practically always round, steel grain bins equipped with perforated drying floor, drying fan or fans, grain spreader, and grain unloading equipment as shown in figure 1. They may be equipped with some method to increase the temperature of the drying air by up to a maximum of 10°F. The perforated floor should have at least 7 percent open area. The floor can be supported with either commercial steel supports or concrete blocks.

The airflow that is forced through corn is the key to success for all low-temperature corn drying systems. The total amount of airflow is measured in cubic feet of air per minute (cfm) that a fan will move against a specific static pressure in inches of water. A more useful factor that can be estimated by knowing the total airflow is the *airflow per bushel or cubic feet of air per minute per bushel (cfm/bu)*.

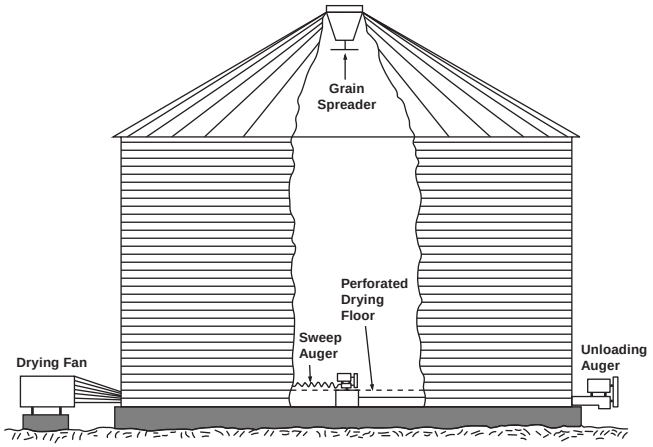


Figure 1. Typical equipment for all types of low-temperature bin dryers.

The minimum airflow recommendations that have been determined by research to successfully dry corn are the same for unheated-air and heated-air low-temperature drying. As shown in figure 2, the recommended full bin airflow rate for most of Iowa is 1.25 cfm/bu. A small part of southeast Iowa, which includes parts of Des Moines, Lee, Louisa, and Henry counties, requires 1.5 cfm per bushel.

You must know the static pressure, measured in inches of water, to select a drying fan. Table 1 provides guidelines for determining the estimated static pressure a fan will operate against at both 1¼ and 1½ cfm per bushel for five different grain depths.

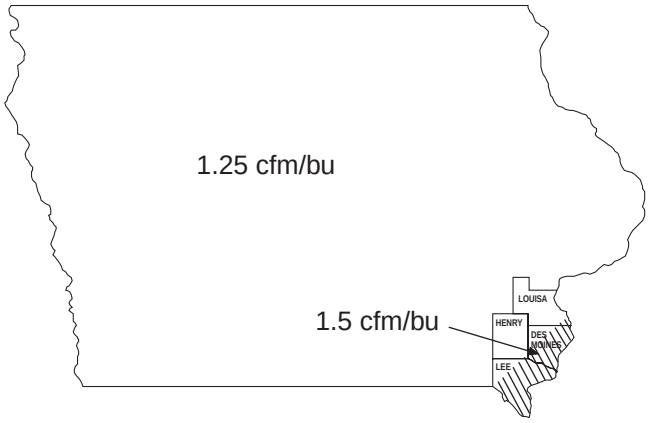


Figure 2. Recommended full-bin airflow for Iowa.

Table 1. Guidelines for fan selection

Maximum corn depth (feet)	Estimated static pressure at 1¼ cfm/bu (inches of water)	Estimated static pressure at 1½ cfm/bu (inches of water)
12	1½	2
14	2¼	2¾
16	3¼	4½
18	4¾	5¾
20	5½	7½

Table 2 shows the grain bin capacity in bushels of corn per foot of depth for 12 common grain bin diameters. These figures assume 1.25 cubic feet of volume for 1 bushel. When a bin is full, the corn will often be slightly compacted and actually hold up to 5 percent more corn than the figures in table 2 indicate.

Table 2. Grain bin capacities

Common bin diameter	Bin capacity
(ft)	(bu/ft)
18	203
21	277
22	304
24	362
27	458
30	566
33	684
36	814
40	1,005
42	1,108
48	1,448
60	2,262

Example: Select a fan for a 27-foot-diameter, low-temperature drying bin with a maximum corn depth of 16 feet for most of Iowa.

Drying bin capacity = 458 bu/ft x 16 ft = 7,328 bu.

Recommended airflow = 7,328 bu x 1.25 cfm/bu = 9,160 cfm.

Estimated static pressure for 1¼ cfm for 16 feet of grain depth from table 1 is 3¼ inches.

The fan selected should be specified to deliver a minimum of 9,160 cfm at a static pressure of 3¼ inches of water.

A fan that will deliver more air at 3¼ inches would be desirable because it will dry corn faster and this will decrease the chances of corn spoiling.

To more accurately estimate the airflow a specific low-temperature drying fan will deliver, follow the procedure provided in ISU Extension pamphlet Pm-1002, “Estimating Fan Airflow for Grain Bins,” that is available in your local extension office.

Research and experience in Iowa show that unheated air will normally dry corn to between 12 and 14 percent moisture content. Adding a little heat to the drying air does the following two things:

1. It dries the corn to a lower moisture content. The greater the amount of heat added, the lower the final moisture content of the corn. Table 3 shows an example of corn drying results under central Iowa conditions for 22 percent corn harvested the middle of October with four different drying air temperatures.

2. Adding heat also dries the corn faster, as shown in table 3. Even though adding heat to the drying air dries the corn faster, the lowest operating or energy cost for low-temperature drying is usually with natural air. Adding a little heat does not significantly decrease the chance of corn spoiling.

If heat is added when it is not needed, the corn will overdry, causing an unnecessary loss of weight. If heat is added to the drying air, the common sources of energy are electricity, LP gas, and solar.

Another question is whether to equip low-temperature drying bins with grain stirring equipment. There are several advantages for using stirring equipment. The final moisture content of the corn can be more closely controlled. Iowa State University and Purdue University research indicates that airflow is increased by as much as one-third with stirring. The price for the stirring equipment and the space occupied by the equipment (usually about 2 feet) are additional drying costs.

An economic analysis of these factors shows that use of stirring equipment does not greatly increase or decrease the annual corn drying profit.

Farmers do experience two problems with grain stirring equipment: breakdowns and accumulated fines on the drying floor.

Frequent attention is the best way for minimizing problems caused by breakdowns. Most of the mechanism that breaks is above the grain, so there is fairly easy access for repair work.

Research has shown that grain stirring does not significantly damage the grain, but stirring leaves the separated fines on the drying floor. Excessive fines can block airflow.

Screening corn to be dried with all low-temperature bins is recommended. Removing as many fines as possible permits air to pass through the corn more easily. Also, fines in the corn are the most susceptible to spoilage. Research at Iowa State University indicates that removing the fines reduces the rate of deterioration of shelled corn about 15 percent.

Table 3. Corn harvested with 22 percent moisture at mid-October in central Iowa and dried with 1⅓ cfm/bu.

Drying air	Final average moisture content	Average drying time
Natural air	13.4%	1,363 hrs. (56 days)
Natural air plus solar heat	13.2%	1,035 hrs. (43 days)
Natural air plus 3°F	13.1%	813 hrs. (33 days)
Natural air plus 6°F	11.9%	696 hrs. (29 days)

Locating the Bin

The specific location for a new low-temperature drying bin usually includes some compromises, but several important principles should be considered so the location will be as close to ideal as possible.

Perhaps most important is to locate a new bin where there is a lot of space around it for further expansion. Leave room to at least double and preferably triple or quadruple the amount of storage and drying capacity. You should also consider leaving room to add equipment such as some type of heated-air dryer or perhaps some type of feed processing. Feed processing systems are practically always best located as a part of grain storage and drying. You may not think you will expand or modify the system, but perhaps someone will in the future.

If the low-temperature drying bin will be a part of an existing drying system, the obvious location may be close by. But if the system is getting crowded, you should project your thinking into the future as far as possible and at least consider starting the move to a better location.

It is best to select a new bin site at least 200 feet from your house. Locate the drying fan, particularly a vane axial or propeller fan, on the side of the drying bin that is farthest from the farm house so the bin will be a noise shield.

Locate the bin as close as possible to an all-weather road so there will be good access for filling and unloading the bin. Try to select a site so the roads to and from the bin will not have a serious problem with drifting snow. Be sure there is ample room around the area for tractors and wagons or large grain trucks, perhaps even semis, to easily maneuver. Farmsteads with the farm home as the closest building to the public road generally have the most pleasant appearance.

It is generally better to have the grain unloading augers from bins discharge on the south or perhaps east side of the bin because they will be more protected from prevailing west, northwest, and north winter winds.

Select a site with good drainage. Be sure no surface water will drain toward the site. When drying bins are erected, the concrete floor surface should be 12 to 18 inches above the existing grade. This will not only prevent surface water from entering the bin, but grain unloading augers will be at a convenient height above the ground.

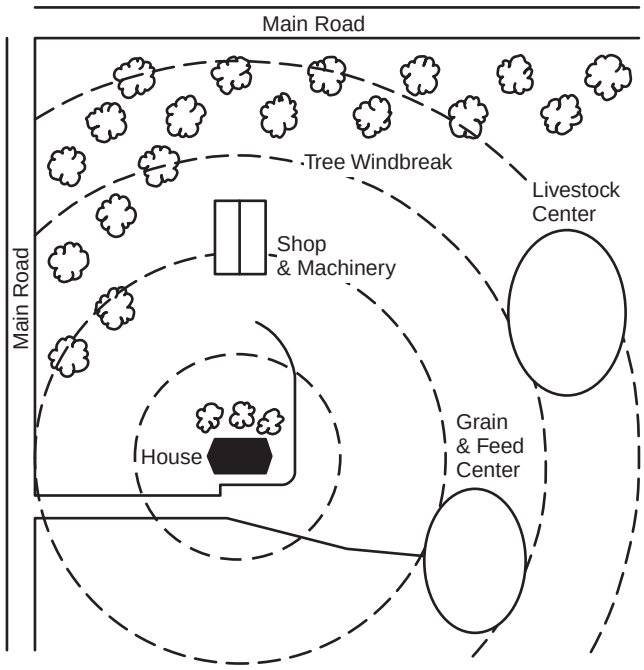


Figure 3. An example farmstead arrangement. Circles around house are about 1000 feet apart. Grain storage systems should be at least 200 feet from the farm house.

Be sure ample electric power is available. Check with your local electric supplier's power use advisor. He or she can give you valuable advice. For example, discuss the possibility of putting electric service underground, so you will not need to be concerned about overhead power lines. Never locate a bin so overhead power lines can come in contact with equipment such as augers or other grain elevators. Figure 3 shows a general suggestion for locating drying systems.

Operating Low-Temperature Drying Bins

One of the most important operating decisions to make for successfully drying with low temperatures is the moisture content of corn that can be safely loaded into a bin. Table 4, which is taken from MWPS-22, gives recommended *minimum* airflow for the *maximum* moisture content for corn harvested in Iowa on or after seven specific dates.

This table is a result of much research. It is highly recommended the table be carefully followed and anyone who is going to dry corn in Iowa with low temperatures should study MWPS-22, which is available from Iowa county extension offices.

Table 4. Recommended airflow for Iowa

Minimum airflow per bu. (cfm/bu.)	Corn harvested on or after						
	Sept. 1	Sept. 15	Oct. 1	Oct. 15	Nov. 1	Nov. 15	Dec. 1
	Maximum corn moisture content, %						
1.0	19	20 (19.5)*	20	21	23 (22)	20	18
1.25	19	20	20.5	21.5	24 (22.5)	20.5	18
1.5	19.5	20.5 (20)	21	22.5 (22)	24 (23.5)	21	18
2.0	20	21	22.5 (22)	23.5 (23)	25 (24.5)	21.5	18
3.0	21	22.5 (22)	23.5	24.5	26 (25.5)	22	18

* Numbers in parentheses are recommended minimum airflow for the area in Iowa shown in figure 2.

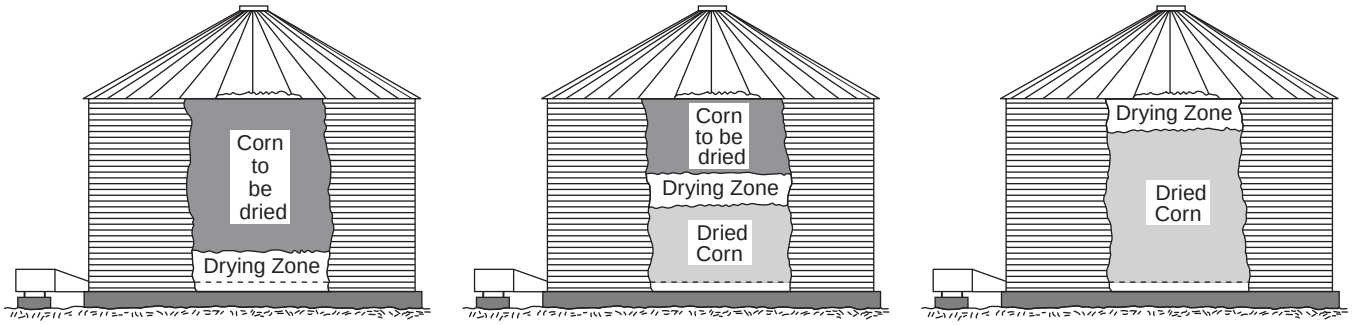


Figure 4. How drying progresses through a layer of corn.

In addition, you will need to follow the procedure outlined in Pm-1002 to determine the airflow your fan will deliver at different corn depths.

USDA research shows that high-moisture corn properly treated with anhydrous ammonia extends the storage time for corn. This practice is only approved for corn to be used for livestock feed.

There are three basic procedures for filling a low-temperature drying bin. (1) Single filling, the most common method, is loading the bin in as little time as possible, such as 1-3 days; (2) layer filling is loading the bin with specific amounts of corn; one-fourth, one-third, or half a bin full each week; (3) controlled filling is similar to layer filling except the amount of corn added each time depends on the specific corn moisture and drying process. All three are workable systems, but must be carefully selected to be compatible with the user's corn harvesting capacity. MWPS-22 has an excellent discussion about these three loading procedures for low-temperature corn drying.

How Corn Dries

Understanding how corn dries in a low-temperature drying bin is helpful. In a drying bin where the air flows up through the corn and no stirring equipment is used, drying begins in a shallow layer next to the perforated floor. This shallow layer, called the drying zone, usually is about a foot thick. As the drying zone moves through the corn, the corn below the drying zone is dried and the corn above the drying zone is not dried until the zone moves through it. The bin of corn is dried when the drying zone has moved completely through the corn.

Figure 4 is a simplified version of the way a drying zone moves through a bin of corn to be dried. Figure 4 is a simplified version because there are several minor drying zones and also rewetting zones in a bin of corn being dried with low temperatures. But the simplified version does show the basic way that corn dries.

If the low-temperature drying is equipped with stirring equipment, the drying zone stays at or near the bottom of the bin. As the corn is dried, it is augered to the top surface, which permits the wet corn to drop or move toward the floor for drying. Other than increasing the airflow through the corn and allowing the drying to be stopped at a higher moisture content (14-16 percent) than normal for non-stir drying, stirring does not significantly increase the effectiveness of low-temperature drying.

If a bin is equipped with both stirring equipment and a heater capable of drying with high temperatures (140°F-160°F), the bin can be used as a combination high-temperature/low-temperature bin. If corn is too wet to safely dry with low temperatures, the corn can be rapidly dried in 1-3 days to approximately 20 percent and finished with low temperatures. This is only one example of combination drying. Keep in mind that some type of combination high-temperature/low-temperature drying adds tremendous flexibility to a drying system because much higher moisture content of corn can be satisfactorily dried.

Drying bins used for combination drying should be equipped with perforated wall liners or air tubes to minimize problems from moisture condensing on bin walls.

Another important principle about how corn dries in a low-temperature drying bin is that the corn below the drying zone will dry to a final moisture content, depending on the temperature and relative humidity of the drying air. The final moisture content of the corn, or when the corn is in equilibrium with the drying air, is called equilibrium moisture content. Table 5 is a brief table of equilibrium moisture contents. A more complete table is provided in MWPS-22.

Table 5. Equilibrium moisture content for shelled corn

Temp.	Relative humidity, %					
deg. F	40	50	60	70	80	90
40	11.9	13.1	14.5	16.0	17.9	20.5
50	11.2	12.5	13.8	15.4	17.3	20.2
60	10.6	11.9	13.3	14.8	16.8	19.7
70	10.0	11.4	12.7	14.3	16.3	19.3

Following is an example of what table 5 describes: If the temperature of the air moving through the corn is 40°F and the relative humidity is 40 percent, the corn will dry to 11.9 percent moisture content.

Fall weather conditions in Iowa will normally dry corn to between 12 and 14 percent moisture content with natural or unheated low-temperature drying air.

If the fall weather temperatures in Iowa are abnormally high, three situations might occur: (1) Regardless of the relative humidity, the corn might spoil. When temperatures are high, the corn dries faster, but it also spoils fast. This condition, commonly known as a warm Indian summer, is potentially the worst condition for low-temperature drying. (2) If the relative humidity is lower than normal and if the corn is safely dried, as indicated in table 5, it will be drier than normal. (3) If the relative humidity is abnormally high, the final moisture content of the dried corn will be higher than normal.

If the fall weather temperatures in Iowa are abnormally cold, two things will occur: (1) Drying will be quite slow and may not be completed during the fall. (2) If relative humidity is abnormally high, drying will also be slow, and if the drying is completed in the fall, the final moisture content will be greater than average (perhaps as high as 16 or 18 percent). Adding a small amount of supplemental heat will help when the relative humidity is higher than 75 percent.

Whether the relative humidity is abnormally high or low, chances of the corn spoiling before spring are very low because temperatures are low. If the corn is not dried during the fall, it should be used or sold during the winter, or dried during early spring.

Drying Fan Operation

Regardless of the fall weather conditions, it is essential to continuously operate the drying fan. Start the fan as soon as the drying floor is covered with a few inches of corn. Do not turn off the fan unless:

1. All the corn is dried, preferable to 15½ percent moisture content or lower.

2. It is late in the fall when average outside temperatures drop. If the drying zone has moved completely through the corn and the top foot of corn is 18 percent or less, you can safely turn off the fan if the average outside air temperature is below 35°F, usually in the last half of November. If the drying zone has not completely moved through the corn, do not turn off the fan until the average outside air temperature is below 25°F, usually in the middle of December.

If the corn is not dried during the fall, maintain the temperature of corn between 35°F and 40°F during the winter. You can do this by operating the fan when the outside temperatures are between 35°F and 40°F. It is a good idea to run the fan 10-15 hours every week or two during the winter to remove any heat that might be developing in the corn. Do not run the fan when the outside relative humidity is greater than 75 percent.

If the corn is not dried during the fall and it is not sold or used during the winter, be sure to start the drying in the spring as soon as the average daily temperatures reach 40-50°F. This will usually occur during the first half of April.

Regardless of the weather conditions, one of the most important rules for operating a low-temperature bin dryer is to frequently check the drying process. *During the first couple of weeks of drying, corn should be checked at least every 3 or 4 days.* For the rest of the drying time, the corn should be checked every day.

One of the best ways to check corn during the drying process is to smell the air leaving the corn. If it starts to have a foul or musty odor, this is a strong indication the corn is starting to spoil. If this occurs, the best choice probably is to remove the corn in the upper part of the bin that is not dried and sell or dry the corn before it spoils so badly that it has no market value.

The possibility of spoilage is much greater if the corn is harvested too wet for the amount of low-temperature air the fan will deliver and if the fall weather is unseasonably warm. *If both occur at the same time, chances for spoilage are drastically increased.*

Several other important operating procedures for each low-temperature corn drying technique are discussed in MWPS-22.

Managing the Dried Corn

After you have successfully dried your corn in a low-temperature drying bin, be sure you know how to properly aerate the corn to prevent moisture migration. The best recommendation is to study the Midwest Plan Service publication, AED-20, “Managing Dry Grain in Storage.” It is available at your Iowa county extension office.

Safety

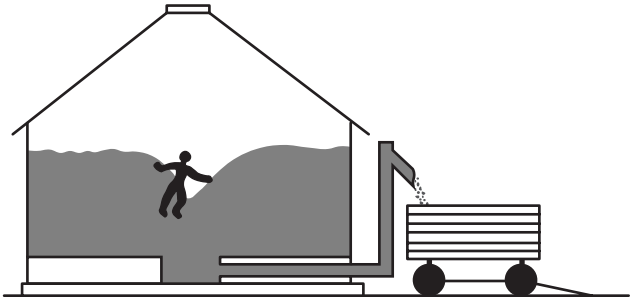
The following information about safety is reprinted from AED-20. Conscientiously know and follow these suggestions. They could save a life!

Take time to review safety measures with workers and all family members. “Better safe than sorry” is good advice around grain and hazardous machinery.

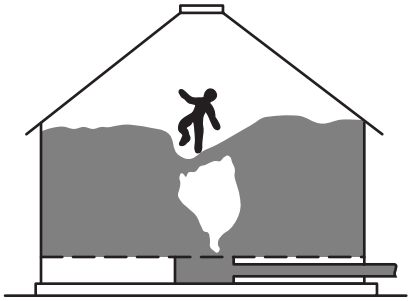
Absolutely forbid entry into a bin, wagon, or truck when grain is flowing. It is a major cause of accidental death when handling grain.

With modest flow rates of a 6-inch auger, you are helpless within 2 to 4 seconds after stepping into a cone of grain flowing from a bin. You are totally submerged within 20 seconds at a grain flow rate of 1,000 bushels per hour.

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



Flowing grain can trap and suffocate a person in seconds.



Crusted or bridged grain can collapse and bury a person.

Safety Precautions

• Do not enter a bin of flowing grain.

• Do not 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 does not start it.

• Do not 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.

• Do not 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 worker in the bin with the two outside workers capable of lifting out the person without entering the bin. One outside person cannot do this and also go for help while giving first aid.

• Always wear a respirator capable of filtering fine dust when working in dusty or 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.

Other Publications

Following is a list of publications mentioned in this bulletin. They should be available at your Iowa county extension office or you can obtain them by writing to Agricultural Engineering Extension, 200 Davidson Hall, Iowa State University, Ames, Iowa 50011.

MWPS-22—Low-Temperature and Solar Grain Drying Handbook—$6.00 per copy
AED-20—Managing Dry Grain in Storage—$2.00 per copy
Pm-1002—Estimating Fan Airflow in Grain Bins—Single copies free

Prepared by Larry Van Fossen, former extension agricultural engineer.

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