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Maintaining Stored Grain Quality

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Nearly all decreases in the quality of stored grain are the direct result of infestations by fungi and insects. Like all other living creatures, these organisms have certain requirements for temperature, moisture, food, atmosphere and time. Each fungus requires certain minimum conditions for growth. Fungi growth in grain bins is affected mainly by moisture and temperature while insects are affected mostly by temperature (3). Therefore, farm or commercial storage operators can influence quality of grain in bins by managing bin temperature and moisture conditions. As a rule of thumb, the storage life of grain is cut in half for every 1% increase in grain moisture. Risk of spoilage doubles for each 10° F increase in grain temperature.

More effective management of stored grain is important for both farm and commercial storage operators. Risk of deterioration increases as the size of unaerated bin increases, so the problems potentially become greater with construction of more and larger grain storage bins. Currently, we do not know how large a bin can be without risking loss of grain quality in an average year when no quality control measures are used.

The goal of effective stored grain management is to maintain grain quality. Millers are now using x-ray equipment to detect, within the kernel, insects which were previously undetected. International markets are also upgrading quality requirements for milling grain. As a result, many commercial grain dealers have purchased grain that looked satisfactory but failed to meet milling standards and had to be sold as feed grain.

This publication discusses factors that are important for preventing quality losses while grain is stored. Though it primarily addresses bins on the farm, it also applies to commercial storage since the basic conditions that cause deterioration are the same at either location.

Moisture Content

Table 1 shows the moisture content of several common grains when kernel moisture is in equilibrium with the relative humidity of the surrounding air. The relationship of grain moisture content to equilibrium relative humidity (RH) of surrounding air is important because, in the bin, moisture is relocated within the grain mass by air movement. Control of air movement in the grain is one of the most important ways to maintain grain quality because it permits control of moisture movement.

Table 1. Moisture contents of various grains and seeds in equilibrium with different relative humidities at 77 to 86°F.*

Relative humidity %	Percent moisture		
	Wheat, corn sorghum, barley, oats	Sunflower Seeds	Sunflower Meats
65	12.5 to 13.5	8.5	5.0
70	13.5 to 14.5	9.5	6.0
75	14.5 to 15.5	10.5	7.0
80	15.5 to 16.5	11.5	8.0
85	18.0 to 18.5	13.5	9.0

* From Christensen (2).

Moisture content limits for safe storage implies that nowhere in the entire storage facility is the moisture content higher than that specified. This is a problem because moisture content may vary considerably from one part of an uncontrolled storage to another. Grain temperature can also vary considerably.

Warm air can hold more moisture than cold air. Fig. 1 shows warm air from the center of the bin rising and contacting cooler grain near the surface. The cold grain causes the warm air to cool and as a result, the relative humidity of this air increases. Moisture then moves out of the air and into the grain at this location. If the air is cooled enough, moisture will condense and form water droplets on the cold grain. Even though the average moisture content of the grain in the bin might be 10 to 11%, local spots in the upper 2 or 3 feet of the bin can readily reach 18 to 20% moisture. The psychrometric chart in Fig. 2 shows the relationship between the relative humidity of the air and the air temperature (termed "dry bulb" temperature). The temperature at which moisture condenses is usually termed "wet bulb" temperature. For example, Fig. 2 shows that air at 60°F and 50% RH (point 1) will reach 100% RH if cooled to 42°F (point 2). A sling psychrometer can be used to determine both dry bulb and wet bulb temperatures simultaneously.

Warm air rising from the center of the bin does not have to reach condensation temperatures to cause problems. For example, note points 3 and 4 in Fig. 2. Air initially at 60°F and 65% RH — the

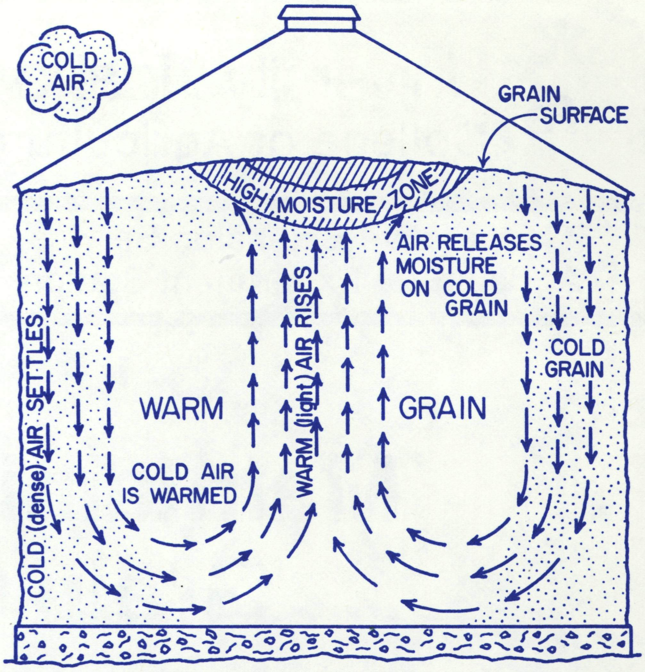

Fig. 1. Example of moisture migration in grain stored several months without aeration [from Noyes (5)].

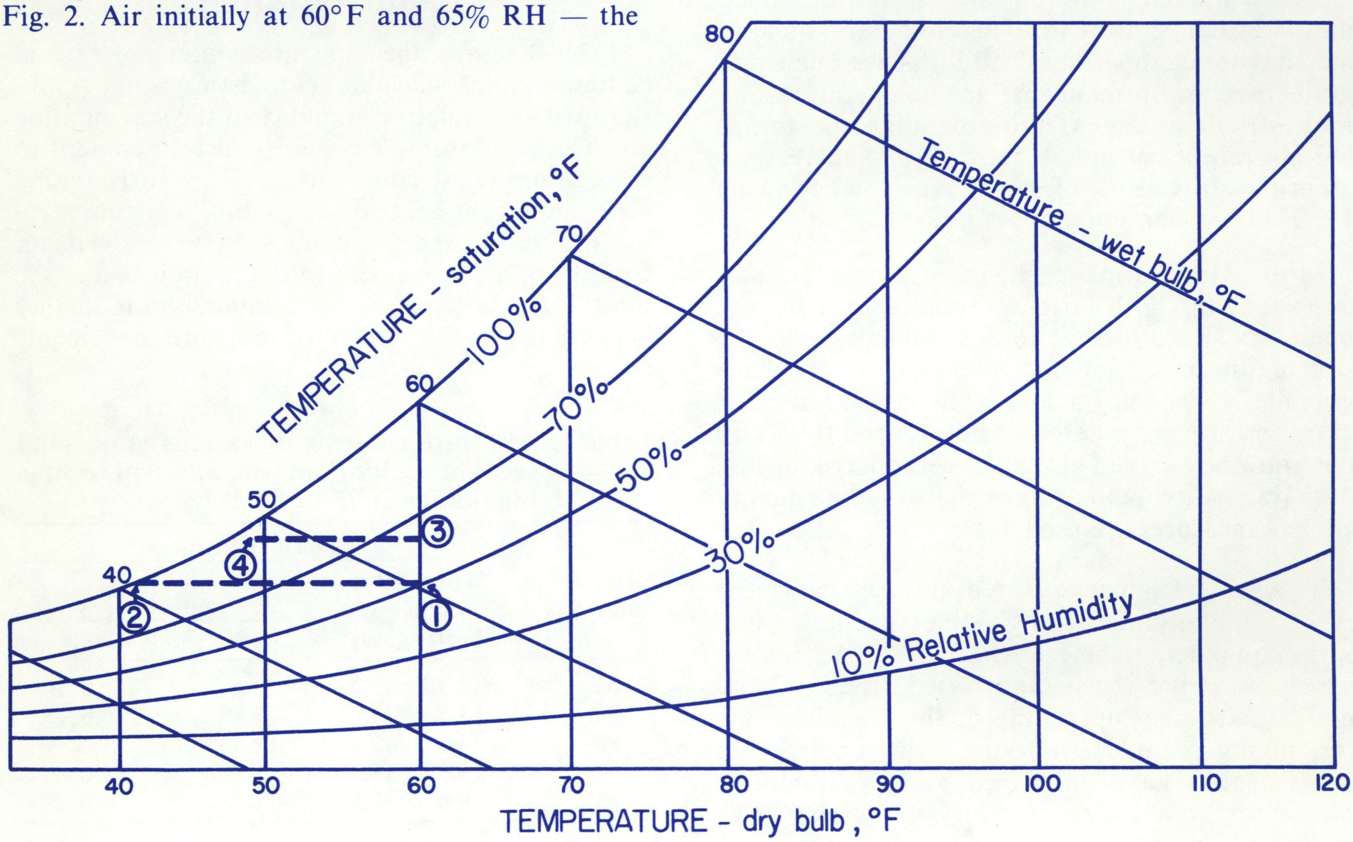

Fig. 2. Psychrometric chart, from Converse et al. (4).

tightly packed columns of fine material. Additionally, fine material tends to provide a more suitable habitat for growth of certain insects and fungi. Fines may accumulate and become a problem under filling spouts even when only 2 to 3% of foreign matter is present in the grain. Screening of fines and uniform distribution within the bin are important management tools for minimizing this problem. One of the problems associated with turning or moving stored grain with conveyors, to control wet spots or temperature, is that additional fines are produced each time from grain damaged in the conveying operation.

Automatic Controls

Automatic timers, humidistats and temperature controllers can be used partially or completely to automate the aeration fan and reduce labor requirements. Manual control can produce suitable fan operation but air humidity and temperature must be tested periodically. A completely automated fan would likely have a manual on-off switch and a high-low limit thermostat connected in series with a high limit or high-low limit humidistat. Where several fans are operated by one set of controls, indicator lights are helpful to show which fans are operating.

Humidistats should be set to open above 70 to 75% RH in winter. Summer humidities of up to 80% can be used if the outside air temperature is at least 10°F lower than grain temperatures. The low limit humidistat could be used if one wants to maintain or slightly increase moisture content of the grain.

Costs

Aeration system equipment costs range from 4 to 10 cents per bushel of capacity including both ownership and repair cost. These costs are influenced by the type of storage, method of control, type of ducts and size and type of fan used. Annual ownership costs are typically 13% of the system capital cost.

Operating costs are based on rate of airflow, grain type and depth, cost of labor and power and total fan and labor time. One could also include the costs of a moisture meter, grain probe and equipment to indicate bin temperature if such costs are distributed annually over their life. Because of the wide variation in equipment and labor used to maintain grain quality, the best estimates of cost are obtained by using figures for one's own set of circumstances.

Cost Example

Based on 13% of capital cost per year, ownership costs range from 0.5 cent to 1.3 cents per bushel. For a 7,500 bushel bin with a ¼ HP fan, operated 400 hours in 30 weeks to cool to 40°F, hold, then warm, the costs are calculated as follows:

The fan motor consumes ¼ KW per hour or 100 KWH total. At 3 cents per KWH, power costs $3. If labor costs $3 per hour and ½ hour per week is required for the 30-week period, labor cost would be $45, or 0.6 cent per bushel. Thus, power costs are very small compared to labor costs. Annual ownership and operating costs therefore range from 1.1 to 1.9 cents per bushel for this example.

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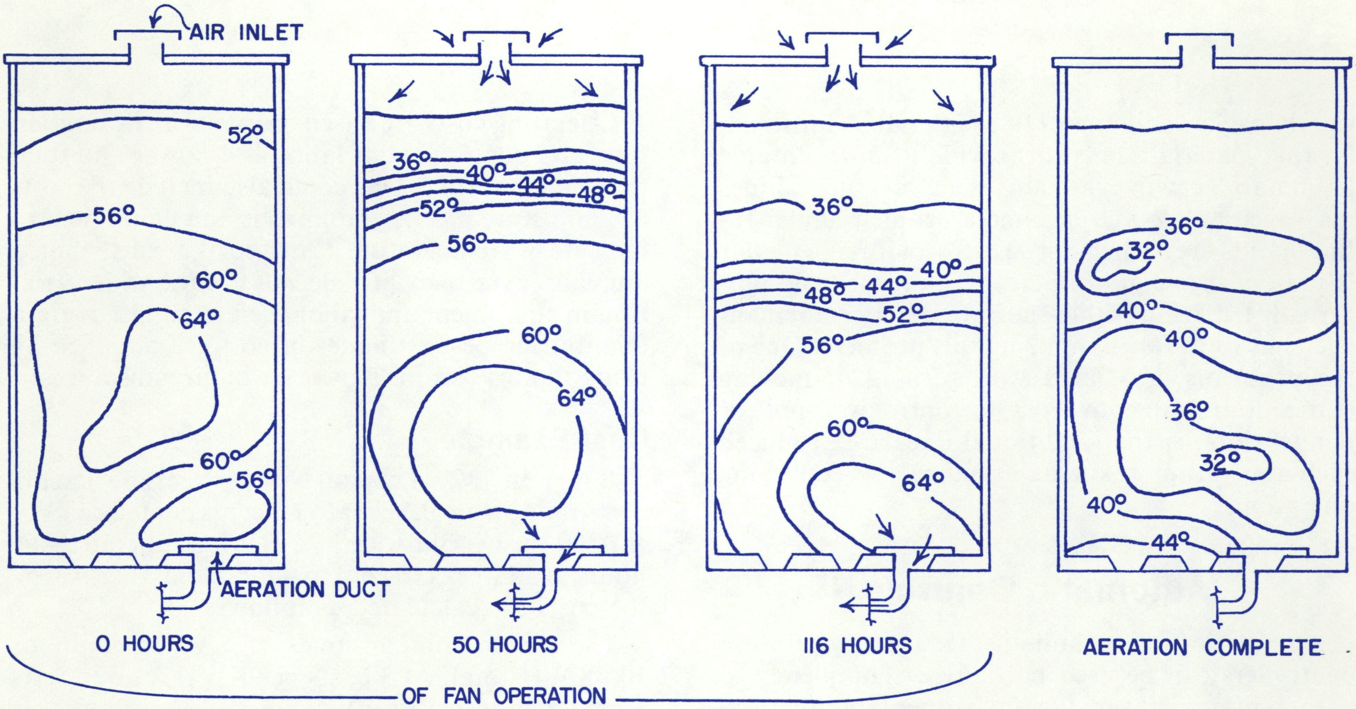

Fig. 3. Temperature changes in aerated vertical (silo) storage [from Anon (1)].

Periodic Check and Cooling

After initial cooling is completed, grain should be checked for condition every week to 10 days. Probe the top 2 to 3 feet of grain to check temperatures in various locations and to withdraw samples which can be tested for moisture content in the bin. If moisture testing is to be done elsewhere, place samples in plastic bags and close them tightly to prevent moisture loss. Also check the samples for mustiness since mold is an early indicator of undesirable conditions. Operate fans again when grain temperatures are 15 to 20° F different from average weekly outdoor air temperature.

Excessive Drying

The humidity of the air being used for aeration is a factor that can be used to advantage, especially when automatic humidistats are used to control fan operation. If grain is dried excessively, it will lose marketable weight. Table 1 shows that 65% RH air is in equilibrium with approximately 13% grain moisture. Although the low airflow rates of aeration do not move moisture as rapidly as a drying system, average moisture content of the grain can be changed by 1% or so. If wheat that went into the bin at 13% moisture comes out at 12% (wet basis figures), then approximately 6,800 pounds of moisture have been lost for every 10,000 bushels initially put into the bin. This is equivalent to approximately 114 bushels or $342 if wheat is $3 per bushel. While this isn't a large amount of money, it would help considerably to pay the annual cost of an aeration system. Ideally, one should keep the grain moisture content as close to the maximum allowed by commercial buyers without incurring a dock because of excess moisture and without incurring degradation while in storage. An aeration system equipped with automatic humidistat controls makes it much easier to maintain the desired moisture content.

Spring Warm-up

As temperatures rise in the spring, the same conditions exist which caused moisture movement in the stored grain during the fall. That is, temperature differences of greater than approximately 15° F can become established in the grain. Grain to be stored into the summer should be warmed 5 to 10° F per month until the final grain temperature is within 10° F of the average weekly outside air temperature. One should not wait too long before aerating or warm, humid outside air can transfer moisture into the cool grain. Again, once a temperature change is started, aeration should be continued until complete, barring unsuitable ambient air conditions.

Fines Management

Fine material within the grain tends to block air passageways and make it impossible to establish and maintain uniform temperatures, even with good aeration systems. The beneficial effects of aeration can be entirely negated by air channeling around equilibrium moisture conditions of grain at 12.5 to 13.5% moisture (Table 1) — need only be cooled to 49°F to reach 85% RH. Air with 85% RH will eventually cause grain to reach a moisture content of 18% or more (Table 1). Therein lies the difficulty with unaerated grain bins.

The situation shown in Fig. 1 is typical of any grain storage structure. Temperature differences in the grain occur naturally as ambient air conditions change. These differences cause air to circulate slowly within the grain because cold air is heavier than warm air. As the air circulates, it moves moisture with it and causes moisture migration.

Reducing moisture migration within a bin requires two things: (1) cooling the grain soon after it is stored to reduce natural convective air movement, and (2) periodic checking of the upper 2 to 3 feet of grain, at several locations across the surface, to measure changes in temperature and moisture content. Without aeration, the only corrective action which can be taken is to move deteriorating grain to another bin by conveyors. Since moving does very little to lower temperatures (approximately 2°F maximum) or to uniformly distribute wet grain, the most effective control is to aerate.

Aeration

The practice of moving small volumes of air through stored grain to establish and maintain uniform temperature conditions is termed **aeration**. Rates of airflow are usually about 1/10 to 1/20 cubic foot per minute per bushel (CFM/bu). At these rates, fans must operate for 15 to 20 hours to change the temperature 1° F (3). Low airflow rates are more efficient than higher rates from a power usage standpoint, since friction losses from airflow through the grain are reduced. Slow-moving air also comes more closely into moisture and temperature equilibrium with the surrounding grain so that each volume of air moved accomplishes more than high airflow rates.

The most common arrangement is to create a downward airflow with the fan located in ductwork at the bin bottom. Downward airflow permits aerating with smaller airflow rates since the air does not come into contact with colder material just before it is discharged. With upward airflow at low rates, moisture would migrate to the cool grain at the top of the bin. Additionally, ground level equipment is more readily serviced and maintained.

Initial Cooling

Grain brought from the field at harvest can be at temperatures of 70°F or higher when it is placed in the bin. As the outside surface of the bin cools in the fall, temperature differences are established within the grain. Because grain is a fairly good insulator, these differences can be quite great over a short distance. To minimize the temperature differences, aeration fans should be operated after a bin is filled and whenever outside air temperatures are 10°F or more below the maximum grain temperature. Once a cooling cycle is started, fans should be operated continuously as long as outside air temperature permits. RH of the outside air is also a factor and should usually be 70% or less when fans are running. Completion of aeration is determined by measuring exhaust air temperature or by checking grain at the bottom of the bin with a temperature probe.

Uniform airflow through the grain provides for uniform cooling and best efficiency. Obtaining uniform airflow is done by proper equipment design, selection and installation. This is usually left to the equipment supplier. Fig. 3 shows temperature changes from start to finish of aeration in a vertical storage unit. The cooling front can be seen to move quite uniformly through the contents — pea bins in this example.

For Idaho, a final grain temperature of 35 to 40°F is desirable for winter storage. These temperatures would effectively control mold and insect growth. Insects need not be killed to control infestations. Grain should be held at a temperature that will interrupt some function of their life cycle, such as prevention of egg laying (Table 2). Grain should not normally be frozen because of lack of moisture control during spring warm-up and because frozen lumps will usually clog conveying equipment. To prevent grain from freezing, the lower temperature limit of fan operation is about 30°F.

Table 2. Temperature (°F) for reproduction of stored product pests.

	Adult dormant	No mating	No egg laying	No larval development	Optimum development
Rice weevil	45	53	—	60	84 to 88
Granary weevil	35	55	—	60	82 to 86
Confused flour beetle	—	—	60	64	95 to 100
Red flour beetle	—	—	60	68	97
Saw-toothed grain beetle	—	—	60	—	93
Lesser grain borer	—	—	—	—	90

Note: According to Christensen (2), temperatures less than 63°F provide safe storage except for hot spots.

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