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Grain Drying Concepts and Options

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Introduction

Grain harvested from the field contains water. While water is necessary for plant growth and grain production, excess moisture after grain maturity can lead to storage-related problems. Grain moisture content is expressed as a percent of the grain weight. For example, 100 pounds of 15-percent moisture content corn contains 15 pounds of water and 85 pounds of dry matter corn. Grain moisture content and temperature play a key role in determining safe storage life (see Tables 1 and 2). As a rule, dryer grain and cooler temperatures increase safe storage durations. In contrast, wetter grain and warmer temperatures increase the potential for pests, insects, mold and fungi to reduce grain quality and market value.

Grain drying begins in the field after the grain is fully mature. A layer of tissue is formed between the seed and the plant which blocks additional moisture and nutrient inputs from the plant (Figure 1). At this point the maximum grain quality and yield are set. The primary objective of grain drying and storage is to manage the temperature and moisture of the air around the grain to minimize grain quality and market value losses while holding grain for better market opportunities. Maintaining grain quality requires drying the grain to safe moisture content levels after harvest followed by lowering and maintaining the grain temperature within a few degrees of ambient air temperatures.

Traditionally, on-farm grain drying and storage has seen limited use in Arkansas. However, recent changes in agricultural markets have made grain production more attractive, resulting in more producers and more production. This increased supply is associated with a larger grain price swing between harvest and nonharvest periods. Therefore,

FIGURE 1. Grain Maturation and Drying Moisture Paths.

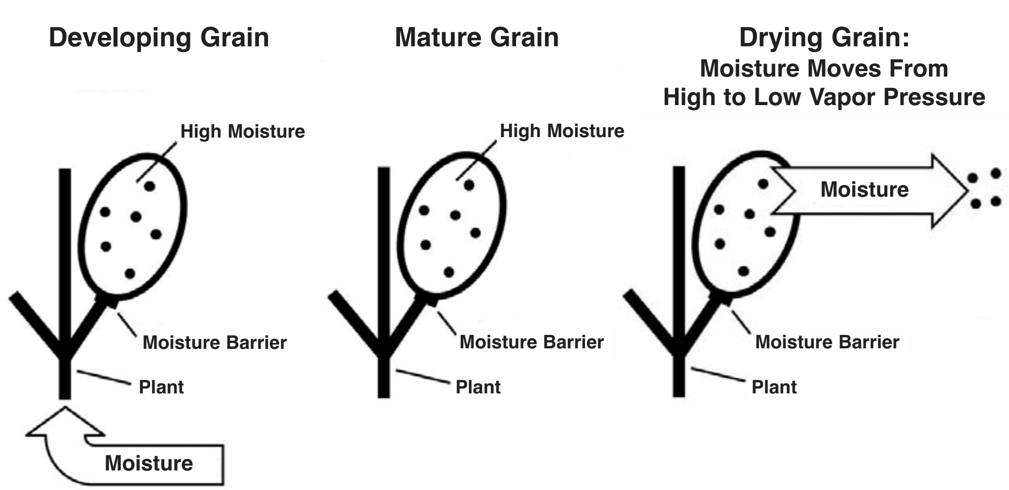

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TABLE 1. Maximum Storage Time for Corn (months).

Corn Temperature (°F)	Moisture Content (%)						
	13	14	15	16	17	18	24
40	150	61	29	15	9.4	6.1	1.3
50	84	34	16	8.9	5.3	3.4	0.5
60	47	19	9.2	5	3	1.9	0.3
70	26	11	5.2	2.8	1.7	1.1	0.2
80	15	6	2.9	1.6	0.9	0.9	0.06

Based on 0.5% maximum dry matter loss – calculated on the basis of USDA research at Iowa State University. Corresponds to one grade number loss; 2%-3% points in damaged.

TABLE 2. Maximum Storage Time for Soybeans (months).

Soybean Temperature (°F)	Moisture Content (%)					
	11	12	13	14	15	16
40	150	61	29	15	9.4	6.1
50	84	34	16	8.9	5.3	3.4
60	47	19	9.2	5	3	1.9
70	26	11	5.2	2.8	1.7	1.1
80	15	6	2.9	1.6	0.9	0.9

Based on 0.5% maximum dry matter loss – calculated on the basis of USDA research at Iowa State University. Corresponds to one grade number loss; 2%-3% points in damaged.

TABLE 3. Abbreviated Grain "Shrinkage" Table.

The full table is available for printing and electronic use at *http://www.aragriculture.org/storage_drying/default.htm*

Moisture Content %	Shelled Corn	Wheat	Soybeans	Rice	Grain Sorghum
	lb/bu	lb/bu	lb/bu	lb/bu	lb/cwt
10.0	52.58	57.67	58.00	43.50	95.56
12.5	54.08	59.31	59.65	44.74	98.29
15.0	55.67	61.06	61.41	46.06	101.18
17.5	57.36	62.91	63.28	47.45	104.24
20.0	59.15	64.88	65.25	48.94	107.50
25.0	63.09	69.20	69.61	52.20	114.67
30.0	67.60	74.14	74.58	55.93	122.86

in addition to more control in harvest timing, there are potential economic advantages to on-farm drying and storage. This publication provides an overview of basic on-farm grain drying/storage concepts and options.

Storage Moisture Content

The first step in drying grain is determining the desired, or target, grain moisture content level. Underdrying grain reduces safe storage time, increases the potential for quality losses and increases the likelihood of high moisture price dockages upon sale. Overdrying grain reduces income due to increased drying costs. In addition, since grain is usually sold on a weight basis, one of the expenses involved in drying grain is the "cost" of the weight loss that occurs during the drying process. This weight loss by drying is referred to as "shrink" and is expressed as a percentage of the original quantity before it is dried. Shrinkage should be considered to accurately determine the total cost of mechanical drying. Shrinkage tables (Table 3) provide bushel weights for various moisture content level grains. When choosing the desired target moisture content, safe storage time, grain shrinkage and your buyer's requirements should be considered.

Grain conditioning by drying and cooling to target ranges should begin immediately after harvest. If possible, avoid leaving grain in carts and buggies for more than a few hours or overnight. As indicated earlier, grain temperature and moisture content dictate how quickly grain quality and market value are reduced. Drying and cooling freshly harvested grain will delay spoilage and must begin within 24 hours and preferably within 12 hours after the harvest.

Equilibrium Moisture Content

The moisture in grain creates vapor pressure. In a like manner, the moisture in the air around the grain also creates vapor pressure. Moisture moves from areas of high vapor pressure to areas of low vapor pressure. This moisture movement continues until the vapor pressures in the grain and air are equal. The point at which vapor pressure in grain and air are equal is called the Equilibrium Moisture Content (EMC). The EMC is dependent on three things: air temperature and relative humidity around the grain and grain type. As shown in Table 4, EMC values for corn decreases as air humidity decreases or air temperature increases. Thus, grain drying will

KEY CONCEPTS

- Moisture moves from high to low vapor pressure areas.
- Grain drying occurs when the vapor pressure in the grain is greater than the vapor pressure of the air surrounding the grain.

TABLE 4. Corn Equilibrium Moisture Content (EMC).

This table as well as other grain EMC tables is available for printing and electronic use at *http://www.aragriculture.org/storage_drying/default.htm*

	Relative Humidity (%)													
Temperature (°F)	25	30	35	40	45	50	55	60	65	70	75	80	85	90
35	9.3	10.3	11.2	12.1	13.0	13.9	14.8	15.7	16.6	17.6	18.7	19.8	21.2	22.9
40	9.1	10.0	10.9	11.8	12.7	13.5	14.4	15.3	16.2	17.1	18.2	19.3	20.7	22.3
45	8.8	9.8	10.6	11.5	12.3	13.2	14.0	14.9	15.8	16.7	17.7	18.9	20.2	21.8
50	8.6	9.5	10.4	11.2	12.0	12.9	13.7	14.5	15.4	16.3	17.3	18.5	19.8	21.4
55	8.4	9.3	10.1	11.0	11.8	12.6	13.4	14.2	15.1	16.0	17.0	18.1	19.3	20.9
60	8.2	9.1	9.9	10.7	11.5	12.3	13.1	13.9	14.8	15.7	16.6	17.7	18.9	20.5
65	8.0	8.9	9.7	10.5	11.3	12.0	12.8	13.6	14.5	15.3	16.3	17.4	18.6	20.1
70	7.9	8.7	9.5	10.3	11.0	11.8	12.6	13.4	14.2	15.0	16.0	17.0	18.2	19.8
75	7.7	8.5	9.3	10.1	10.8	11.6	12.3	13.1	13.9	14.8	15.7	16.7	17.9	19.4
80	7.6	8.4	9.1	9.9	10.6	11.4	12.1	12.9	13.7	14.5	15.4	16.4	17.6	19.1
85	7.4	8.2	9.0	9.7	10.4	11.2	11.9	12.6	13.4	14.3	15.2	16.2	17.3	18.8
90	7.3	8.1	8.8	9.5	10.3	11.0	11.7	12.4	13.2	14.0	14.9	15.9	17.0	18.5
95	7.2	7.9	8.7	9.4	10.1	10.8	11.5	12.2	13.0	13.8	14.7	15.6	16.8	18.2
100	7.1	7.8	8.5	9.2	9.9	10.6	11.3	12.0	12.8	13.6	14.5	15.4	16.5	17.9

occur as long as the EMC is less than the current grain moisture content. If the EMC is greater than current grain moisture content, drying will not occur. Instead, additional water will be added to the grain bin. Water will increase the potential for mold and needs to be removed as soon as possible.

EMC calculators for various grains are available on the specific crop drying areas of the University of Arkansas Division of Agriculture–Cooperative Extension Service web site. These tools can be used to determine EMC values for your specific atmospheric conditions and grain.

If the current air conditions will not result in grain drying, the easiest way to adjust EMC is by heating the air. Heated air lowers the air relative humidity and thus lowers the EMC and decreases drying times. As a result, after heating air, the new relative humidity must be measured or calculated before determining the new EMC. Grain drying calculators are available that calculate the new relative humidity and EMC heating. Go to *www.uaex.edu*, then click on the agriculture link, then the corn link and then the grain drying and storage link for available grain drying and storage tools and calculators.

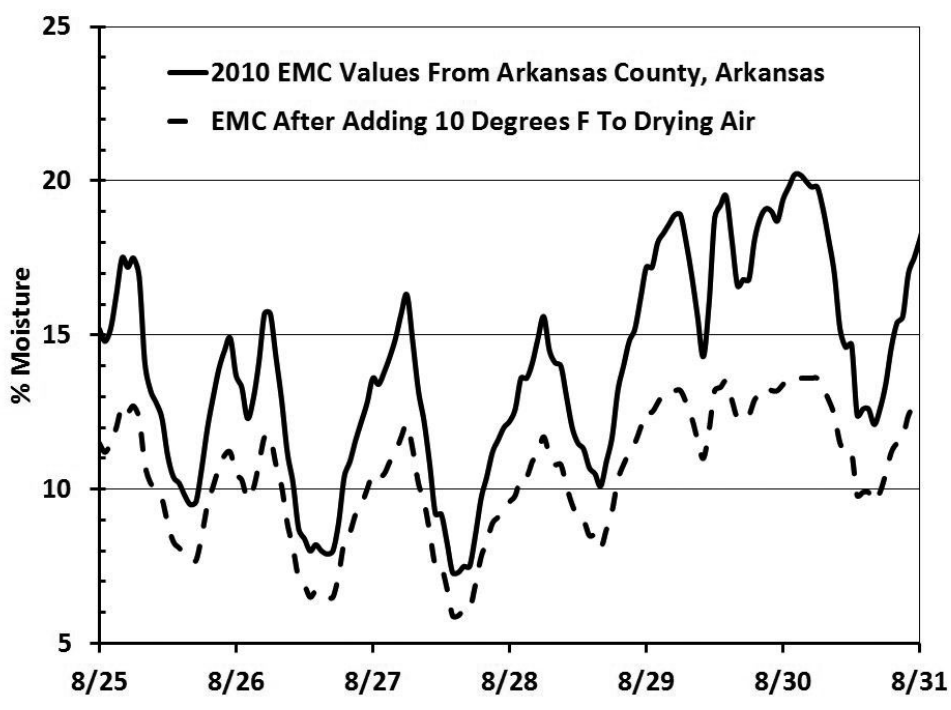
Temperatures and Humidities

As indicated, air temperature and humidity determine EMC levels and thus the drying capacity of the air around the grain. Since ambient air temperatures and humidities fluctuate over time, the EMC and drying potential of air also fluctuate (Figure 2). Therefore, in drying systems that use ambient air (with or without low levels of supplemental heat), air temperature and humidity should be monitored and used to determine when the drying system should be operated. If mismanaged, drying opportunities could be missed or moisture could be added back to the grain environment, increasing storage risks and wasting the energy to run fans again to re-dry.

The ability to heat drying air increases the opportunities to dry grain and provides more control over the grain drying and storage process (Figure 2). If the EMC of ambient air will result in grain drying, adding heat will reduce drying time and lower the final grain moisture content achievable. The reduced drying time is usually desirable. However, if mismanaged, there is an increased risk of overdrying grain. There is also energy costs to run fans and heaters. If the EMC of ambient air will not result in grain drying, adding heat can provide drying that otherwise would not take place. As a result, the decisions of what type of grain drying/storage system to install and when to run fans and/or heaters become a process of balancing risks and economic inputs.

For manually controlled systems, the temperature for determining EMC should be an average temperature over the drying period. The relative humidity should be the average expected during the drying period. However, several companies make automated grain drying controls which measure grain moisture, air temperature and air humidity. These automated controls can take much of the "guess work" out of grain drying. Temperature can be read with a thermometer in the plenum or on the farm. Ideally, temperature and relative humidity should be measured on-farm, but local weather information has been used in the decision making process with acceptable results.

FIGURE 2. Weather and Supplemental Heat-Related EMC Variations.

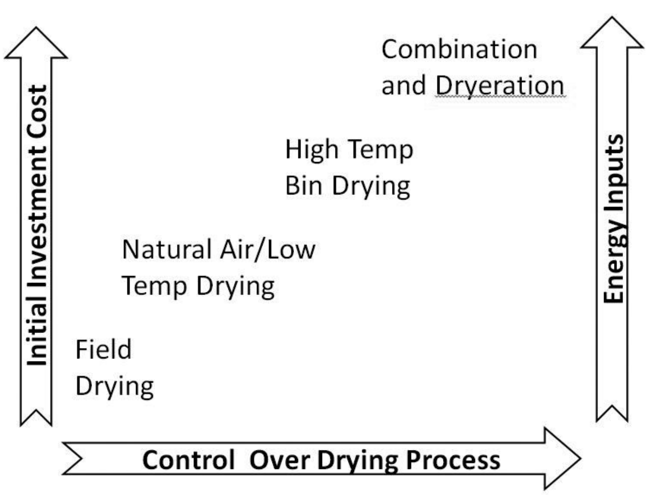


Evaporating moisture from grain requires energy in the form of heat. In general, it takes 1,100 BTUs of heat to vaporize one pound of water at 100-percent efficiency. Heat energy can be supplied by the natural heat content of air or by supplemental heating. The amount of moisture that air can absorb and transport as it moves through the grain column is dependent primarily on EMC along with some influences from air velocity, the distance the air travels and grain moisture content. As air moves through the grain column, it absorbs moisture and thereby loses some or all of its drying capabilities.

Grain Drying Options

Grain drying strategies can be divided into four approaches: field drying, natural air/low temp grain drying, high temperature drying, and combination and dryeration. Allowing the grain to dry in the field is the most widely used method. In many cases, partial field drying is often used in conjunction with post-harvest drying to reach target storage moisture content. Natural air/low temp grain drying is best described as filling or partially filling bins with freshly harvested grain, then running fans to force air through the bins until the desired moisture content is achieved. High temperature drying is either conducted in the bin or within a pass dryer. Air is heated to high temperatures and forced through the grain until the grain dries. Combination and dryeration are done by partially drying grain with high temperature dryers, and then the remainder of the drying process is done with low temperature air and fans. Each method has its advantages and disadvantages. In general, more drying process control reduces potential risk. However, an increase in control is usually associated with increased investment costs and energy costs (Figure 3).

FIGURE 3. General Relationships Among Management Control, Initial Investment Cost and Operational Energy Costs for Various Grain Drying Approaches.



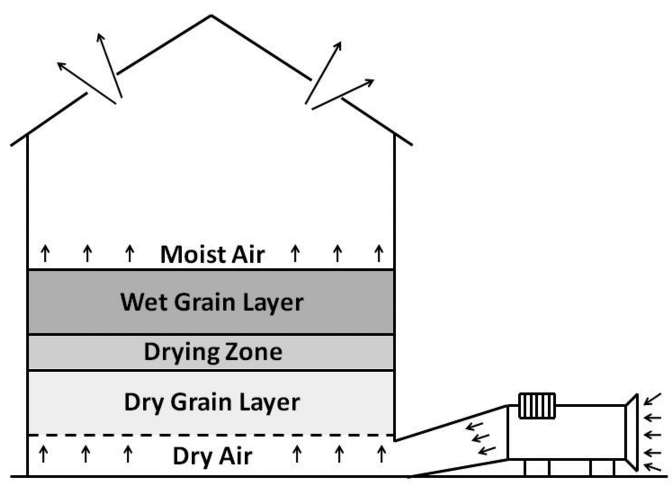
Field Drying

Once the grain matures and the layer of tissue is formed between the seed and the plant, the sun and air can remove moisture and dry grain at a rate of ½ to 1 percent per day (Figure 1). Once moisture reaches near storage goal levels, drying slows. Drying using this method is very common. Most producers field dry grain to a certain moisture content and then harvest and dry further or market the grain at harvest. The disadvantage with this method is the reduced control of the drying process and potential exposure to weather and pests which cause damage. In addition, dryer grain moisture usually increases shatter and losses during harvest. Field drying should be used to manage grain moisture at the time of harvest. Carefully monitor grain in the field to watch for pests, incoming weather and disease when field drying.

Natural Air/Low Temperature Drying

Following field drying, natural air/low temp drying is the most common on-farm drying method. Natural air drying and low temperature drying refers to the process in which grain bins are filled or partially filled with grain and then air, with little (<10°F) or no heat added, is moved through the grain with fans (Figure 4). This is typically done in bins with a perforated floor or ducts. As dry (lower vapor pressure) air passes wet (higher vapor pressure) grain, moisture moves from the grain into the air. The addition of water to the air reduces its ability to dry the grain it passes through next. This process continues as the air moves through the column of grain until the air no longer dries the grain, or the air exits the grain. As the fans continue to run, a drying front moves from where the air enters the grain to where it exits the grain. Behind the drying front, the grain is at EMC. Ahead of the drying front, the grain is above EMC. The vapor pressure and flow rate of

FIGURE 4. Grain Bin Utilizing Natural Air/ Low Temperature Drying.



the air entering the grain determine the formation of this drying front and how quickly it moves through the grain. As discussed earlier, air vapor pressure depends on the temperature and relative humidity of the air entering the grain and can be reduced by adding heat. The air flow rate depends on fan properties as well as the type and depth of the grain. As grain depth increases, air flow rates decrease. Therefore, increasing grain depth slows the drying front and increases the amount of time it takes for all the grain to reach EMC and the potential for grain quality losses.

A common mistake with natural air/low temperature drying is to add too much grain to the bin at once. This will slow drying times and delay grain drying, which increase the likelihood of grain quality losses. How much grain can be safely added to a bin for drying will be affected by grain moisture, air temperature and relative humidity, the addition of supplemental heat and fan properties. To address this concern, it is commonly recommended to only add 4 to 5 feet of grain to a bin at a time. Then avoid adding more grain until the layer is dry. Depending on the system setup, several bins can be loaded alternatively, or the dry grain can be moved to another bin.

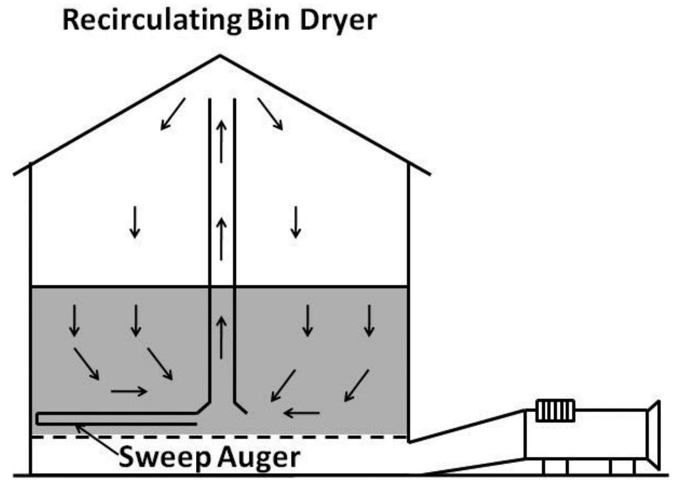
High Temperature Drying

High temperature drying is done either in the bin or in a dryer. There are four approaches to high temperature drying: in-bin batch drying, recirculating bin drying, continuous flow bin drying and pass drying. In-bin batch drying is similar to natural air/low temperature drying except that air temperatures are often 120°-160°F and air flow rates are from 8 to 15 cfm/bushel. Drying time is greatly reduced with high temperature drying. However, grain near the floor often becomes excessively dried while the top layer of grain often stays moist. Stirring devices provide more uniform drying and should be considered in conjunction with this method. Stirring also allows for increased batch depth (7 to 8 feet).

Recirculating bin dryers (Figure 5) are bins that are filled with grain and then the fans and heat are turned on. There is a sweep auger in the bottom of these bins that is activated by temperature or moisture sensors. When a target condition is met, the sweep auger makes one full pass and stops until those conditions are met again. Grain discharged by the sweep auger is placed onto the top of the grain within the bin. Some rewetting of dried grain may take place, causing inefficiency concerns.

Continuous flow bin dryers (Figure 6) use the same bin setup as the recirculating bins except sweep auger grain is discharged into a cooling bin. High temperature bin drying tends to be more efficient than other high temperature drying processes because the heat is used to dry grain at the drying front, which then continues up the grain column to aid in drying before being discharged.

FIGURE 5. High Temperature Drying With Grain Recirculation Within the Bin.

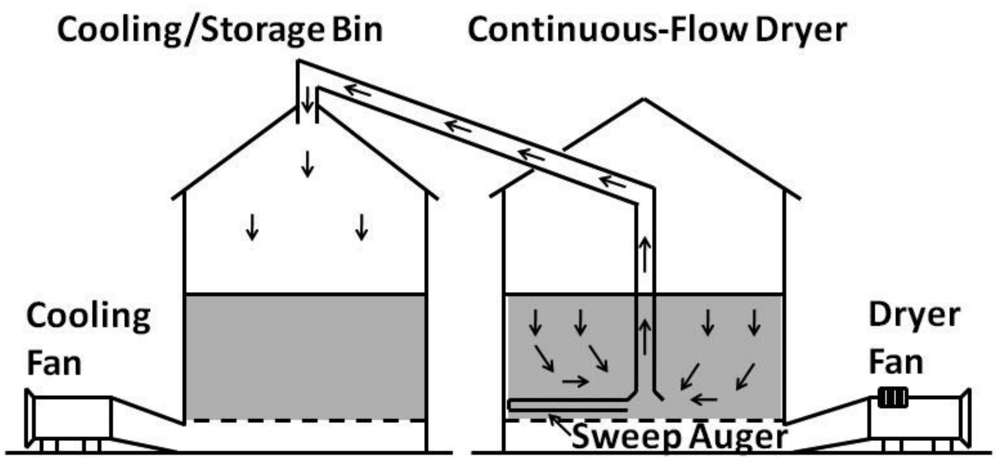


Pass drying (Figure 7) is typically the fastest method for drying grain. Most grain elevators use some form of pass dryers to dry large amounts of grain quickly. This method requires the highest energy inputs of all drying methods. The biggest benefit to using pass dryers is the large volumes of grain that they can dry. When used in conjunction with a short-term wet grain storage bin, grain can be harvested at a rate that exceeds the capacity of the pass dryer. Then, when harvesting pauses such as at night, the dryer which runs continuously empties the wet holding bin. While pass dryers tend to be the most expensive drying option, they do have the advantage of providing the most control during grain harvesting and drying. Pass dryers are made in several models, including some portable models mounted on trailers. Due to the higher temperatures being used, the potential exists to dry the grain too rapidly or too much and cause cracked grain or other problems. However, with proper management, high grain quality can be maintained, providing the opportunity to market higher quality grain.

Combination and Dryeration

Combination drying and dryeration (Figure 8) are done by moving grain directly from either a pass or heated bin dryer into an aeration bin at one or two moisture points higher than the final desired moisture content. For dryeration, grain is allowed to temper without airflow for 4 to 6 hours. During this time the moisture content within individual kernels equalizes. Once the first grain that was placed in the bin has tempered, cooling fans are turned on while additional hot grain is added to the bin. The cooling front moves slowly up through the grain so that all grain within the bin has ample time to temper. The cooling fans dry grain the remaining 1 to 2 percent. This process maintains grain quality better than using high temperature dryers alone. Individual grain kernels redistribute moisture throughout the kernel during the tempering process, which is

FIGURE 6. High Temperature Drying With Separate Drying and Cooling/Storage Bins.



followed by lower temperature drying reducing stress to individual kernels. Combination drying is essentially the same as dryeration, yet it does not have a tempering step. Both of these methods can significantly reduce energy use and increase dryer capacity.

Summary

Production priorities and degree of grain quality control must be considered when choosing a grain drying system. If initial cost is the highest priority, the producer should consider field drying or natural air/low temperature drying. If the main goal of the producer is to get the crop out of the field as quickly as possible, high temperature drying should be evaluated. If grain quality is the priority, combination and dryeration should be considered. As with any investment, costs and returns can be spread over a number of years.

FIGURE 7. Pass Dryer Diagram.

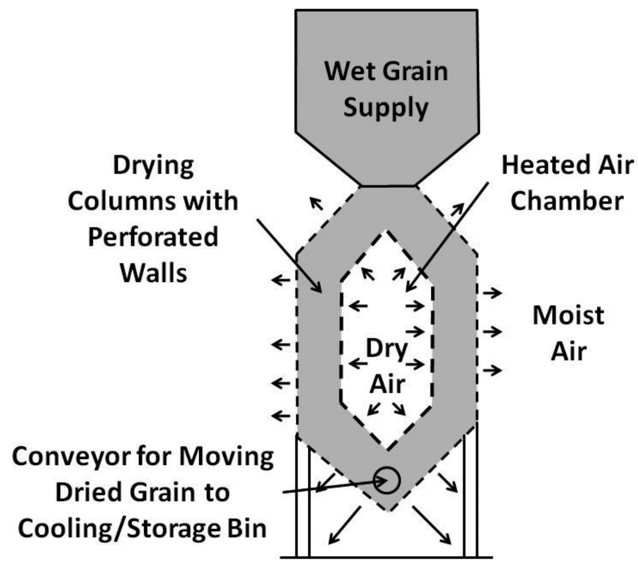
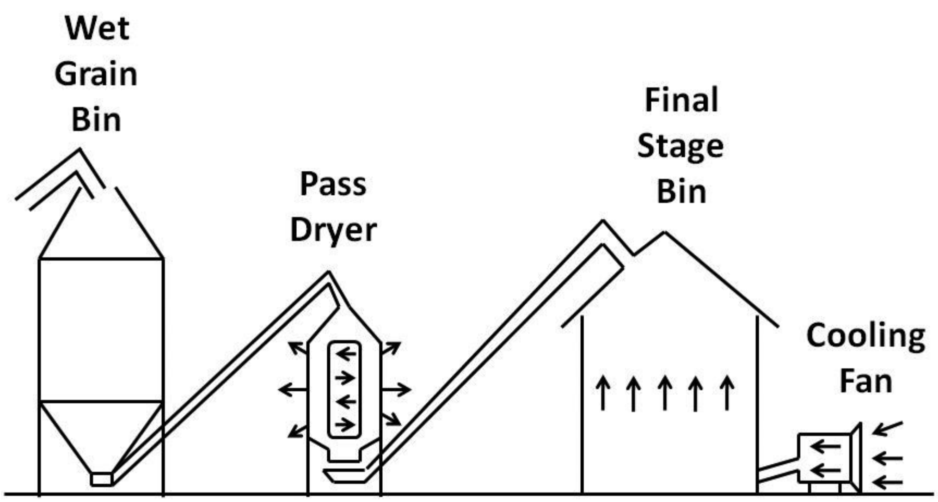


FIGURE 8. Combination and Dryeration System Diagram.
The final stage bin is where the tempering, final drying and cooling take place.



Further Reading

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