OPERATION OF MODERN AERATION SYSTEMS

Grain quality is the highest just after harvesting. Providing proper conditions exist, grain can be stored for several years, with little or no detectable loss of quality. Under improper conditions, however, grain can begin to spoil within a few hours.

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Grain spoilage is the result of microorganisms (bacteria, fungi and yeast) using grain nutrients for growth and reproductive processes. Microorganisms can produce heat during growth, that can increase the temperature of stored grain. The result can be "heat damage" that renders the grain unfit for human consumption or even animal feed.

Managing grain storage conditions

Successful grain storage requires that grain and the atmosphere in which it is stored be maintained under conditions that discourage or prevent the growth of microorganisms that cause spoilage. The major influences on the growth and reproduction of microorganisms in grain include: moisture, temperature, oxygen supply, pH, condition of the grain, storage time, initial infestation and the amount of foreign matter present.

Aerating stored grain, whether it be contained in bags, boxes, concrete or steel silos, or flat storage buildings, helps to maintain its quality. Before the principles of aeration were known or aeration equipment developed, the only method available to storage operators was to turn the grain in the storage system, thus providing some contact with fresh, cooling air. This method required additional storage space, machinery and manpower for moving the grain, causing wear and tear on machinery and creating stress cracks and handling damage in the grain itself. This increased the percentage of fine material in the total grain mass.

Grain storage aeration systems have four basic functions. These systems:

1. Remove storage odors. Aeration systems will remove undesirable odors from moldy, sour or fermented grain.

2. Protect against mold growth. High grain temperatures and moist grain conditions encourage the growth of mold and fungi. Lower grain temperatures, below 21°C, discourage this growth. Fungi growth rates decrease to a minimum from 2° to 5°C.

3. Retard insect activity. Insects multiply rapidly in grain when the grain temperatures exceed 20°C. In general, insect reproduction is low when grain temperatures are below 15° to 16° C. Low temperatures retard insect movement, feeding and reproduction. However, lowering grain temperatures just 10° C (from maximum levels) can greatly reduce the movement and growth of some types of grain pests (others are affected differently), even if ambient atmospheric conditions do not allow the lowering of grain temperatures to the levels suggested above. If it is possible to lower grain temperatures to 4° to 5° C, the resident insect population in the grain mass may starve and die. If climatic conditions at the storage site offer these kinds of temperature

possibilities, it may be possible to avoid costly grain fumigation to deter insect infestations. Aeration is not, however, a total substitute for fumigation or good management practices.

4. Resist moisture migration and accumulation. Grain placed into the storage at harvest time is usually quite warm. Grain acts as an insulator, meaning that heat dissipates slowly from the interior of the grain mass. In areas with four seasons that include cool fall and winter periods, grain within 1 to 2 feet (300 to 600 mm) of the outside wall cools, while grain in the center of the silo remains at higher harvest temperatures. Cool air in the grain mass near the silo walls moves downward, forcing warm air upward through the center of the grain mass. Simple psychometrics explains that this warm rising air has more capacity to absorb moisture than cool air. It therefore absorbs moisture from the grain. When warm, moist air rising in the grain mass makes contact with the cool grain surface at the top of the silo and, condensation may (depending on temperatures) occur in the same way moisture condenses on the exterior of a glass of ice water. This sometimes causes a crust to form on the top surface of the grain and, if severe enough, can create a small amount of sprouting.

Effects of moisture on grain

Although the moisture migrates slowly, it continues to occur as long as temperature differences exist in the grain. If allowed to continue for months or even a few weeks, the accumulated moisture may promote insect activity, microbial growth, and spoilage in the upper layers of stored grain, particularly in large silos. The direction of migration reverses itself when the weather changes from winter to springtime conditions, with potential moisture condensation occurring near the bottom center of the grain mass.

Aeration can control moisture accumulation by creating a uniform grain temperature throughout the grain mass. An effective method is to move small quantities of air (1/10 CFM/bushel [about 6.25 M3/Hour/metric ton]) through the grain more or less continuously until temperatures are equalized to within a range of the average ambient air temperatures. In this regard, the goal is to maintain the grain temperature within 4° to 5°C of the average daily ambient air temperature.

Four-seasons operations

Operation of the aeration system in a four-season climate is relatively simple. During harvest, or at the initial filling of the storage in the case of grain just transported to the site, the aeration fan should begin operation as soon as the aeration ducts are completely covered. Aeration should operate continuously for about ten days during this period, with the goal of lowering the grain temperatures to about 15° C. Obviously, this is dependent upon the ambient temperatures available for cooling. In some locations, nighttime-only aeration operation may provide the necessary cooling potential. Keep in mind that it will require about 150 to 200 hours of fan operation to lower grain temperatures 2° to 3° C. Use of a temperature monitoring system will provide finite results of the effects of aeration and provide the operator with another management tool in deciding how long to operate the aeration system.

During the late fall, when ambient temperatures begin to stay cool, the aeration system should operate for another week, with the goal being of lowering the grain temperatures to as low as 4° to 5° C. Although air with ambient temperatures below freezing can be used for aeration, caution is advised to avoid freezing any portion of the grain mass and frosting over of the roof vents, which can lead to roof damage or structural failure.

Warming grain in the spring is recommended in some situations to avoid moisture migration to the lower center of the grain mass. To accomplish this, when temperatures begin to stay warm, operate the aeration system for about one week. The goal is to raise grain temperatures to within 2° to 3° C of the average ambient air temperatures.

Operation of the aeration system in subtropical climates presents a completely different management philosophy than operation in four-season fall crop conditions. In subtropical climates, the goal is to maintain the lowest possible grain temperatures without increasing the moisture content of the stored grain. In this case, the use of some type of grain temperature monitoring system is indispensable to provide the operator with timely information from which to make fan operation decisions.

Humidity considerations

Both the moisture content of the grain and the relative humidity of the surrounding air affect microbial growth and spoilage. Relative humidity of 100% indicates that the air contains all the water it can normally hold at that temperature, whereas a relative humidity of 0% indicates that there is no water in the air; in other words, the air is completely dry. Grain will attempt to establish equilibrium moisture content with the surrounding air. Because grain is hygroscopic, it will exchange moisture with the surrounding air until the vapor pressure of the moisture in the grain and that of the air reach a state of equilibrium. If grain comes to equilibrium with air maintained at a relatively constant environmental condition, the grain moisture content is referred to as the equilibrium moisture content (EMC) corresponding to the existing air conditions. Grain stored outdoors, in constant contact with atmospheric conditions, will reach its equilibrium moisture content with the surroundings very quickly.

On the other hand, if the grain is surrounded by a relatively limited amount of air (such as occurs in the interstitial space of a grain mass in a storage silo), the air will reach moisture equilibrium with the grain without any significant change in the grain moisture content. The relative humidity of the air in this situation is referred to as the equilibrium relative humidity (ERH) corresponding to the existing grain moisture content at the prevailing temperature. All equilibrium moisture properties are a function of temperature; that is, the properties change with changes in temperature.

Effect of ambient conditions on grain drying

Equilibrium moisture properties are specific to each type of grain and are important in developing storage recommendations.

Grain will dry when the relative humidity of the air that surrounds it is lower than the equilibrium relative humidity corresponding to the moisture content of the grain. Alternatively, grain will absorb moisture from the atmosphere if the air surrounding it has a relative humidity greater than the relative humidity corresponding to moisture content of the grain.

Climates with high relative humidity make it necessary to take into account the moisture held in the ambient air when aerating grain to avoid increases in moisture in the grain mass. In these situations, it is not recommended to operate the aeration system during extended rainy periods, or periods of extremely high relative humidity. The relative humidity of ambient air changes on a diurnal basis. Relative humidity is usually lowest at midday (the hottest part of any day) and highest at night, with the maximum usually occurring just before daybreak. However, since no cooling potential exists during most of the daylight hours, operation of the aeration system is a must at night to take advantage of lower ambient temperatures. Thus, it becomes a juggling act for the storage operator to maintain low grain temperatures without increasing grain moisture contents beyond acceptable storage levels. These moisture contents are generally accepted to be 14% for shelled corn, sorghum and paddy rice and lower for other crops such as wheat, and soybeans.

A strategy for operating aeration systems in subtropical climates is based on research from the International Grains Program at Kansas State University. Their recommendations are for the following aeration operations:

• The goal is to attempt to keep grain temperatures as low as possible, i.e. within 4 to 5°C of the average ambient temperature.
• Do not aerate stored grain in the middle of the day. Relative humidity is lowest in the middle of the day, but temperatures are highest.
• Late afternoon represents an ideal time for aeration of stored grain. Ambient air is cooling and the relative humidity is still low. Plan for starting the fans about 5:00 PM and operating them until 8:00 PM.
• Early morning also is a good time to aerate stored grain. Begin fan operation about 5:00 AM and operate the fans until 8:00 AM.
• If the grain temperatures are near your pre-determined goals, do not operate the aeration fans. Remember, pumping ambient air into the storage means that the grain will eventually reach the same temperature and relative humidity as the ambient air.
• Check the grain temperatures often, perhaps even daily, to help decided if grain aeration is necessary.

Cooling air can be provided to aeration systems using commercially available portable refrigeration units. These units can effectively lower grain temperatures, even in tropical conditions, without risking the addition of moisture to stored grain.

Distribution of air to the grain mass is the third component in aeration system design. Computer modeling indicates that air distribution becomes relatively uniform at about 60% to 70% of the grain depth in a silo, regardless of the geometry of the floor duct air distribution system. The arrangement of this distribution system, however, affects how much air reaches the grain mass in the lower 30% of the silo.

Fans can be connected to the aeration ducts either in the pressure mode or the suction mode (positive or negative pressure systems). Either system is acceptable and offers unique advantages. A consideration when choosing between these alternatives is that positive pressure systems add heat to the air that enters the grain mass because of the inefficiency of the fan. This inefficiency results in a temperature increase of up to 1° C.

A negative pressure system is preferable if dust control at the surface of the grain is a priority. Negative system operation prevents condensation on the silo or building roof as the grain is cooled, and allows use of solar heat in the roof when warming the grain. One disadvantage of this system is that, because the bottom layers of the grain are the last to cool, it may be difficult to know when cooling is complete, and any moisture movement in the grain is drawn downward, where moisture or quality problems become harder to detect.

Positive pressure systems allow the addition of grain layers on top of the existing grain mass without rewarming or cooling grain. It is also easier to determine when the grain is in proper condition, because the top layer is the last to cool and there is usually personnel access to this level. There is some evidence that positive systems provide better air distribution than negative systems.

In either case, it is necessary to provide adequate entry or exit areas for the aeration air. This is usually accomplished in silos by the use of roof vents. The number of roof vents correlates directly with the size of the fan(s). Lack of roof vents, or inadequate numbers of vents, can result in structural failure or roof damage.

Conclusions

Grain aeration systems are a management tool for storage operators. They can be used to maintain and occasionally change the condition of stored grain, regardless of climatic conditions. Aeration systems can prevent the growth of molds, fungi, and insect populations. Properly designed and equipped and operated aeration systems are an economical tool that can maintain grain quality and increase profits for the storage operator.