On-Farm Grain Storage and Drying Considerations

UNIVERSITY OF MISSOURI
Extension

On-Farm Grain Storage Planning Considerations

A number of factors that ultimately affect the profitability of on-farm storage facilities are difficult to include in a budgeting framework. Grain handling and storage facilities require careful planning. Normally, storage capacity can be doubled without any major problems. However, tripling the storage capacity requires careful planning before construction of the first bin. Most producers want to expand their facilities over time, as capital becomes available, rather than borrowing large sums to construct a total system. Therefore, planning becomes all the more critical, as it is easier to change things on paper than after construction begins.

All systems have bottlenecks that limit the throughput of the operation. Grain handling and storage components are part of the overall harvesting system. The storage facilities should not create bottlenecks that cause less than optimum performance of the combine(s) or truck(s). It is important to recognize where some of the bottlenecks can occur during harvest and plan to minimize them. The following are nine common bottlenecks in the harvesting system:

1. Truck's inability to maneuver around storage equipment.
2. Mismatch of harvesting, trucking, and unloading systems.
3. Distance from the field to the storage site.
4. Auger movement and positioning between bins.
5. Lack of drying capacity or storage for high-moisture grain.
6. Lack of preventive maintenance.
7. Lack of adequate all-weather roads and driveways.
8. Lack of conveniences for weighing trucks across scales.
9. Inadequate temporary storage ahead of cleaner or dryer.

Each of these bottlenecks can be avoided. However, in many cases, poor planning can result in at least three or four being built into the system. Thus, the producer must either make additional investments to correct the problem or live with it. The following is a discussion of factors that can alleviate or prevent the bottlenecks.

Site Selection

There are three main components of site selection. The site must be accessible, have electricity, and be well drained.

Accessibility includes adequate entrances off county or state roads and space around the bins. A minimum of 40-foot access off of a main road is required. A square open area of ¼ to ½ acre is needed for trucks to be able to turn around without backing long distances. Semi-trucks require a minimum turning radius of 55 feet or a diameter of 110 feet.

Electricity is the second requirement. Single- phase electricity generally limits the largest motor to 10 horsepower. This is normally adequate for most drying fans, but could limit the capacity of the handling equipment or high-temperature dryers (HT dryers). Three-phase electricity is preferred for high-volume facilities and those that are planning on incorporating HT dryers, electrically driven augers, or pneumatic conveyors. A phase converter, which converts single-phase to three-phase, may be used. Producers need to work with electrical suppliers to make sure the electrical distribution lines can carry the load, adequate lines are installed, and allowances are made for future expansion. It is recommended that power lines be at least 100 feet from the grain bins, with underground lines used to bring power into the sites.[1]

The site's physical attributes is the third factor to consider. Most on-farm storage facilities can be constructed on a site of 1 to 2 acres. The storage bins should be located at least 50 feet from any building, although 100 feet is desirable. Groundwater should be a minimum of 10 feet below surface, with 15 to 20 feet preferred. Most pits used with legs are in the ground 8 to 10 feet, with large capacity pits exceeding 15 feet. The surrounding area should drain away from the site, with diversions constructed if necessary. Sump pumps never work as well as planned because of lack of maintenance and plugging of drains.

Under no conditions should runoff from surrounding areas drain through the grain handling facility. The driveways and bin pads should be 12 inches higher than the surrounding terrain to minimize erosion or water problems into pits or bins. Another site factor to consider is nearby residences. Prevailing winds can carry chaff, foreign material, or debris toward residences. Fan noise also can be a problem if the fans are installed on the residence side of the bin. It is recommended that bins be located 200 feet from residences. A professional engineer may be needed for site preparation to ensure the soils will carry the dead loads created during storage.

Bin Selection

Each producer should determine how much storage is needed based on annual harvest, marketing potential, distance to elevator, and capital availability. The largest bin on the farm generally should not exceed 50 percent of the largest crop harvested. Multiple bins allow more flexibility than one large bin. Also, if a portion of the grain goes out of condition, the entire harvested crop is not jeopardized.

A minimum number of bins probably is one per crop per season. Therefore, someone who raises corn, grain sorghum, and soybeans should have at least three bins. As was demonstrated in Figure 4, larger bins normally have a lower initial investment, as compared to multiple smaller

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[1] Minimum guidelines are outlined by the National Electrical Safety Codes for installation of power lines near grain bins and storage facilities.

bins, but lack long-term flexibility. Bins used primarily for seed storage should be limited to 2,000 to 3,000 bushels per bin and preferably have a hopper bottom. For grain storage, bins continue to get larger, with 100,000 bushel and larger bins becoming more common. However, it is important to recognize the increased importance of managing the grain quality and condition in these large bins.

Drying Systems

Options available for in-bin drying systems include natural-air drying; low-temperature drying (LT); layer drying; batch-in-bin drying; dryeration; LT with recirculator, stirrers, or continuous flow drying. LT drying systems, as a minimum, require a full perforated floor, a fan capable of providing 0.75 cubic feet of air per minute (cfm) per bushel, and a burner unit. At least 25 to 50 percent of the total storage capacity should be equipped for low-temperature drying. Additional drying capacity can be obtained by installing a recirculator, stirrer or continuous flow drying system within a bin. Once storage capacity exceeds 50,000 bushels, installation of a HT dryer should be considered. Under no condition should a bin be constructed without having an aeration fan installed (only moves 0.1 to 0.5 cfm/bu as compared to 0.75 or greater cfm/bu with a drying fan). The sidewall depth should be limited to 16 feet or less if the bin is used for LT drying. The bins used strictly for storage can have deeper depths. Publication MWPS-13, Grain Drying, Handling and Storage Handbook, is a resource on various drying systems.

Bin Layout

Bin layout has two primary shapes: straight line or circular. Bins located in a straight line are easier to expand and incorporate into a vertical bucket elevator at a later date. The main disadvantage is with filling the bins with augers. Each time a bin is filled, an auger has to be moved. With increased auger capacities, a horizontal auger across the top of a row of bins enables an inclined auger to be set up once without having to move it each time a different bin is filled. Circularly arranged bins require careful planning.

As the auger is rotated around a pivot point, it must be able to fill each bin. The auger is mounted such that the wheels rotate around the inside of bins and can be manually moved between bins. It is the opinion of the authors that straight-line bin arrangements are preferred to circular over the life of the system.

Other Considerations

Grain facilities are usually at one central site. Advantages to a central site include more efficient use of equipment, potential to automate equipment, less road construction and maintenance, more security, and central storage of records and grain quality equipment. However, some landlords may require their grain to be stored elsewhere, requiring multiple storage sites. Also, if the farm is ever sold, it may be easier to sell two smaller storage facilities than one large unit.

For long-range planning, it is better to plan a central site and then subdivide at a later date, if necessary. It is often easier to downsize than to upsize the system.

Bins should have a minimum of 2 to 3 feet between them with 6 feet preferred if handling equipment must pass between bins. All mechanical systems eventually break down, accessibility or future repairs should be considered in the planning phase. The extra space between bins normally will not result in a noticeable difference in the cost of the handling equipment. The area around the bins should be treated to prevent grass and weeds from growing. Vegetation often serves as a home for rodents and insects and is difficult to maintain. Bins should have factory-installed ladders inside and outside, along with a man door and fill port. Other desirable accessories include roof vents (a must if fans are eventually to be automated), grain spreader, and temperature monitoring systems. Appropriate handling equipment for emptying the bin must be purchased and installed as the bin is erected.

Two rows of bins should be spaced a minimum of 20 feet apart. If a leg, dryer, scales, or feed processing center ever are installed, there is still adequate room for a driveway, along with these components. Roads should be crowned to provide adequate drainage for all-weather use. Planning bin layout should include consideration for the 110-foot diameter turning circle required by semi-trucks.

Grain is handled on-farm with augers, bucket elevators (legs), or pneumatic conveyors. Once the capacity exceeds 100,000 bushels, a leg should be considered to provide flexibility in handling, blending, and turning of grain. High-temperature dryers should have smaller leg or auger arrangements to load and unload the dryer and not depend on the main grain handling equipment. Careful planning is required to make sure all of the components have at least equal capacity. As a planning guide, each time grain is transferred between handling equipment, the second piece of equipment should have a 10 to 25 percent higher capacity than the first. This will prevent bottlenecks within the grain handling system. The capacity of holding tanks ahead of a dryer or cleaner should equal 2 to 4 hours of combine harvesting capacity. Handling equipment can be eliminated if holding tanks are placed in the air and gravity feed.

The capacity of the handling equipment should be based on the desired truck unloading time. A 1,000-bushel truck unloading in 10 minutes requires the handling equipment to have a minimum capacity of 6,000 bushels per hour (bph). If a pit is used, then the unloading time is based on the expected time between loads received. Changing the unloading time from 10 to 15 minutes reduces the handling equipment capacity from 6,000 bph to 4,000 bph. A new facility using a bucket elevator should have a minimum capacity of 5,000 bph.

Material adapted from Kansas State University Publication - MF-2474 – The Economics of On-Farm Storage - http://www.ksre.ksu.edu/bookstore/pubs/MF2474.pdf

Appendix – Figures of storage system layouts

Figure A1. 50,000 bushel system.

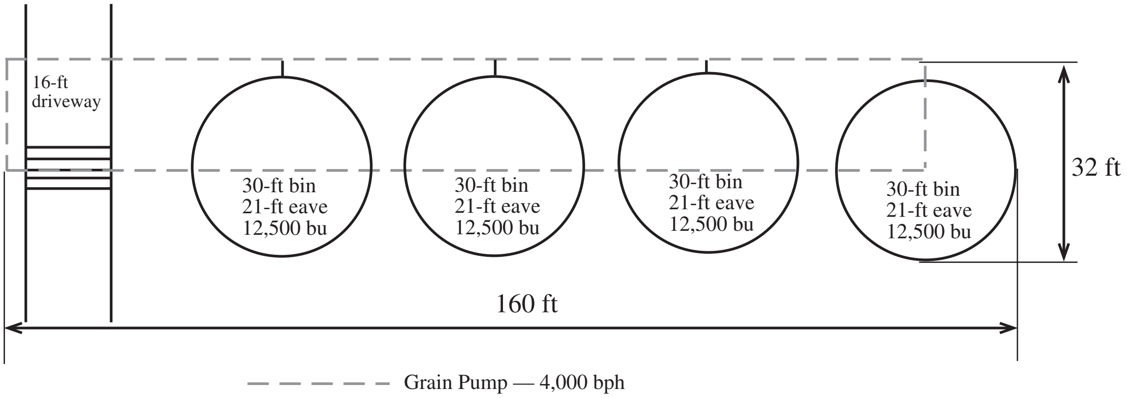


Figure A2. 95,000 bushel system.

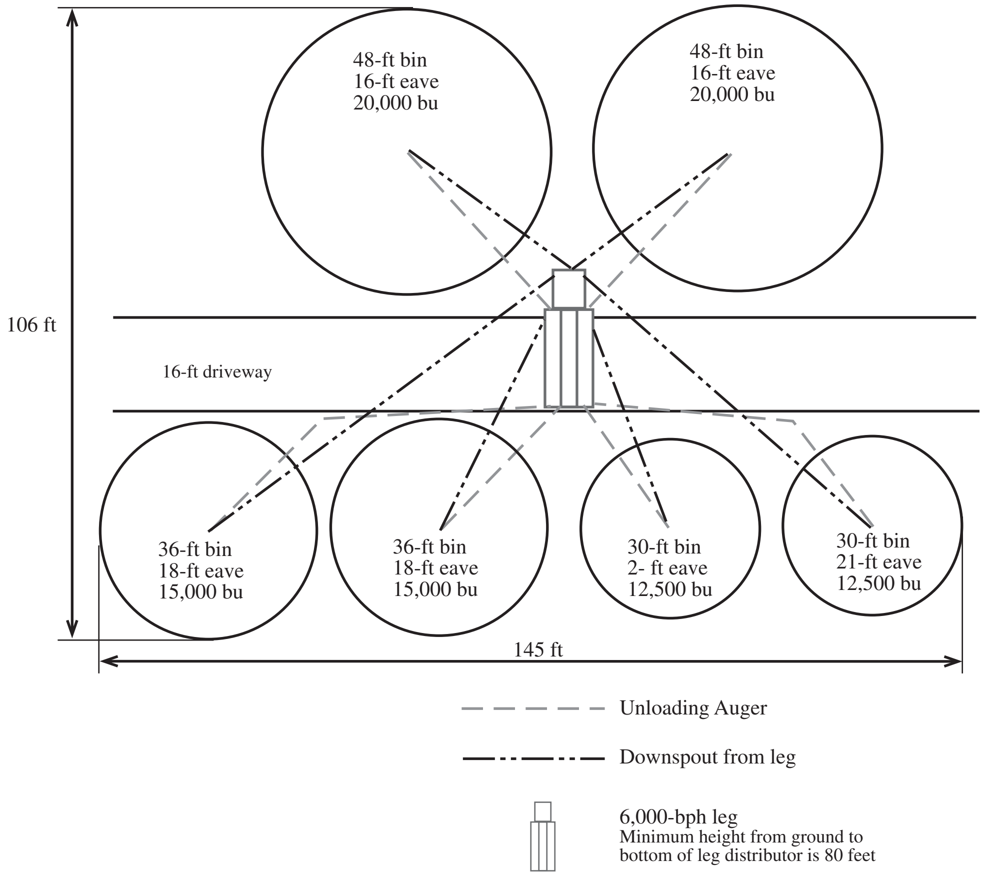


Figure A3. *163,100 bushel system.*

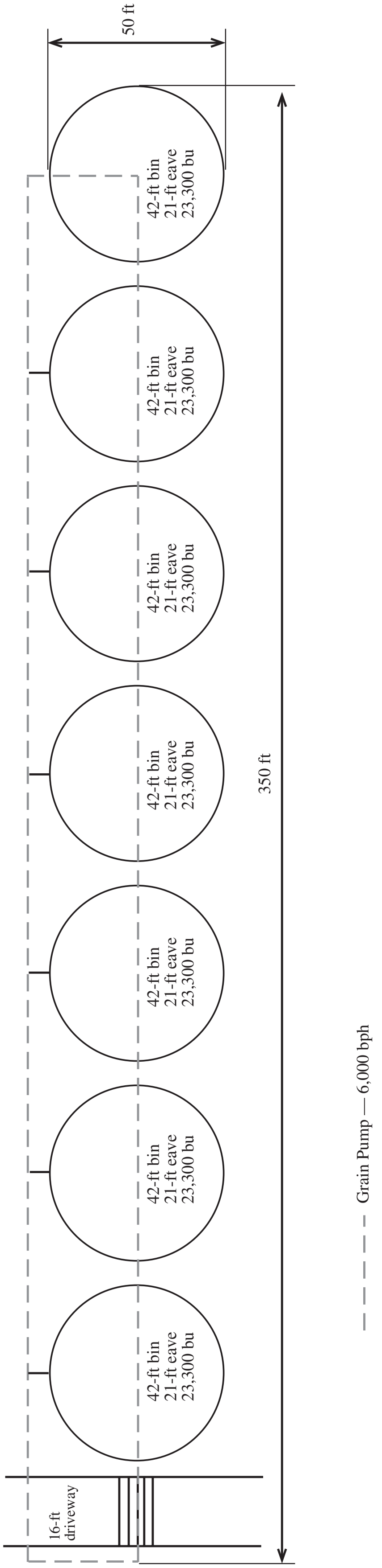
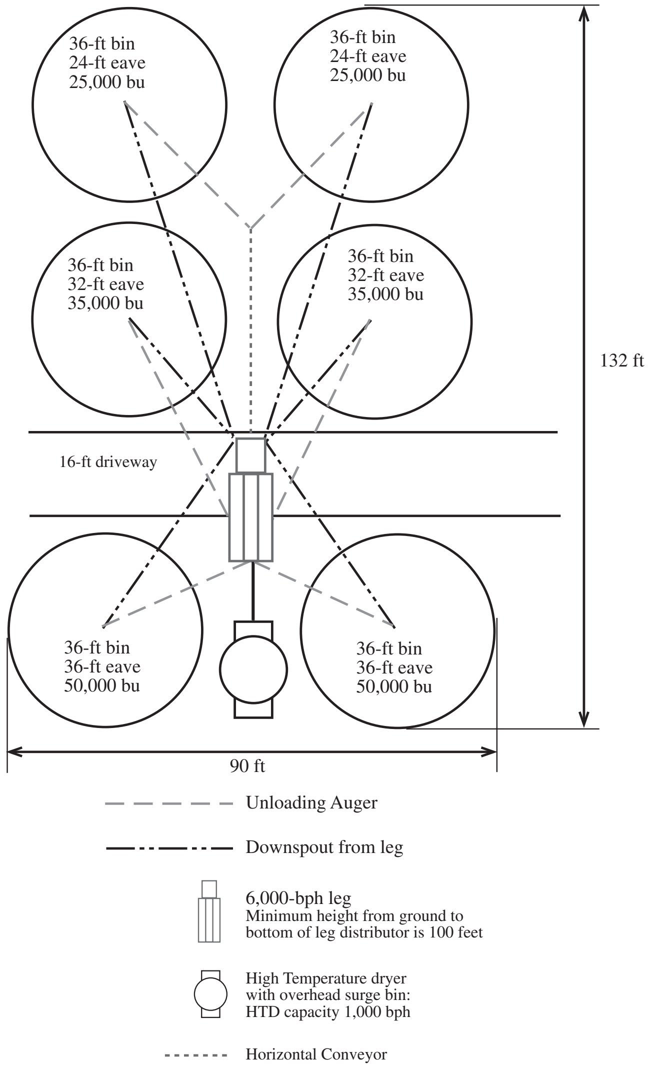


Figure A4. *220,000 bushel system.*



Your Storage Facility

Scale: 1 inch = ____________

Calculating Combine Efficiencies for Grain Storage Considerations

This example utilizes a combine with an 8-row corn head and 280 bushel grain tank with a discharge rate of 2.8 bushels/hour. The area you need to harvest per season is 2000 acres. The corn is yielding 200 bushels/ac and is in ½ mile rows. The maximum speed in the field is 5 mph, and average travel distance to the trucks for offloading is 1/4 mile. The turn time at the end of field rows is 20 seconds. The combine travel speed to offload is 5 mph when full and 6 mph when empty. A single 1000 bushel grain cart is available with the same travel speeds as the combine. The unloading rate of the wagon is 500 bushels/min. A maximum of four, 1000 bushel trucks are available to move grain to the elevator which is 15 miles from the field and the average speed of the truck is 30 mph. The unloading time at the elevator is 30 min.

Determine the Theoretical Field Capacity, Effective Field Capacity, Field Efficiency, Operating Material Capacity, and Effective Material Capacity under the following conditions below (Part 1, 2, and 3).

First need to calculate,

Theoretical Field Capacity = Speed x Width of Harvest
= 5 mph x 20 ft x 5280 ft/acre x 1 acre / 43560 square feet = 12.12 acres/hour

Operating Material Capacity = Theoretical Field Capacity x Yield
= 12.12 acres/hour x 200 bu/acre = 2424 bu/hr

Next calculate, Field Efficiency % = (Total Time – Wasted Time) / Total Time x 100

To calculate Total Time will need to first calculate Time Harvesting = Distance Traveled / Speed

Distance Traveled = 2000 acres x 43560 sq ft/acre x 1/20 ft (8 row corn head) = 4,356,000 feet x 1 mile/5280 feet = 825 miles

Time Harvesting = 825 miles / 5 mph = 165 hours

Time Turning on the End Rows

Number of Turns = 4,356,000 total feet traveled / 2640 ft (1/2 mile rows)
= 1650 turns

Time Turning = Number of Turns x Time During Turns
= 1650 turns x (20 seconds / turn) = 33000 seconds x (1 hr / 3600 sec)
= 9.17 hours

Time Unloading

Time to truck = 0.25 miles / 5 mph = 0.05 hours
Time from truck = 0.25 miles / 6 mph = 0.0417 hours
Time unloading grain tank = 280 bu / 2.8 bu/sec x (1 hr / 3600 sec)
= 0.0278 hours
Total Time for One Unloading = 0.1195 hours

Number of unloadings = 2000 acres x 200 bu/acre / 280 bu/dump = 1428.57 dumps

Total Time Unloading = 0.1195 hours x 1428.57 dumps = 170.71 hours

Field Efficiency % = (Total Time – Wasted Time) / Total Time x 100
= ((165 hrs + 170 hrs + 9 hrs) – (170 + 9)) / (165 + 170 + 9) x 100
= 48%

1). The grain wagon is not used, and the combine unloads at the trucks. (For this ignore trucking time and assume that the trucks are capable of transporting all grain harvested.)

With a field efficiency of 48%,

Effective Field Capacity = 12.12 acres/hour x 0.48 = 5.8 acres/hour

Operating Material Capacity = 5.82 acres/hour x 200 bu/acre = 1164 bu/hr

2). The grain wagon is used, and the combine unloads on the go. (For this ignore trucking time and assume that the trucks are capable of transporting all grain harvested.)

One will first need to figure out if there will be any down time waiting for trucks or grain cart.

Check of timing of grain cart:

Time to and from truck same as calculated for combine
= 0.05 + 0.417 = 0.0917 hours x 60 min/hr
= 5.5 minutes travel time for grain cart
Time to unload grain cart
= 1000 bushels / 500 bu/min = 2 minutes
Total time for grain cart would be 7.5 minutes

Time to fill grain tank on combine = Tank capacity / Operating Material Capacity
= 280 bu / 2302 bu/hour = 0.1216 hour x 60 min/hr = 7.3 minutes

Note: the Operating Material Capacity of 2302 bu/hour was calculated utilizing a effective field capacity of 11.51 acres/hour (field efficiency was 95% with only wasted time being time turning on the ends of 9 minutes)

So one would have to wait .2 minutes per grain cart x 400 grain cart loads = 80 minutes total wait time

This would improve field efficiency of the combine as calculated:

Field Efficiency % = (Total Time – Wasted Time) / Total Time x 100
= ((165 hrs + 9 hrs + 1.33 hrs) – (9 + 1.33)) / (165 + 9 + 1.33) x 100
= 94%
Effective Field Capacity = 12.12 acres/hour x 0.94 = 11.4 acres/hour

Operating Material Capacity = 11.4 acres/hour x 200 bu/acre = 2281.14 bu/hour

3). The grain wagon is used, and the combine unloads on the go. Include the effect of transportation in this analysis.

Time to unload a truck = 30 miles round trip / 30 mph = 1 hour travel time and 30 minutes to unload = 90 minutes total time to unload a truck

Time to load a truck or grain cart = 1000 bushels / 2281 bu/hour = 0.43 hours x 60 min/hr
= 25.8 minutes

(25.8 minutes x 3 trucks) + 25.8 minutes per grain cart = 103.2 minutes

4th truck is finished uploading and back to the field in 90 minutes

So one would not have to wait on a truck, there is 13.2 minutes to spare.

This would keep Effective Field Capacity at 11.4 acres/hour with an Operating Material Capacity of 2281 bu/hour as in part 2.

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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.

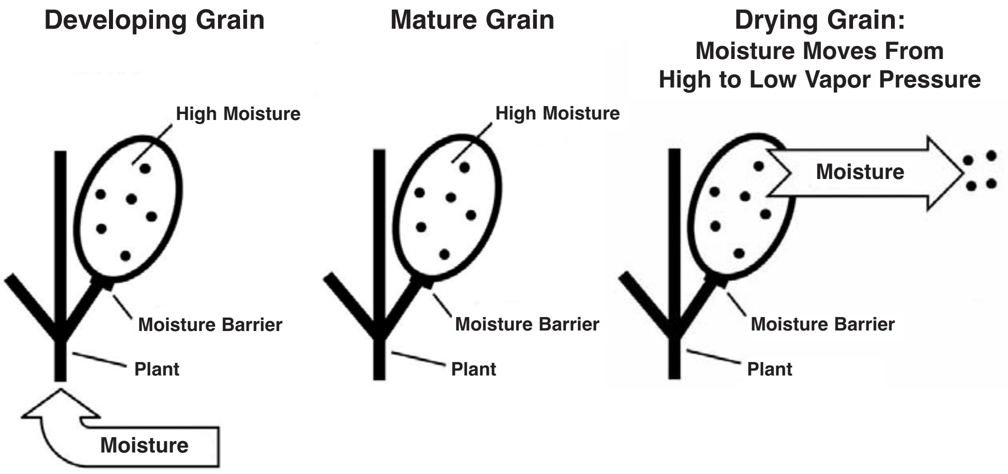
Developing Grain **Mature Grain** **Drying Grain: Moisture Moves From High to Low Vapor Pressure**

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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 (%)													
		25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**
Temperature (°F)	**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.

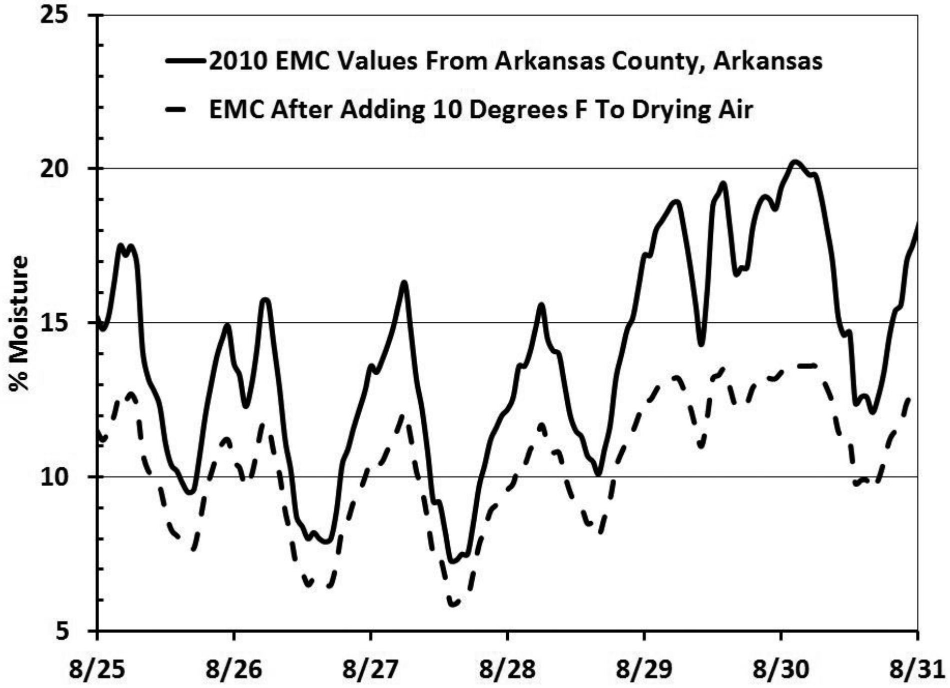
Temperatures and Humidities

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.

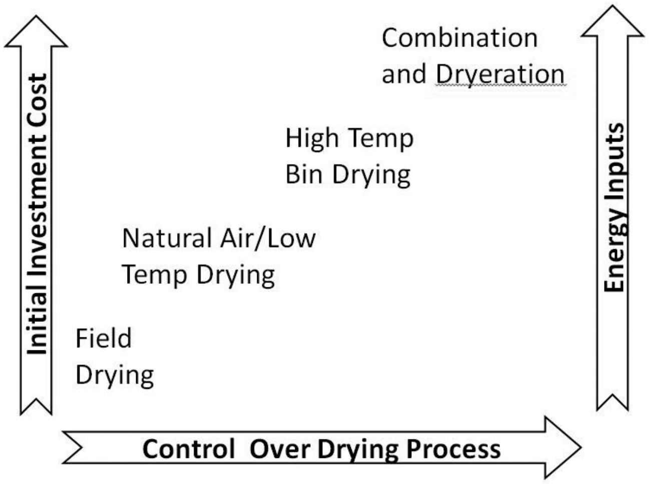


Evaporating moisture from grain requires energy in the form of heat. In general, it takes 1,100 BTUs of heat to vaporize one pound of water at 100-percent efficiency. Heat energy can be supplied by the natural heat content of air or by supplemental heating. The amount of moisture that air can absorb 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.



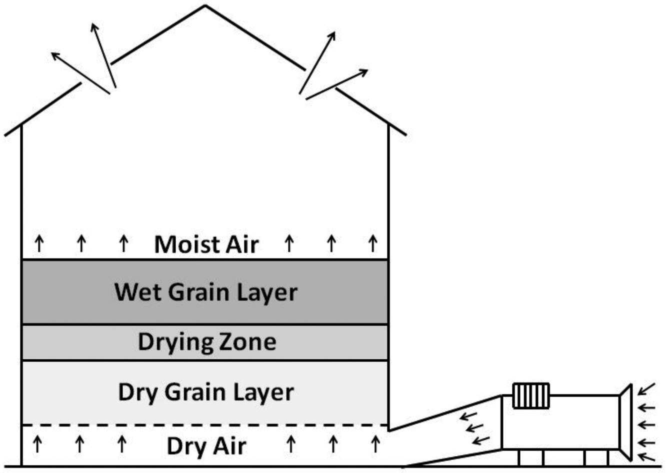
Field Drying

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.

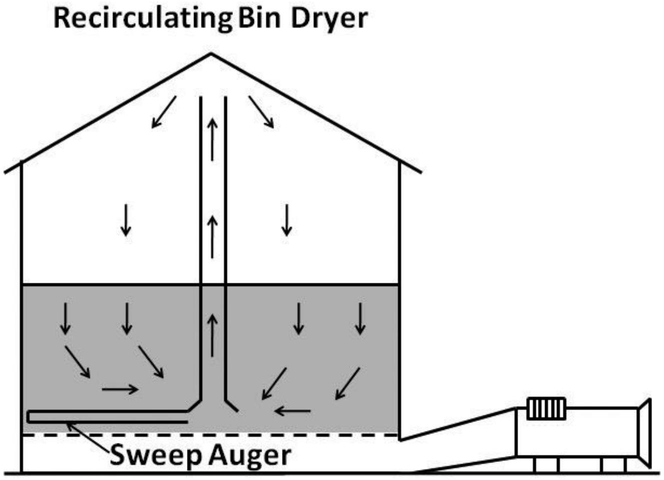
High Temperature Drying

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.

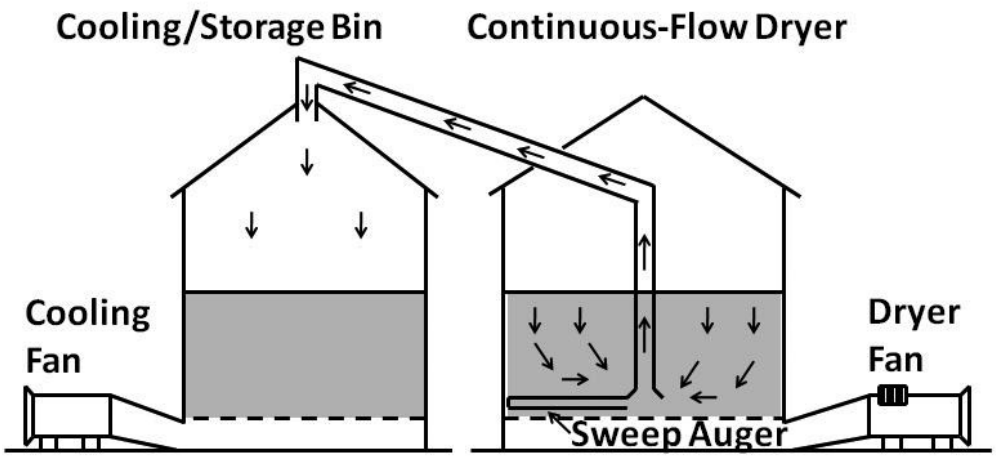


Pass drying (Figure 7) is typically the fastest method for drying grain. Most grain elevators use some form of pass dryers to dry large amounts of grain quickly. This method requires the highest energy inputs of all drying methods. The biggest benefit to using pass dryers is the large volumes of grain 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.

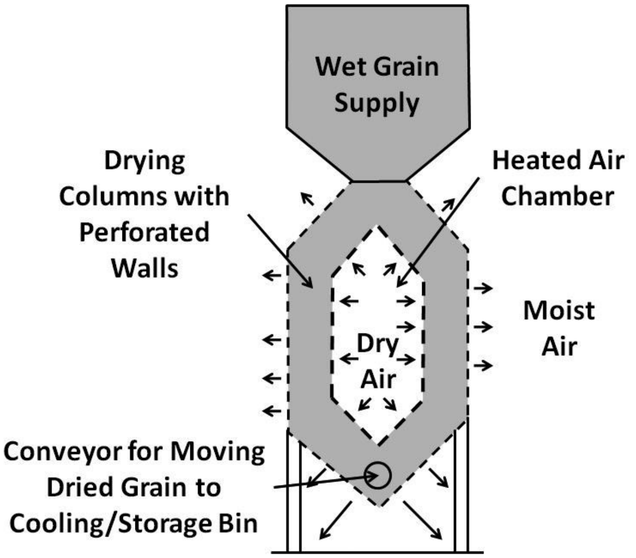
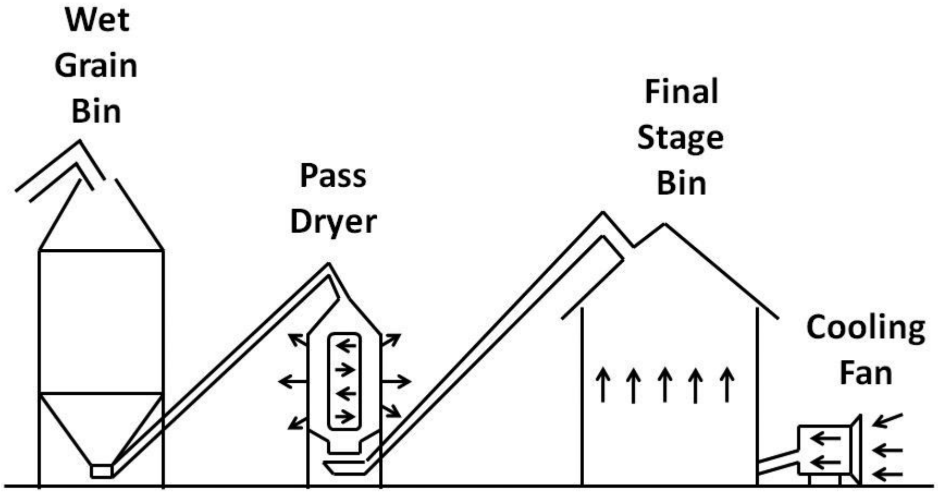


FIGURE 8. Combination and Dryeration System Diagram.
The final stage bin is where the tempering, final drying and cooling take place.



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Equilibrium Moisture Content for Grains

Implications for drying:

- Grain will eventually reach the moisture levels shown in the tables when exposed to the corresponding temperature and humidity levels for long periods of time. This can occur in the field or in the top layers of a low-temperature bin dryer.
- Drying time will depend on the airflow rate through grain, which in turn depends on the depth of grain in a bin. The minimum drying rate for natural air drying is 1 cfm/bu, but this can take up to a month to dry the top layer depending on the grain and air conditions--during which time spoilage can occur.

Implications for storage:

- The air space between kernels in a bin of corn will have the humidity indicated at the corresponding moisture and temperature. For example, 15% corn at 60 degrees will generate a relative humidity in the air space between kernels of 70%, but when cooled to 45 degrees will have a relative humidity of 65%.
- Mold growth is suppressed during storage when the environment is maintained at a relative humidity level of 65% or lower.

Table 1. Equilibrium moisture content of yellow corn (%wb) at different temperature and relative humidity levels.

	Relative Humidity (%)									
Temp.	10	20	30	40	50	60	65	70	80	90
F	Equilibrium moisture content, %wb									
35	6.5	8.6	10.3	11.8	13.3	14.8	15.7	16.6	18.7	21.7
40	6.2	8.3	9.9	11.5	12.9	14.5	15.3	16.2	18.3	21.3
50	5.7	7.8	9.4	10.9	12.3	13.8	14.7	15.5	17.6	20.5
60	5.3	7.3	8.9	10.3	11.8	13.3	14.1	15.0	17.0	19.9
70	4.9	6.9	8.4	9.9	11.3	12.8	13.6	14.4	16.4	19.4
80	4.6	6.5	8.0	9.4	10.8	12.3	13.1	14.0	16.0	18.8
90	4.2	6.1	7.7	9.1	10.5	11.9	12.7	13.5	15.5	18.4

Source: ASAE Data D245.4 / Average of two prediction equations.

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Table 2. Equilibrium moisture content of soybeans (%wb) at different temperature and relative humidity levels.

Temperature		Relative Humidity (%)									
		10	20	30	40	50	60	65	70	80	90
C	F	Equilibrium moisture content, %wb									
1.7	35	4.2	5.3	6.5	7.8	9.4	11.5	12.8	14.4	19.1	28.9
4.4	40	4.1	5.3	6.4	7.7	9.3	11.3	12.6	14.2	18.9	28.7
10	50	4.0	5.2	6.3	7.6	9.1	11.1	12.4	14.0	18.6	28.2
16	60	4.0	5.1	6.2	7.4	8.9	10.9	12.2	13.7	18.3	27.8
21	70	3.9	5.0	6.1	7.3	8.8	10.7	11.9	13.5	17.9	27.3
25	77	3.8	4.9	6.0	7.2	8.6	10.6	11.8	13.3	17.7	27.0
32	90	3.7	4.8	5.8	7.0	8.4	10.3	11.5	13.0	17.3	26.5

Source: ASAE Data D245.5 / modified-Halsey equation.

Table 3. Equilibrium moisture content of soft red winter wheat (%wb) at different temperature and relative humidity levels.

Temperature		Relative Humidity (%)									
		10	20	30	40	50	60	65	70	80	90
C	F	Equilibrium moisture content, %wb									
1.7	35	7.3	8.9	10.2	11.3	12.3	13.4	14.0	14.7	16.1	18.2
4.4	40	7.1	8.7	10.0	11.1	12.1	13.2	13.8	14.4	15.9	18.0
10	50	6.8	8.4	9.6	10.7	11.8	12.9	13.4	14.1	15.5	17.6
16	60	6.5	8.1	9.3	10.4	11.4	12.5	13.1	13.7	15.1	17.2
21	70	6.2	7.8	9.0	10.1	11.1	12.2	12.8	13.4	14.8	16.9
25	77	6.0	7.5	8.7	9.8	10.9	11.9	12.5	13.1	14.5	16.6
32	90	5.8	7.3	8.5	9.6	10.6	11.6	12.2	12.8	14.2	16.3

Source: ASAE Data D245.4 / Average of two prediction equations.

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