

Managing Stored Grain

Basic Principles

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

Grain Temp. °F	Grain Temp. °C	Corn Moisture						
		18%	20%	22%	24%	26%	28%	30%
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 aerated shelled corn

Corn is a perishable commodity with a limited shelf life that depends on moisture content and temperature of the corn. "Shelf Life" refers to the length of time that aerated good quality 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 temperature, storage time is cut in about half when held at a given moisture content.**

Grain moisture content changes with relative humidity of surrounding air. Table 2 shows moisture content of corn at various temperatures and relative humidity. Contact your local extension office for information on other grains.

Grain Temp. °F	Grain Temp. °C	Relative Humidity								
		10%	20%	30%	40%	50%	60%	70%	80%	90%
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 fan is operated, grain may not reach desired moisture content that will allow it to be stored without spoilage. Keep in mind that air temperature and relative humidity are not constant. Use daily average for determining final moisture content.

Moisture Content				CFM/bu	m ³ /hr./MT
Corn	Soybeans	Wheat	Rice	Airflow	Airflow
14%	10-11%	12-13%	10%	1/10-1/8	8-10
15-17%	10-11%	14-15%	11-12%	1/7-1/5	11-15
18-20%	10-11%	16-17%	13-14%	1/4-1/2	19-38

Table 3 - Wet holding tank airflow requirements

Table 3 shows recommended aeration when storing grain for short periods in a wet holding tank at various moisture contents. These rates will only hold grain for length of time shown in Table 1. If no aeration is provided, grain may deteriorate much faster if small “hot spots” develop, producing heat and moisture that accelerate deterioration. Aeration is intended to prevent hot spots by keeping all grain at same temperature.

Grain Storage

More grain is damaged by improper storage than any other reason. The most common problems are:

- Inadequate observation of grain during storage - not checking grain frequently.
- Improper grain management - not using aeration to control grain temperature.
- Pockets of fines (broken kernels, weed seeds and debris) restricting airflow and providing food for insects and mold.
- Grain deteriorating because it was held too long without adequate aeration prior to drying.
- Improper cooling of grain after drying. Grain must be dry and cool before storing.
- Poor initial grain quality or insufficient drying to safe moisture content.
- 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 determine whether there will be significant deterioration. Short-term storage generally refers to storage over winter. Long-term storage spans more seasons. Grain with damaged kernels or with significant amounts of foreign material needs to be stored at moisture levels 1 to 2 percentage points lower than clean grain. Contact local elevator or bin dealer for recommended moisture contents and storage times.

Table 4 shows recommended maximum moisture contents for safe grain storage. Values are for good-quality, clean grain and aerated storage. Reduce moisture content 1% for poor-quality grain, such as grain damaged by blight, drought, etc.

Grain	Max. Safe Moisture Content
Shelled Corn & Sorghum	
To be sold as #2 grain or equiv. 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 - Maximum moisture content for safe storage

Grain should be dried to moisture content required for storage period intended. If problems with bin and/or grain arise, refer to 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 Aeration section.

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

Short-Term Storage of Wet Grain

Wet corn is defined as having moisture content of 16% or higher. Temperatures will not remain constant because wet corn releases heat. Resulting higher temperatures can rapidly lead to corn deterioration due to hot spots. Aeration systems are crucial to prevent this temperature rise. Even with aeration, however, allowable storage time for wet corn is limited, as shown in Table 1.

Storage Preparation

Insects are either already in bin before filling or will enter later. Steps below will aid in prevention of insect problems in grain.

- Clean bin thoroughly prior to filling.
- Repair cracks and/or crevices where moisture and insects may enter.
- Avoid filling bins with new crop before removing all of old crop.
- Clean and check aeration system. Foreign material may collect in ducts, creating an insect breeding environment and obstructing airflow.

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

Grain Condition for Storage

Grain stores best if it is cool, dry and clean. Mold growth depends on temperature and grain moisture content. Grain that contains considerable foreign material or broken kernels will be more susceptible to mold and insects. Such grain should be cleaned to reduce this hazard or be dried to a moisture content level that is 1 to 2 percent lower than clean grain.

Checking Grain

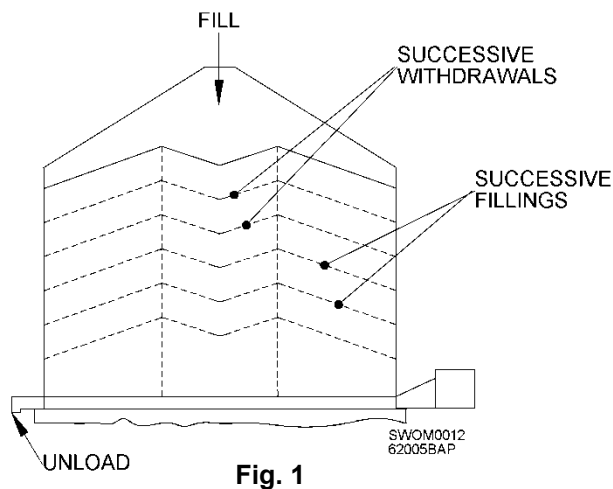
All stored grain needs to be checked on a regular basis. Check at least bi-weekly during critical fall and spring months when outside air temperatures change rapidly. Check at least once a month during winter, but more often if there are problems. Search for small changes that are indicators of potential problems, such as crusting or condensation on bin roof. It may also be necessary to check moisture of grain with a moisture meter. Check and record temperatures at several points in bin. Any increase in temperature indicates a problem unless outdoor temperatures are warmer than the grain. Testing weight of grain is another way to monitor its quality.

Filling and Coring of Bin

Best storage results are obtained when grain is level in bin. Lowering center core of stored grain improves airflow and makes checking grain easier. Leveling can be done with a grain spreader or by withdrawing grain from center after filling.

In most bins, normal grain discharge flow creates a center core that flows directly down to center sump. This creates an inverted cone in surface grain that gradually increases in diameter. As unload continues, grain funnels down center core to center sump.

A bin filled to its 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. It is important to core bins filled with moist grain, especially if bin does not have a grain spreader that levels the surface and spreads fines and trash. Coring will remove the majority of fines and foreign material because most fines tend to accumulate in center of bin. This is important since fines are more susceptible to spoilage and will restrict airflow. This practice improves airflow through grain, which reduces chance of spoilage and helps aeration fans work more efficiently.

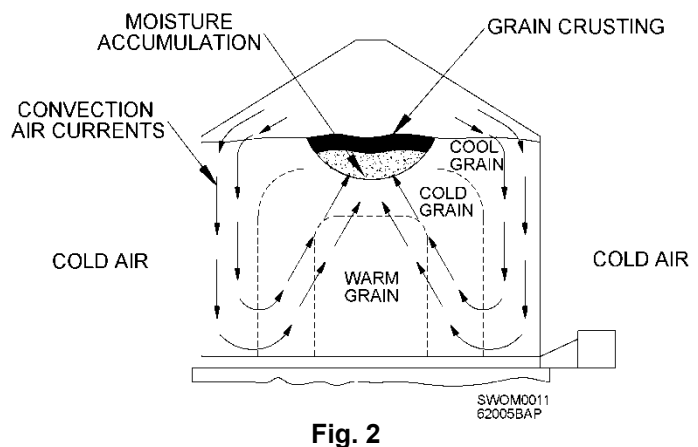


Coring is done by unloading grain periodically while bin is being filled. Pull down peak after several feet of new grain is added. See Fig. 1. **NOTE: Do not fill and core bin simultaneously.** Coring periodically during initial filling will remove a major portion of fines and foreign material. Coring after bin is filled will remove some fines, but not as much as coring periodically when filling. When coring a bin after filling is complete, remove about half of peak height for improved aeration. After coring, top of grain should be visually inspected to ensure an inverted cone has been created. If no cone is created, bridging of grain has occurred and a very unsafe condition has been created. No one should enter bin until bridging has been eliminated.

Moisture Migration

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

Air near bin wall cools and sinks to bottom of bin, pushing air up in center. When grain 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 top center of bin. See Fig. 2. Crusting is an indication of moisture accumulation and mold growth. An aeration system cools grain uniformly, limiting moisture migration. In spring and summer months when outside air gets warmer, moisture migration can occur in the opposite way and moisture will accumulate at bottom of bin.



Accessories and Practices for Proper Grain Storage

- **Properly Installed Transitions** will prevent pressure loss and air loss. Outlet area of transition must be adequate for airflow produced by fan. Transition's shape should provide a smooth airflow without any abrupt direction changes. Transition must be properly sealed at both ends to prevent air loss. If any bin stiffeners need to be cut to install transition, suitable alternative support must be provided to prevent bin wall collapse.

- **Temperature sensors** accurately trace progress of aeration cooling or heating cycles. They help identify hot spots in grain. They also indicate overall heating and approximate average grain temperature. Check with bin manufacturer to be sure cables, supports and roof can withstand drag from grain filling and unloading. Tie cables to floor or concrete with breakable string (fishing line) to assure alignment but allow for a sweep auger. Cables suspended from roof should be properly supported and secured to floor.

Absolutely NO weights or plates should be attached to bottom of temperature cables.

Temperatures may change only 1°F to 2°F (.5°C to 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 grain 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 storage. Fines, foreign material and broken kernels can create grain storage 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 load-out. Cleaning is easier at low flow rates. Coring bin also will remove a major portion of fines and foreign material.

- **Roof vents** ensure proper airflow and prevent snow and rain from entering bin. Roof vents also increase efficiency of aeration system and should always be used in drying. Without adequate open area to let air and moisture out of bin, aeration or drying system will not work sufficiently. There should be a 1ft² (.093 M²) opening for every 1500 CFM (2550 m³/hr.) that fan will produce. Have at least 1" (25.4 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 and debris after each season to prevent roof damage.

- **Grain Spreaders** are available for bins up to 60' diameter and provide a more level grain surface in bin. Peaked grain produces uneven airflow in bin. Also, fines and foreign material in grain tend to gather in center of bin. These fines contribute to airflow resistance. Properly adjusted and operated grain spreaders will leave top surface of grain closer to level, with fines and foreign material more evenly distributed throughout grain mass. Level surface and more evenly distributed fines result in uniform airflow throughout the bin. See Fig. 3.

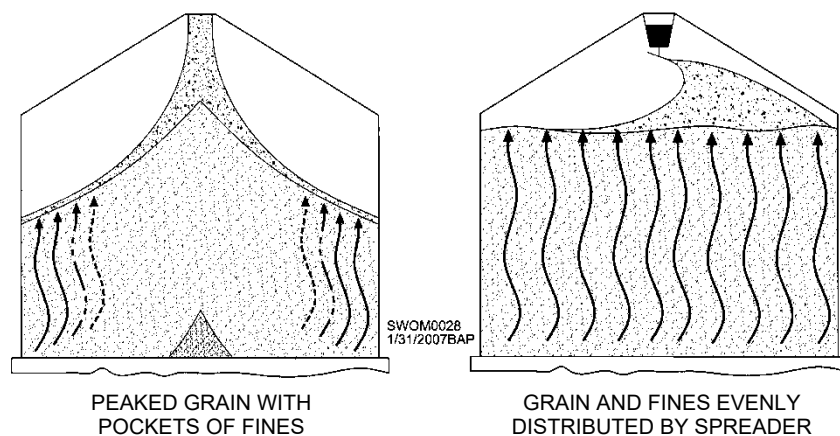


Fig. 3

Aeration

The objective of aeration is to maintain uniform temperature in the grain to prevent hot spots that accelerate spoilage. Ideally a fully perforated floor would be used. However, aeration ducts may be used for structures storing only cool, dry grain. Since most problems develop in center of bin and grain will cool naturally near wall, aeration system must at least provide good airflow in center of structure. If ducts placed directly on floor of structure are to be held in place by grain, be sure grain is loaded directly on top of duct to prevent movement and damage to ducts. Duct must be strong enough to support grain regardless of its shape or material used. Ensure 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

Grain should be kept near average outdoor temperature during fall. Increasing airflow rate reduces time needed for cooling or warming, but also increases power requirement. **Begin aeration to reduce grain temperature when average outdoor temperature is about 10°F to 15°F (6°C to 8°C) lower than 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 grain by measuring the temperature. **Repeat this cycle** as often as necessary, checking temperature at several locations, **until grain has cooled to 35°F to 45°F (2°C to 7C).**

Airflow rate		Fall Cooling	Winter Cooling	Spring Cooling
CFM/bu	m ³ /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

Table 5 - Approximate grain cooling or warming times

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 grain.** This minimizes the chance for a moisture front within the grain mass to cause spoilage. Table 5 shows length of time required to change grain temperature. To be sure cooling front has passed through grain, check grain and air temperature.



WARNING: Read and follow all safety information below. Failure to do so could cause bin collapse resulting in death or serious injury.

DO NOT FREEZE GRAIN due to problems it can create, particularly during warming and in larger bins. Condensation during aeration can be a problem in grain cooled below freezing. It will be difficult to warm grain in spring without condensation immediately freezing into ice. Frozen chunks block aeration warming cycles and grain unloading. **NOTICE: Condensation also re-wets grain and can cause sudden bin failure and collapse due to expansion of kernels.** If grain does freeze, begin thawing it once the average outdoor temperature is 10°F to 15°F (6°C to 8°C) above grain temperature. Follow steps outlined in segment below. **NOTICE: Failure to follow instructions for thawing frozen grain may result in sudden bin collapse and failure.**

Managing Grain in Spring and Summer

Start fan when average outdoor temperature is 10°F to 15°F (6°C to 8°C) above grain temperature. Once warm-up cycle is started, do not turn fan off. Stopping the warming front before a cycle is completed encourages condensation of moisture and spoilage. As outside temperatures continue to rise, repeat this cycle as often as needed until average grain temperature is 50°F to 60°F (10°C to 16°C). **Maintain grain temp. within 10°F and 15°F (5°C and 8°C) of the average monthly temp.** Do not warm grain to summer temperatures above 60 F (16 C) in the southern U.S. or 50 F (10 C) in the northern U.S. due to insect infestation and other storage issues.

Grain Drying

Grain drying removes moisture from grain by moving air through it after it has been harvested. Heat is usually added to air to speed up drying time. Grain in fields dries naturally as crops mature, giving up moisture until grain is in equilibrium with moisture in the air. Conditions become less favorable for grain to dry to safe storage levels as harvest is delayed late into fall. **NOTE:** Not all bins are designed for drying. See Bin Description section.

The basics of drying can be summarized as:

- Air removes water from 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 relative humidity by one-half. Table 6 illustrates how heating air decreases drying time and is expressed by the “Drying Ratio” column. Example: A 2.6 drying ratio means grain will dry 2.6 times faster than the conditions with a drying ratio of 1.

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

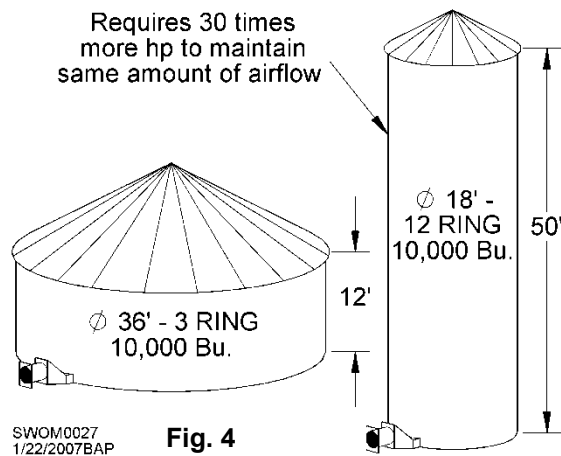
Table 6 - Drying basics

Unfortunately, drying grain to 8% or 5% moisture content is very costly and also results in excessive grain damage. By incorporating a stirring machine to mix dry grain at bottom of bin with upper wet grain, desirable average moisture may be obtained. University tests found that a properly stirred bin will have less than 1% variation of moisture content from top to bottom.

Drying Advantages

- Preserves quality of harvested grain by reducing its exposure to weather.
- Reduces grain quality losses due to head shattering and cracked kernels.
- Reduces dependency on weather conditions for harvest.
- Allows use of straight combining for small grains.
- Reduces 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



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

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

Overdrying

Overdrying grain will cost the producer money in two ways: (1) An excessive amount of energy is used to dry the grain. (2) The grain is worth less because of shrinkage. See Table 7. Using a stirring machine is an excellent way to eliminate over-drying and is essential when a heater is used with a drying bin.

Moisture Content	Extra Drying Costs		Extra Shrinkage Costs		Total Overdrying Costs	
	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 7 - Over-drying 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 cooling can be delayed to reduce fuel cost, increase dryer capacity, and reduce stress cracks. The cooling method can affect the type, operation and management of dryer system. Cooling 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 desired final moisture content and run fan(s). Make sure grain is completely cooled before turning off fan(s). For pressure fan systems, check grain temperature at top of bin to ensure cooling front has passed completely through grain. After 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 outer portion of kernel with heat. However, moisture is left in the center. By transferring hot grain to a separate dryeration bin and delaying cooling for 12 hours while steeping and tempering occur, remaining moisture will migrate to outside of 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 grain. Fans, perforated floors and additional handling equipment are needed for dryeration. This is the most economical way of cooling hot grain.



Fig. 5

- **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. Partially dried grain is moved to a low-temperature 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 that create high static pressures, 3,500-rpm centrifugal fans are recommended.

Fan Type	HP	RPM	Static Pressure (Inches)				
			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 8 - Fan airflow comparisons (CFM)

Fan Type	HP	kW	RPM	Static Pressure (mm)				
				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

Table 9 - Fan airflow comparisons (m³/hr.)

Contact your Sukup dealer for help in selecting fan(s) that will work best.

Airflow Requirements

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/bu*	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
	Low Temp:	1 to 3 CFM/bu
	High Temp:	1-1/2 to 5 CFM/bu
	Roof Dryer:	12 to 22 CFM/bu

*Airflow based on dryer capacity should be calculated as follows: 12 CFM per bu/hr. (815 m³/hr. per MT/hr.)

Table 10 - Airflow requirements CFM/bu (m³/hr./MT)

Heater Selection

Major factors 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 & Natural Gas

$$\text{BTU/Hr.} = \text{Temp. Rise (}^\circ\text{F)} \times \text{CFM} \times 1.08$$

$$\text{kW} = \text{Temp. Rise (}^\circ\text{C)} \times \text{Cubic meters/hr.} \times .000333$$

Electric

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

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

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

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

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 when drying corn, in-bin drying temperature should not exceed 120°F (49°C) for stir drying or 160°F (71°C) for in-bin continuous-flow drying. See Table 11 for maximum plenum temperatures depending on type of grain and drying. Also see Table 13.

Grain	Stand Alone Dryer				
	Cont. Flow Dryer	Recirc. Batch Dryer	Column Batch Dryer	In-Bin Drying	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

Table 11 - Maximum air (plenum) temperatures for drying selected grains*

*From North Dakota State University (NDSU) extension service, AE 701 (Revised), November 1994.

NOTE: These are **general guidelines only**. Drying temperatures may need to be lower for your specific situation. Please contact your local extension office for further information.

Fan & Heater Placement

It is critical that fan and heater are located so airflow and heat are evenly distributed under bin floor. By placing a heater downstream between fan and transition, air goes through fan and then is heated.

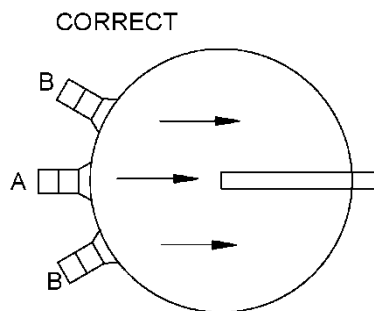
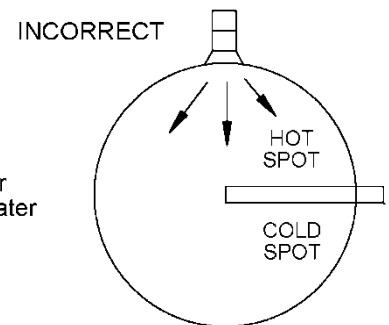


Fig. 6

- A = Single Fan/Heater
- B = Double Fan/Heater
- A & B = Triple Fan/Heater



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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 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. Sukup downstream heaters are equipped with adjustable air deflecting devices so that heat distribution in plenum can be altered if necessary.

Heater Control Options

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 are types of controls that are commonly available.

Thermostat – A thermostat cycles heater on and off to maintain plenum temperature. It is the least expensive control, but also least efficient. When burner is shut off, fan is blowing outside air into plenum, cooling it off. On-and-off action provides an average plenum temperature based on setting by user, but there is more short-term temperature variability.

High-Low Burner - The high-low control cycles burner from a high setting to a 20°F to 30°F (10°C to 15°C) lower setting to maintain a more uniform plenum temperature. This eliminates extremes in plenum temperatures from 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 the most precise temperature control by continuously regulating burner flame to maintain a constant temperature. Modulating valve relies on 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. It cycles burner on and off based on relative humidity to control humidity of drying air.

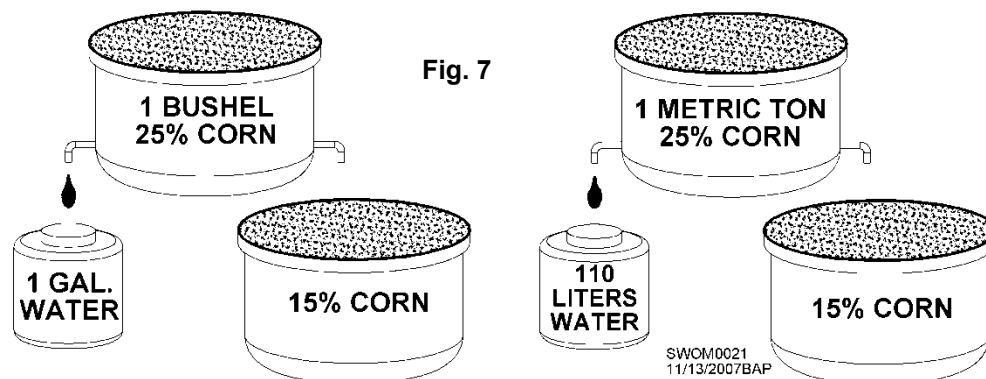
Type of Fuel

Use of either propane or natural gas is based on availability. Burners for both fuels can be sized to provide required heat. 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 Sukup heater manual for size of propane tanks required when using vapor propane.

If natural gas is preferred, contact gas company to find out if adequate line pressure is available for operation. Some companies may be unable to provide a sufficient natural gas supply. For high-temperature heaters, 15 psi (100 Kpa) supply pressure while operating is required to reach maximum Btu/hr (kW/hr) capacity from heater. If natural gas company cannot supply this, a heater with larger piping (e.g. 1-1/4" or 31.75 mm) should be used. Electric heaters provide 1°F to 4°F (1°C to 2°C) of temperature rise. LP and natural gas burners usually have lower operating costs than electrical heaters.

Drying Guidelines to Prevent Spoilage along Bin Wall

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



Follow guidelines below to prevent grain spoilage caused by moisture condensation that results from drying. This problem is most severe when drying at higher temperatures in colder climates.

- **Use bin floors** with perforated flashing to ensure maximum airflow along bin wall.
- **Fans** should provide a minimum of 1.75 CFM/bu (117 m³/hr./MT) aeration rate when bin is full. Listed below are minimum fan recommendations based on 16' (5M) grain depth and 1.75 CFM/bu (117 m³/hr./MT) aeration rate.

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

Table 12 – Minimum Fan Recommendations Based on 16' (5 m) Grain Depth & 1.75 CFM/bu (117 m³/hr/MT)

- **Use stirring machines** to eliminate over-dried grain, increase airflow and preserve grain quality. Stirring mixes driest grain at bottom of bin with wetter grain toward the top. This results in more uniform moisture content. University tests have shown less than 1% moisture variation from top to bottom in stirred grain.
- **Install Sukup Airway tubes**, which are perforated, triangular tubes that attach to inside of bin sidewall. They help remove moisture condensation and reduce spoilage costs. Drying of hot grain in a 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 bin wall, causing spoiled grain. Airway tubes help remove water from walls. Ensure they are not plugged with fines or debris. Make sure flashing is punched so tubes extend through flashing to allow maximum airflow.
- **Completely empty bin before filling with final batch of grain.**
- **Dry grain at no more than 100°F (38°C) on final batch.** In cooling process (after grain is dried), run fan with heater for 1 day at 50°F (10°C) to cool grain (run until air does not steam eye glasses when checked), then run fans with no heat for two 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.

Drying Precautions



WARNING: Read and follow all safety information below. Failure to do so could cause bin fire resulting in death or serious injury.

Precautionary Steps to Help Prevent an In-Bin Fire

- Maximum plenum temperature for in-bin drying without stirring should be no more than 10°F (5°C) above ambient (outside) air. This will help prevent a fire as well as maintain grain quality. See Table 13.

	Maximum Plenum Temperature for Corn*	
In-Bin Drying - without a Stirring Machine	10°F (5°C) above ambient (outside) air	
In-Bin Drying - with Stirring Machine	120°F	49°C
In-Bin Continuous Flow Drying	160°F	71°C
Portable, Mixed-flow or Tower Dryer	200°F	93°C

Table 13 – Maximum plenum temp. for corn to avoid an in-bin fire and maintain grain quality

*Temperatures are only general recommendations. Drying temperatures for other grains vary due to ambient temperature, moisture content and rate of drying, and may need to be lower. See Table 11, which shows maximum plenum temperatures for drying other grains and seeds. Consult your local extension office for information regarding your specific situation.

- **DO NOT** combine drying equipment from various companies. Sukup heaters are intended to be used with Sukup fans only. Sukup heaters have a variety of automatic controls to shut them down in case of ignition failure, high temperature limits or airflow failure. Combining equipment from various companies may result in a lack of safety controls needed to cut power. Inspect these items regularly for proper operation.

- **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.**

- Grain should be screened before going into bin to avoid formation of fines and debris. Use of a grain spreader will help distribute fines.

- Thoroughly ventilating bins with dryer fan before igniting heater will reduce risk of a fire or explosion from leaking fuel.

- Faulty electrical wiring can also cause fire. Be certain components are wired by a qualified electrician.

If a fire is suspected, follow these basic fire safety procedures to ensure safety for you, your 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 bin wall or manhole and into grain to direct water at source of fire. This may help keep 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 bin.

- Take note of bin surroundings to avoid heat transfer onto neighboring structures. Pay special attention to propane tanks. 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. Grain may bury you.

- Grain may smolder for days. Do not restart fan in hope that fire has gone out unless all grain has been removed from bin.

NOTE: Grain management information contained in this manual provides general guidelines and comes from sources listed below. Your specific situation may require additional procedures or attention. Seek advice from your local extension office or consulting engineer for your specific operation.

SOURCES:

- MWPS-13 Grain Drying, Handling and Storage Handbook.
- AED-20 Managing Dry Grain in Storage
- ASABE 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 and from Midwest Plan Service, 4306D Elings Hall, Iowa State University, Ames, Iowa 50011. Email: mwps@iastate.edu



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