MANAGING STORED GRAIN

Basic Principles

Grain will deteriorate faster as temperature and moisture content incre ase. Using corn as an example, Table 1 illustrates how fast grain can spoil even with proper aeration.

		Corn Moisture, Percent						
Grain	Grain	18%	20%	22%	24%	26%	28%	30%
Temp °F	Temp °C	Days						
30°	-1°	648	321	190	127	94	74	61
35°	2°	432	214	126	85	62	49	40
40°	4°	288	142	84	56	41	32	27
45°	7°	192	95	56	37	27	21	18
50°	10°	128	63	37	25	18	14	12
55°	13°	85	42	25	16	12	9	8
60°	16°	56	28	17	11	8	7	5
65°	18°	42	21	13	8	6	5	4
70°	21°	31	16	9	6	5	4	3
75°	24°	23	12	7	5	4	3	2
80°	27°	17	9	5	4	3	2	2

Table 1 Allowable Storage Time for Shelled Corn with Aeration: °Fahrenheit (F) & °Celsius (C).

Corn is a perishable co mmodity with a limited shelf life th at depends on the moi sture content and temperature of the corn. "Shelf Life" is the length of time good quality, aerated shelled corn can be stored before losing 1/2 % of dry matter. With this amount of dry matter decomposition, it is assumed that the corn loses some quality, but maintains its market grade. **For each 10° F (5° C) increase in tem perature, storage time is cut in about half when held at a given moisture content.**

Grain Moisture Content will change with the relative humidity of the surrounding air. Table 2 shows th e moisture content of corn at variou s temperature and relative humidity situations. Contact your local extension office for information on other grains.

		Relative Humidity %								
		10%	20%	30%	40%	50%	60%	70%	80%	90%
°F	°C	Corn Equilibrium Moisture Content %								
20°	-7°	9.4	11.1	12.4	13.6	14.8	16.1	17.6	19.4	22.2
25°	-4°	8.8	10.5	11.9	13.1	14.3	15.6	17.1	19	21.8
30°	-1°	8.3	10.1	11.4	12.7	13.9	15.2	16.7	18.6	21.1
35°	2°	7.9	9.6	11	12.3	13.5	14.8	16.3	18.2	20.8
40°	4°	7.4	9.2	10.6	11.9	13.1	14.5	16	17.9	20.5
45°	7°	7.1	8.8	10.2	11.5	12.8	14.1	15.7	17.6	20.5
50°	10°	6.7	8.5	9.9	11.2	12.5	13.8	15.4	17.3	20.2
55°	13°	6.3	8.2	9.6	10.9	12.2	13.5	15.1	17	20
60°	16°	6	7.9	9.3	10.6	11.9	13.3	14.8	16.8	19.7
65°	18°	5.7	7.6	9	10.3	11.6	13	14.6	16.5	19.5
70°	21°	5.4	7.3	8.7	10	11.4	12.7	14.3	16.3	19.3
75°	24°	5.1	7	8.5	9.8	11.1	12.5	14.1	16.1	19.1
80°	27°	4.9	6.7	8.2	9.6	10.9	12.3	13.9	15.9	18.9
85°	29°	4.6	6.5	8	9.3	10.7	12.1	13.7	15.7	18.7
90°	22°	4.4	6.3	7.7	9.1	10.4	11.9	13.5	15.5	18.5
95°	35°	4.1	6	7.5	8.9	10.2	11.7	13.3	15.3	18.4
100°	38°	3.9	5.8	7.3	8.7	10	11.5	13.1	15.1	18.2

Table 2 Equilibrium Moisture Content for Corn

Under certain conditions (see Table 2), no matter how long the fan is operated, the grain may not reach the desired moisture content that will allow it to be stored without spoilage. K eep in min d, the ai r temperature and relat ive humidity are not con stant; however, use the daily average for deter mining the final moisture content.

L1109
2007/2
Rev. 3

Moisture Content				CFM/BU	m³/hr/MT
Corn	Soybeans	Wheat	Rice	Airflow	Airflow
14%	10-11%	12-13%	10%	1/10-1/8	8-10
15-17%	12-13%	14-15%	11-12%	1/7-1/5	11-15
18-20%	14%-Max	16-17%	13-14%	1/4-1/2	19-38

Table 3 Wet Holding Tank Airflow Requirements

Table 3 shows the recommended aeration when storing grain for short periods in a wet holding tank at various moisture contents. This will only hold the grain for the length of time shown in Table 1. If no aeration is provided, the grain may deteriorate much faster due to small "hot spots" that may begin to develop, producing heat and moisture which accelerate deterioration. The purpose of aeration is to reduce the chance of hot spots by keeping all of the grain the same temperature.

Grain Storage

More grain is lost because of improper storage than for any other reason. Most common problems are as follows:

1. Inadequate observation of grain during storage: not checking grain frequently.
2. Improper grain management, not using aeration to control grain temperature.
3. Pockets of fines (broken kernels, weed seeds and trash) restrict airflow and provide food for insects and mold.
4. Grain began to deteriorate because it was held too long without adequate aeration prior to drying.
5. Improper cooling of grain after drying. Grain must be dry and cool before storing.
6. Poor initial grain quality or not dried to a safe moisture content.
7. Improper or lack of insect control.

Moisture Content of Grain Storage

The length of time grain can be stored without aeration and the moisture content at which it is stored determines significant deterioration. Short-term storage generally refers to storage under winter conditions while long-term storage considers the effect of summer conditions. Grain with damaged kernels or with significant amounts of foreign material needs to be stored 1 to 2 percentage points lower than sound, clean grain. Contact your local elevator or bin dealer for recommended moisture contents and storage times. Table 4 shows the recommended maximum moisture contents for safe grain storage. Values are for good quality, clean grain, and aerated storage: reduce 1% for poor quality grain, such as damaged by blight, drought, etc.

Grain	Max. Safe Moisture Content
Shelled Corn & Sorghum	
To be sold as #2 grain or equivalent by Spring	15%
To be stored up to 1 year	14%
To be stored more than 1 year	13%
Soybeans	
To be sold by spring	14%
To be stored up to 1 year	12%
Wheat	13%
Small Grains (oats, barley, etc.)	13%
Sunflowers	
To be stored up to 6 months	10%
To be stored up to 1 year	8%
Rice	12-1/2%

Table 4. Max Moisture Content for Safe Storage

Grain should be dried to the moisture content required for the storage period intended. If problems with bin and/or grain arise, refer to the troubleshooting section for recommended actions. Each of these problems can be minimized with good management. **Aeration must be used to control grain temperature and prevent grain loss** (see following aeration section).

For best results in storing dried grain, an accurate moisture test is needed to determine that the grain is dry. Also, an aeration system is necessary for controlling grain temperature. The drying fan can be used for cooling if the grain is stored in the bin in which it is dried. If the grain is to be placed into a different bin, it should be equipped with an aeration system to control grain temperature during storage. It is imperative that the grain be cooled during storage to control insects and reduce moisture migration. The moisture content of grain for safe storage depends upon the grain and the length of time stored.

Short term storage of wet grains

We define wet corn as being 16 % or higher moisture content. Temperatures will not remain constant because corn releases heat that increase corn temperatures. Higher corn temperatures can rapidly lead to corn deterioration due to hot spots. Aeration systems are crucial to prevent this temperature rise. **Note:** wet corn with aeration is limited to the allowable storage times given in Table 1.

Storage Preparation

Insects are either already in the bin before filling or will enter later. The following steps will aid in the prevention of insect problems in your stored grain.

1. Clean bins thoroughly prior to filling.
2. Repair cracks and crevices where moisture and insects may enter.
3. Avoid filling bins with new crop where old crop already exists.
4. Clean and check the aeration system. Foreign material may collect in ducts creating an excellent insect breeding environment and obstructing airflow.

For more information on insect control, contact your local county extension office.

Grain Condition for Storage

Crops store best if they are cool, dry, and clean. Mold growth is dependent on both temperatures and crop moisture content. Crops that contain considerable foreign material or broken kernels will be more susceptible to mold and insects. The crop should be cleaned to reduce this hazard or be dried down to 1 to 2 percent lower than clean crops.

Checking the Grain

All stored grain needs to be checked on a regular basis. Check stored grain bi-weekly during the critical fall and spring months when outside air temperatures are changing rapidly. Check at least once a month during the winter after a storage history without problems. Also, search for small changes that are indicators of potential problem such as crusting on the crop or condensation on the bin roof. It may also be necessary to check the moisture of the grain with a moisture meter. Any increase in temperature indicates a problem, unless outdoor temperatures are warmer than the crop. Check and record the temperature at several points in the bin. The test weight of your crop is another evaluation that can be done to ensure your crop is at its best quality.

Filling and Coring the Bin

Best storage results are obtained when the crop is leveled in the bin. Lowering the center core of the stored crop improves airflow through the central area and makes checking the crop easier. Leveling can be accomplished with a grain spreader or by withdrawing grain from the center after filling.

In most bins, the normal grain discharge flow creates a center core that flows directly down to the unload conveyor or unload spout. This creates an inverted cone in the surface grain that gradually increases in diameter. As the unload runs, grain on the inverted cone side slopes gradually and slides into the bottom of the cone, where it funnels down the center core and to the conveyor or unload spout.

A bin filled to the peak will not have uniform airflow. Peaked grain is hard to manage and is especially risky when grain is stored above its safe moisture content. Part of the peak in all bins should be removed by coring the bin. It is important to core bins filled with moist grain, especially if the bin does not have a powered grain spreader that levels the surface and spreads the fines and trash. Coring the bin will remove the majority of the fines and foreign material because most fines tend to accumulate in the center of the bin. This is important since fines are more susceptible to spoilage and will restrict airflow. This practice obviously improves airflow through the grain, which reduces the chance of spoilage, and helps aeration fans work more efficiently.

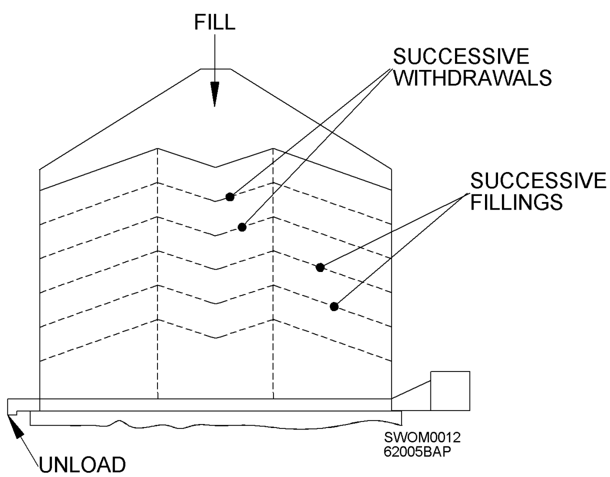


Fig. 1

Coring the bin is done by unloading grain periodically while the bin is being filled to pull down the peak after several feet of new grain is added. See Fig. 1. Coring during initial filling will remove a major part of the fines and foreign material (fm). Coring after bin is filled will remove some fines, but not as much as coring when filling. When coring a bin after filling is complete, remove about half the peak height for improved aeration. After coring, the top of the grain should be visually inspected to ensure an inverted cone has been created. If no cone is created, bridging of the grain has taken place and a very unsafe condition has been created. No one should enter the bin until situation has been safely corrected.

Moisture Migration

Crops are normally placed in storage at temperatures much warmer than the winter temperatures. Since crops are good insulators, the crop in the center of the bin will be the same temperature as at harvest even after outside temperatures have dropped well below freezing. This temperature differential causes moisture migration.

Air near the bin wall cools and sinks to the bottom of the bin, pushing air up in the center. When the crop near the surface cools the warm air, moisture in the air condenses. Cool air cannot hold as much moisture as warm air. As this circulation continues, moisture begins to accumulate near the top center of the storage. See Fig. 2. Crusting is an indication of moisture accumulation and mold growth. An aeration system cools the grain uniformly, limiting moisture migration. In the spring and summer months when the outside air gets warmer, moisture migration can occur opposite Fig. 2 and moisture will accumulate at the bottom of the bin.

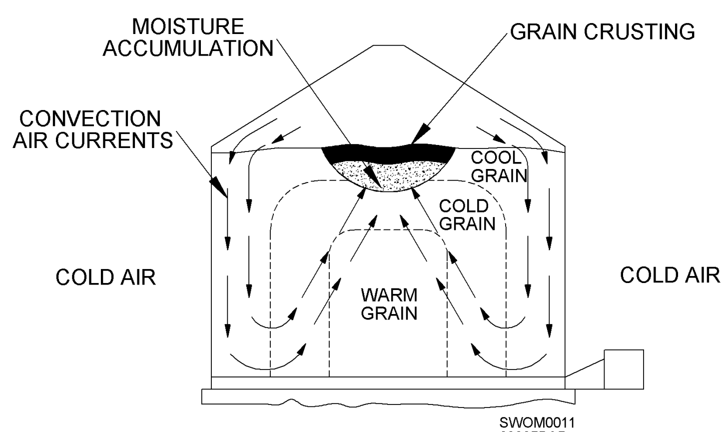


Fig. 2

The following items are recommended for proper grain storage.

- Transitions can cause pressure loss and air loss if improperly installed. The outlet area of the transition must be adequate for the airflow produced by the fan. The shape should provide a smooth airflow route without any abrupt direction changes. If any bin stiffeners need to be cut to install the transition, suitable alternative support must be provided to prevent bin wall collapse. The transition must be properly sealed at both ends to prevent air losses.

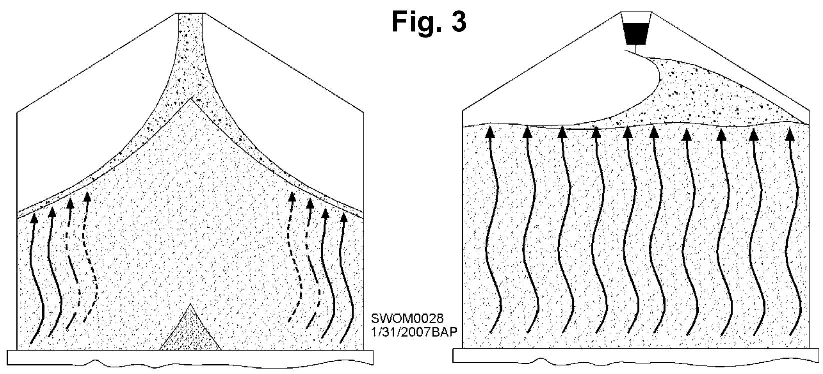
- Temperature sensors accurately trace the progress of aeration cooling or heating cycles. They help identify hot spots within the grain mass. They also indicate overall heating and approximate average grain temperature. Check with the bin manufacturer to be sure the cables, supports, and roof can withstand the drag from grain filling and unloading. Breakaway anchors should be used at the bottom of the cables to assure alignment but allow for a sweep auger. These cables that are suspended from the roof should be properly supported ad secured to the floor by a professional. **Absolutely NO weights or plates should be attached to the bottom of the temperature cables**

Temperatures may change only 1°-2° F (.5° - 1° C) 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 escalate at an increasing rate until cooling is applied.

- Cleaning grain before storing improves storability. Fines, foreign material, and broken kernels are grain handling problems. Kernels break during harvesting and handling. Select a grain cleaner that collects and conveys screenings away. The most common locations are: at receiving, after dryer just before delivery to storage, and at loadout. Cleaning is easier at low flow rates. Coring the bin also will remove a major part of the fines and foreign material.

- Roof vents ensure proper airflow and prevent snow or rain from entering the bin . Roof vents also increase the efficiency of the aeration system and should always be used in drying applications. Without adequate open area to let air and moisture out of the bin, the aeration or drying system will not work sufficiently. 1 ft² (.093 M²) opening for every 1500 CFM (2550 m³/hr) the fan will produce. Have at least 1½" (38.1 mm) eave opening. Keep center cap and manhole open during cooling and drying but closed during storage. Also, roof vents need to be cleaned of dust & debris after each season to prevent roof damage.

Fig. 3



Peaked grain with pockets of fine material.

Spreaders more evelny distribute fines and grain

- Grain Spreaders are available up to 60' diameter bins and provide a more level grain surface in the bin. Peaked grain results in increased airflow resistance in the peak portion of the bin. Furthermore, fines and foreign material in the grain tend to gather in the center of the bin. These fines result in increased airflow resistance. Properly adjusted and operated grain spreaders will leave the top surface of the grain level with the fines and foreign material more evenly distributed throughout the grain mass. The level surface and more evenly distributed fine material results in uniform airflow resistance throughout the entire bin. See Fig. 3.

Aeration

The objective of aeration is to get airflow through the crop to maintain uniform temperature within the bin to prevent hot spots that accelerate spoilage. Ideally a full perforated floor would be used, however aeration ducts may be used for structures storing only cool, dry grain. Since most problems develop in the center of the bin and the crop will cool naturally near the wall, the aeration system must at least provide good airflow in the center. If ducts placed directly on the floor are to be held in place by the crop, be sure the crop is directly on top of the duct to prevent movement and damage to the ducts. The duct must be strong enough to support the grain regardless of its shape or material used. Be sure airflow rate for aeration (storage) is 1/20 to 1/5 CFM/Bu, Usually 1/10 CFM/Bu (4 to 15 m³/hr/MT, Usually 8).

Cooling Grain for Winter Storage

Crops should be held near average outdoor temperatures during the fall. Modern grain management uses airflow to control grain temperature. Increasing the airflow rate reduces the time needed for cooling or warming but also increases power requirement. **Begin aeration to reduce the grain temperature when the average outdoor temp. is about 10° to 15° F (6° to 8° C) lower than the grain temperature.** The average outdoor temperature is the average daily high/low. You can estimate when a cooling or warming cycle has passed through the crop by measuring the temperature. **Repeat this cycle** as often as necessary, checking the temperature at several locations, **until the grain has cooled to 35° to 45° F (2° to 7°C).**

Table 5 Approximate Grain Cooling or Warming Times

Airflow rate		Fall Cooling	Winter Cooling	Spring Cooling
CFM/BU	**m³/hr/MT**	**hrs**	**hrs**	**hrs**
1/20	4	300	400	240
1/10	8	150	200	120
1/5	15	75	100	60
1/4	19	60	80	48
1/3	25	45	61	36
1/2	38	30	40	24
3/4	57	20	27	16
1	76	15	20	12
1 1/4	95	12	16	10
1 1/2	114	10	13	8

For pressure systems, check temperature at top of grain. For suction, check temperature coming out of fan. **Be sure to continue each aeration cycle until cooling front has moved completely through the grain.** This minimizes the chance for a moisture front within the grain mass to cause spoilage. Table 5 shows the length of time required to change grain temperature. To be sure the cooling front has passed through the grain, check the grain and air temperature.

DO NOT FREEZE GRAIN due to the problems this creates. Condensation during aeration can be a problem in grain cooled below freezing. It will be difficult to warm grain in the spring without condensation immediately freezing into ice. Frozen chunks block aeration warming cycles and grain unloading. **Condensation also rewets grain and can cause sudden bin failure due to the expansion of kernels.**

Managing Grain in the Spring and Summer

Start the fan when the average outdoor temperature is 10° to 15° F (6° to 8° C) above the grain temperature. Once the warm-up cycle is started, do not turn the fan off. Stopping the front before a cycle is completed encourages condensation of moisture and spoilage. As outside temperatures continue to warm, repeat this cycle as often as needed until the average grain temperature is 50° to 60° F (10° to 16° C). **Maintain grain temp. within 15° - 20° F (8° to 10° C) of the average monthly temp.** Do not warm grain to high summer temperatures above 80°F (27°C).

Grain Drying

Grain drying, as stated in this manual, refers to the removal of some of the moisture from grain by moving air through the grain after it had been harvested. The addition of heat is usually added to the air to speed up drying time. Grain in the field dries naturally as the crop matures, giving up moisture to the air until the grain moisture is in equilibrium with the moisture in the air. Conditions become less favorable for grain to dry to moisture contents considered safe for storage as the harvest is delayed late into fall. Note: Not all bins are designed for drying.

The basics of drying can be summarized as:

- Air removes water from the grain.
- The more airflow, the faster the drying.
- The warmer the air, the more water can be removed, thus the faster the drying.
- For every 20° F (11° C) heat rise, relative humidity (RH) is cut by about half.
- The warmer the air, the drier the grain.

Airflow rate, air temperature, and relative humidity influence drying speed. Air can hold more moisture when it is warm than when it is cool. The amount of moisture in the air as opposed to the amount it could hold if it were fully saturated is referred to as "Relative Humidity". As a rule of thumb, heating air 20° F. (11° C.), reduces the relative humidity by one-half. Table 7 illustrates how heating air decreases drying time and is expressed by the "Drying Ratio" column. Example: A 2.6 drying ratio means the grain will dry 2.6 times faster than the conditions with a drying ratio of 1.

Table 7 Drying Basics

For Every 20°F (11°C) Heat Rise, Relative Humidity Is Cut by 1/2				
Outside Air	Heated Air To	RH	Dries Grain To	Drying Ratio
70°F (21°C) 60% RH	No Heat	60%	13%	1.0
70°F (21°C) 60% RH	90°F	31%	8%	2.6
70°F (21°C) 60% RH	110°F	17%	5%	4.3

Drying Advantages

Advantages include:
- Preserve quality of harvested grain by reducing crop exposure to weather.
- Reduces harvesting losses, including head shattering and cracked kernels.
- Reduces dependency on weather conditions for harvest.
- Allows use of straight combining for small grains.
- Reduces the size and/or number of combines and other harvest-related equipment and labor required due to extended harvest time.
- Allows more time for post harvest fieldwork.

Influence of Drying Conditions

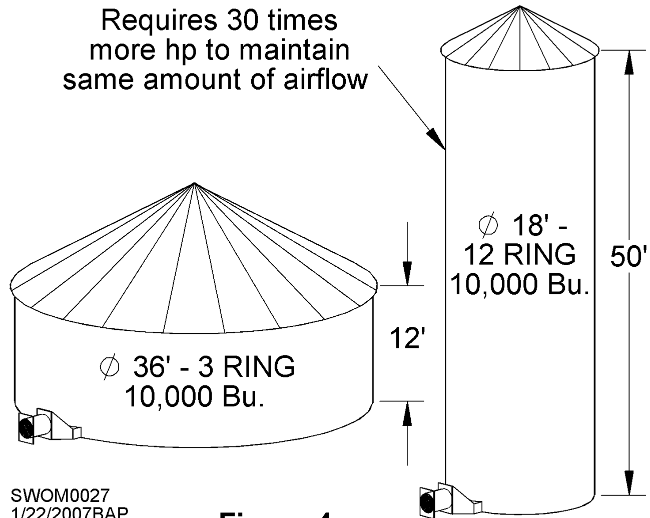


Figure 4

Drying air carries moisture away from the grain, and higher airflow rates give higher drying rates. Fan speed, motor size, and the resistance of the grain to air determine airflow. Deeper grain depths and higher airflow rates cause higher static pressure against the fan. Higher static pressure decreases fan output. Also, It should be noted that short-wide bins allow grain to dry better than tall-thin bins since there is less grain restriction (static pressure) and the same amount of grain. Tall-thin bins may require 30 times more horsepower than that of short-wide bins to maintain the same airflow. See Fig 4.

As air enters the grain it picks up some moisture, which cools the air slightly. As air moves through a deep grain mass, the air temperature is gradually lowered and relative humidity is increased until the air approaches equilibrium with the grain. If the air reaches equilibrium with the grain, it passes through the remaining grain without any additional drying. If high relative humidity air enters dry grain, some moisture is removed from the air and enters the grain. This slightly dried air will begin to pick up moisture when it reaches wetter grain.

Overdrying

Overdrying the grain will cost the producer money in two ways: (1) An excessive amount of energy has been used to dry the grain. (2) The crop is worth less because of shrinkage. See Table 8.

Moisture Content	Extra Drying Costs		Extra Shrinkage Costs		Total Overdrying	
	Dollars	Euros	Dollars	Euros	Dollars	Euros
14%	$0.035	€ 0.031	$0.044	€ 0.040	$0.079	€ 0.071
13%	$0.061	€ 0.055	$0.072	€ 0.065	$0.133	€ 0.120
12%	$0.087	€ 0.078	$0.099	€ 0.089	$0.186	€ 0.167
11%	$0.117	€ 0.105	$0.126	€ 0.113	$0.243	€ 0.219

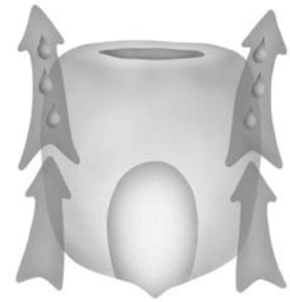
Table 8 Overdrying Costs When Marketing Corn Below 15% (1€ = $1.30)
-Cost Based On $.06 KW/HR (.046 Euro/kW/hr) and $1.00/Gal LP (.266 Euro/Litre of LP)

Grain Cooling

Grain dried with a heater, must be cooled. Grain can be rapidly cooled immediately after it is dried or delayed cooling methods can be used to reduce fuel cost, increase dryer capacity, and reduce stress cracks. The cooling method can affect the type, operation, and management of the dryer system. Cooling's effectiveness increases as drying air temperature increases. Cooling is required when a heater is used. Consider these cooling methods when selecting a drying system.

- With **In-bin Cooling**, stop heated drying about 1% above the desired final moisture content and run fan(s). Make sure grain is completely cooled before turning off fan(s). For pressure fan systems, check the grain temp. at the top of the bin to ensure cooling front has passed completely through the grain. After the grain is cooled, it is usually stored in the bin. Check moisture of grain when cooling is complete to ensure grain is at desired moisture content.

- Dryeration is recommended with a high temperature dryer. The first points of moisture are easily removed from the outer portion of the kernel with heat, however, moisture is left in the center. By transferring the hot grain to a seperate dryeration bin and delaying cooling for 12 hours while steeping and tempering occur, the remaining moisture will migrate to the outside of the kernel. Aeration fans will easily remove the last, and most difficult couple points of moisture just by moving cool air (1/2 cfm/bu) through the grain. Fans, full perforated floors, and additional handling equipment are needed for dryeration. This is the most economical way of cooling hot grain.



- Combination High Temp/Low Temp is for crops that are harvested too wet for safe low temperature bin drying. Wet corn is partially dried with high temperatures down to about 22% or less, often with a continuous flow dryer. The partially dried grain is moved to a low temp. drying bin where it is slowly dried with low temperatures.

Fans

Axial fans are the most common types of fans used for aeration. They require a relatively low initial investment and operate well at static pressures below 3 to 4 inches (76 to 100mm) or (750 pa) water gauge. Centrifugal fans deliver a fairly consistent airflow over a wide range of static pressure but require a higher initial investment than axial fans. Centrifugal fans are much quieter and more efficient. When aeration is required for tall bins or small grains which create high static pressures, 3500-rpm centrifugal fans are recommended.

Table 9 Fan Airflow Comparisons (CFM)

			Static Pressure (Inches)				
Fan Type	**HP**	**RPM**	**0**	**2**	**4**	**6**	**8**
Axial	5-7	3500	12,800	10,300	6,250	-	-
Centrifugal	7.5	1750	12,000	10,400	8,500	6,700	-
High-Speed Centrifugal	7.5	3500	5,005	4,600	4,250	3,850	3,400
In-Line Centrifugal	5-7	3500	6,370	5,815	5,150	4,715	3,935

Table 10 Fan Airflow Comparisons (m^3/hr)

				Static Pressure (mm)				
Fan Type	**HP**	**kW**	**RPM**	**0**	**50**	**101**	**152**	**203**
Axial	7.0	5.2	2900	21,500	15,300	4,750	-	-
Centrifugal	7.5	5.5	1450	22,500	19,000	14,600	-	-
High-Speed Centrifugal	7.5	5.5	2900	10,400	9,200	8,000	7,000	5,700

Select a fan according to the manufacturer's rating tables to deliver the required air volume at the expected static pressure.

Airflow Requirements

Table 6 Airflow Requirements CFM/Bu (m^3/hr/MT)

Aeration (storage):	-	1/20 to 1/5 CFM/Bu (Usually 1/10)	4 to 15 m^3/hr/MT (Usually 8)
Cooling Grain, Hot from Dryer:	-	1/2 CFM per Bu/hr	38 m^3/hr/MT
Cooling in Bin:	-	1/2 to 1 CFM/Bu (Usually 1/2)	38 to 76 m^3/hr/MT
Wet Holding Tank:	-	1/4 to 1/2 CFM/Bu	19 to 38 m^3/hr/MT
Drying: Natural Air	-	1 to 3 CFM/Bu	76 to 228 m^3/hr/MT
Low Temp	-	1 to 3 CFM/Bu	76 to 228 m^3/hr/MT
High Temp	-	1-1/2 to 5 CFM/Bu	114 to 380 m^3/hr/MT
Roof Dryer	-	12 to 22 CFM/Bu	911 to 1670 m^3/hr/MT

Heater Selection

Major considerations in heater selection are temperature rise required, type of fuel, heater placement, and heater controls. Temperature rise is the difference between ambient (surrounding air) temperature and plenum temperature. Use one of the following formulas to determine heater required:

LP and Natural Gas | **Electric**

BTU/Hr = Temp. Rise (°F) x CFM x 1.08

kW = Temp. Rise (°C) x Cubic meters/hr x .000333

LP and Natural Gas:

$$\text{Temp. Rise (°F)} = \frac{\text{BTU/hr} \times .93}{\text{CFM}}$$

$$\text{Temp. Rise (°C)} = \frac{\text{kW} \times 3000}{\text{Cubic meters/hr}}$$

Electric:

$$\text{Temp. Rise (°F)} = \frac{\text{kW} \times 3000}{\text{CFM}}$$

$$\text{Temp. Rise (°C)} = \frac{\text{kW} \times 3000}{\text{Cubic meters/hr}}$$

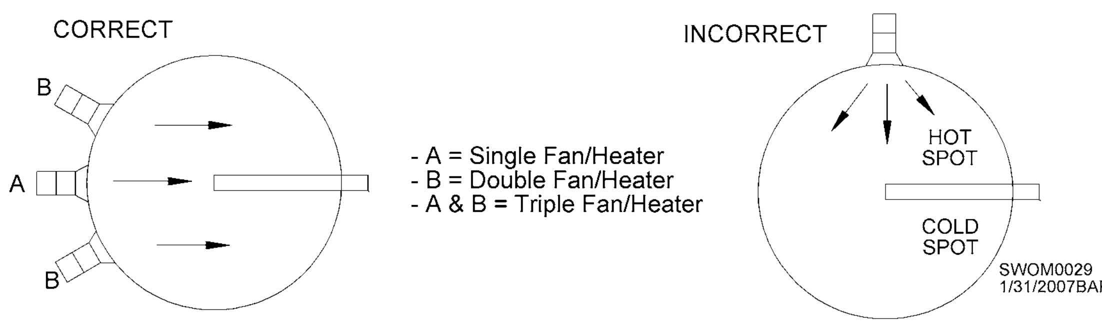
Very little temperature rise is desired for rice or soybeans whereas corn is often dried with higher temperatures. **Important:** To maintain quality and avoid risk of fire, in-bin-drying temperature should not exceed 120° F (49° C) for stir drying and 160° F (71° C) for in-bin continuous-flow drying. Refer to the Drying Precautions page later in this section for maximum plenum temperatures.

Table 7. Maximum Drying Air Temperatures for Selected Grains*

	Stand Alone Dryer				
Grain	**Cont. Flow Dryer**	**Recirc. Batch Dryer**	**Column Batch Dryer**	**Bin Batch Dryer**	**Seed**
Wheat	150° F	150° F	135° F	120° F	110° F
Barley	120° F	120° F	110° F	110° F	110° F
Soybeans	130° F	130° F	110° F	110° F	110° F
Oats	150° F	150° F	135° F	120° F	110° F
Rye	150° F	150° F	135° F	120° F	110° F
Flaxseed	180° F	180° F	160° F	120° F	110° F
Corn	200° F	200° F	180° F	120° F	110° F
Mustard	150° F	150° F	130° F	110° F	110° F
Pinto Beans	90° F	90° F	90° F	90° F	90° F

***Note:** From the North Dakota State University (NDSU) extension service, AE 701 (Revised), November 1994. This is a general guideline and temperatures may need to be lower. Please adjust to your specific situation.

Fan & Heater Placement



It is critical that the fan and heater are located so airflow and heat are evenly distributed under the bin floor. By placing a heater downstream, between the fan and the transition, air goes through the fan and then is heated. Because air expands as it is heated, additional drying capacity is obtained. Normally all axial fan heaters are placed downstream. Air straightener vanes must be included in the axial fan or heater to provide proper burner operation and even heat distribution in plenum of bin.

Centrifugal fans may be equipped with either upstream or downstream heaters. With low temperature heaters, either location may be used. For high temperature operation, downstream is preferred to provide greater drying capacity.

.

Heater Controls

Heater efficiency and cost of operation can be improved through proper selection of controls. For continuous flow drying, use high-low or modulating valve control. When two or more fans are used on a bin, use a high-low or thermostat control, which can be controlled through a dual burner control. Following lists the types of controls that are commonly available.

Thermostat - This unit cycles the heater completely on and off to maintain plenum temperature. It is the least expensive control along with being least efficient. When burner is shut off, fan is blowing outside air into plenum cooling it off. The on and off action provides an average temperature corresponding to the setting, but with short periods of high and low temperatures when the thermostat cycles the burner on or off.

High-Low Burner - The high-low burner control cycles burner from a high setting to a 20° to 30° F (10° to 15 ° C) lower setting to maintain a more uniform plenum temperature. This eliminates the extremes in plenum temperatures of a standard thermostat and provides economy of operation. **Note:** Use High-Low Control with a dual burner control when more than one fan and heater is used on bin.

Modulating Valve - The modulating valve provides most precise temperature control by continuously regulating the burner flame to maintain a constant temperature. Modulating valve works through a capillary tube filled with gas that expands and contracts with changes in plenum temperature. This gas moves a diaphragm controlling LP-gas or natural gas pressure to burner.

Humidistat - The humidistat is used with a low temperature burner and is located in plenum of bin. This cycles burner on and off based on relative humidity to control humidity of drying air.

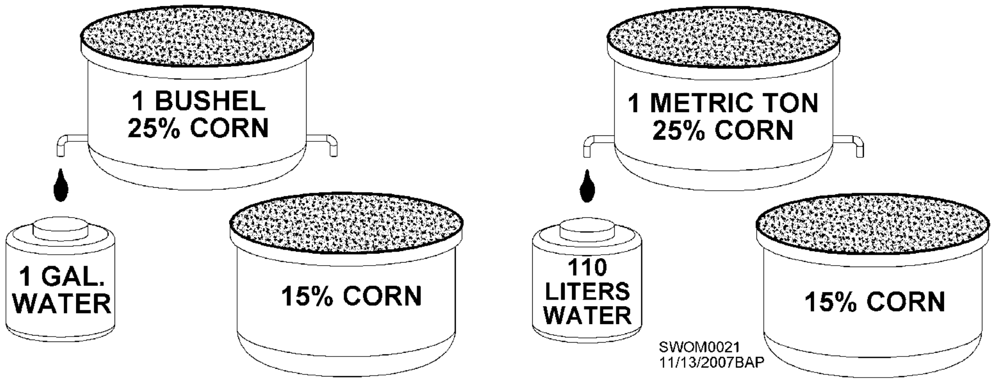
Type of Fuel

The use of either propane or natural gas is based on availability as burners for both fuels can be sized to provide heat required. When using propane as a fuel, either liquid or vapor may be used. Generally, a heater must include a vaporizer for liquid propane when ambient temperature is below 32° F (0° C) and one million BTU/HR (292 kW) is required. See the heater manual for size of propane tanks required when using vapor propane.

When using natural gas, contact your gas company to determine if adequate line pressure is available for operation. Getting sufficient natural gas supply can be a problem from some suppliers. For high temperature heaters, you will need to get 15 psi (100Kpa) supply pressure while operating to get max BTU/HR (kW/hr) capacity from heater. If the natural gas company can't supply this, you will need to buy a heater with larger piping, eg. 1¼" (31.75 mm). Electric heaters provide 1° to 4° F (1° to 2° C) of temperature rise. Usually, the use of LP-gas or natural gas burners provide a lower operating cost than electrical heaters.

Drying Guidelines to Prevent Bin Wall Spoilage

A large amount of moisture is removed during drying. Approximately 1 gallon of water (3.785 Liters) can be removed from one bushel (.029 Metric Ton) of corn at 25% moisture.



Completely empty bin before filling with final batch of grain. Dry grain at no more than 100 °F (38° C) on the final batch. In the cooling process (after grain is dried) run fan with heater for 1 day at 50° F (10° C) to cool the grain (run until air does not steam eye glasses when checked), then run fans with no heat for 2 days before shutting down system. Run fans and stirring machines (no heat) for 24 hours each month while grain is in storage and only on days in which humidity is 50% or less.

The following are guidelines that should be followed to prevent grain spoilage caused by moisture condensation during drying. This problem is most severe when drying at higher temperatures in colder climates.

- **Bin floors** with perforated flashing to insure maximum airflow along the bin wall.

- **Fans** should provide a minimum of 1.75 CFM/bu (117 m^3/hr/MT) when bin is full. Listed below are minimum fan recommendations based on 16' (5M) grain depth and 1.75 CFM/bu (117 m^3/hr/MT).

Bin Dia	Type of Cent.Fan	Qty of Fans	Type of Axial Fan	Qty of Fans
24'	10HP	1	28" 10-15 HP	1
27'	15HP	1	28" 10-15 HP	1
30'	20HP	1	28" 10-15 HP	2
33'	10HP	2	28" 10-15 HP	2
36'	10HP	2	28" 10-15 HP	2
42'	15HP	2	28" 10-15 HP	2
48'	20HP	2	28" 10-15 HP	3

- **Airway tubes** (used in the drying process) are perforated, triangular shaped tubes that attach along the inside of the bin sidewall. The main purpose of airway tubes is to remove moisture condensation and reduce spoilage costs. Drying of hot grain in the bin can cause sidewall condensation. For every 10 points of moisture removed from one bushel of corn, one gallon of water is produced. Some of this water condenses on the bin wall, causing spoiled grain. Airway tubes work to remove the water from the wall. Make certain that they are not plugged with fines or bees wings. Make sure that the flashing is punched so the tubes extend through the flashing to allow maximum airflow.

Drying Precautions

IMPROPER USE AND MAINTENANCE OF EQUIPMENT MAY CAUSE A FIRE!

Carefully read all the information listed below. Failure to do so can cause fire damage to grain, equipment, storage units, and may result in serious injury or even death.

Table 11 – Max Plenum Temp.* For Corn to Avoid an In-Bin Fire and Maintain Grain Quality

	Max Plenum Temperature for Corn	
In-Bin Continuous Flow Drying	160° F	70° C
Portable Dryer	200° F	93° C

***Note:** The above temperatures are only general recommendations. Drying temperatures for other grains vary due to ambient temperature, moisture content, and rate of drying. Temperatures may need to be lower due to special applications such as seed corn, food grade, etc. Consult your local extension office for further information on specific plenum temperatures when drying other grains.

Precautionary Steps to help prevent an in-bin fire.

- The maximum plenum temperature for drying without stirring should be no more than 10°F (5°C) above the ambient (outside) air. This will help prevent a fire as well as maintain grain quality.
- **DO NOT** combine drying equipment from various companies. Heaters have a variety of automatic controls to shut them down in case ignition failure, high temperature limits, or airflow failure. Combining equipment from various companies may cause a lack of safety controls needed to cut power. Check these items regularly for proper operation to reduce the chance of fire.
- **Keep area beneath perforated floor clean of all fines and foreign material as they may cause a bin fire. For even heat distribution, floor supports should not block transition.**
- It is recommended that grain be screened before going into bin to avoid formation of fines and trash. The use of a grain spreader will help distribute the fines.
- Thoroughly ventilating the bins with the dryer fan before igniting the heater will reduce the risk of a fire or explosion from leaking fuel.
- Faulty electrical wiring can also cause fires. Be certain components are wired by a qualified electrician.

If a fire is suspected. Follow these basic fire safety procedures to ensure the safety of yourself, family, and employees.

- Always account for all co-workers, neighboring farmers, and first responders.
- **Shut off gas** at heater and supply tank. **Shut off fan**. Call Fire Department.
- Keep fire away from fuel supply tanks and keep them cool by spraying water on them if needed.
- Seal fan inlet and any other openings to smother fire.
- Remove fan and heater from transition. Sandbag transition opening. If possible, flood bottom of bin (plenum) with water to a depth of 4" (100 mm) above perforated floor. This will protect steel floor supports and may extinguish fire, depending upon its location.
- If fire is located higher in bin, a long pipe with small holes may be inserted through the bin wall or manhole and into grain to direct water at source of fire. This may help keep the fire in a centralized location, but, it's nearly impossible to extinguish a fire in a grain bin by simply pouring water on it. These fires can only be extinguished by completely emptying the bin
- Take note of bin surroundings to avoid heat transfer onto neighboring structures. Be extra observant of propane tanks and cool if necessary.
- **ALL GRAIN MUST BE REMOVED FROM BIN TO REACH POINT OF FIRE**. Do not cut holes in bin to remove grain. Do not enter a bin that is on fire. The danger of getting buried in <u>flowing</u> grain exist.
- Grain may smolder <u>for day</u>s. Do not restart fan in hope that fire has gone out unless all grain has been removed from bin

NOTE: The grain management information contained in this manual are general guidelines and come from the following references. Your specific situation may require additional procedures or attention. Seek advice from your local extension office or consulting engineer for your specific operation.

REFERENCES:

- MWPS-22 Grain Drying, Handling, and Storage Handbook.
- AED-20 Managing Dry Grain in Storage
- ASAE Standard S412.3 Feb ’03, St. Joseph, Mich.
- University Extension Offices
  - Iowa State University
  - North Dakota State University
  - Purdue University
  - University of Kentucky
  - University of Missouri

Additional grain drying and storage Information is available from your local extension service or Midwest Plan Service, 122 Davidson Hall, Iowa State University, Ames, Iowa 50011.