Low-Temperature Grain Drying

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Introduction

Grains such as rice, corn, soybean, wheat and grain sorghum do not always dry sufficiently in the field in Arkansas to allow safe, long-term storage. Producers must carefully manage post-harvest grain to prevent spoilage. High humidity of ambient air during harvest season may not allow thorough drying of grain in the field and may also cause rewetting of dry grain placed into storage after drying. The first step in the proper handling of grain after harvest to maximize its value is to ensure proper drying, which will likely include artificial drying. Drying is an essential process in achieving the target safe storage moisture content to protect the grain from deterioration. Grain drying strategies can be categorized into the following approaches: **field drying, in-bin natural air-drying, low-temperature drying, high-temperature drying and combination drying** (also known as dryeration). This fact sheet describes the low-temperature drying process, its advantages and disadvantages as well as system performance and management.

Low-Temperature Drying

Low-temperature drying is the process of forcing air through grain using a fan while heating the air by 10°F or less using a supplemental heater. Figure 1 illustrates the components of a low-temperature, in-bin drying system. In this process, grain is dried and stored in the same bin, thus minimizing handling and labor costs. Low-temperature drying is typically done in bins with a perforated floor or ducts under the grain. In many locations in the United States, the heater uses electricity, so the term "electric drying" is sometimes used as an alternate description of low-temperature drying. In addition to electricity, heaters can also use liquid propane (LP), natural gas or solar energy as energy sources.

A low-temperature drying system that is properly designed will always be able to dry grain to an acceptable moisture content for long-term storage based on the grain type and weather conditions at the dryer site. Low-temperature drying contrasts with

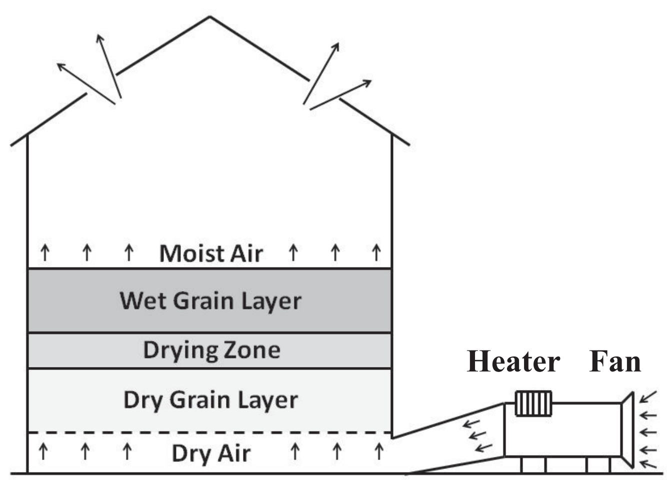

Figure 1. Grain bin utilizing low-temperature drying

natural air-drying (no added heat) in that natural air conditions may not allow the grain to dry to the required safe storage moisture content because of excess humidity of the air during the drying process. Low-temperature drying can reduce some of the risks of natural air-drying caused by weather, especially when the relative humidity of ambient air is higher than the moisture content of the grain. When air is heated, its ability to hold water vapor increases, which allows the air to more effectively dry the grain. Water contained in the grain vaporizes and transfers to the air until the grain and air come into equilibrium. Natural air-drying without a heater does not allow manipulation of the air's ability to hold water vapor. During a wet day when the air is humid, natural air-drying may not have the capacity to carry away water from the grain and will not allow proper drying. Fans force a continuous supply of fresh air through the grain. As air passes from the bottom to the top, it absorbs water from grain and loses its ability to absorb moisture, resulting in a wet grain layer near the upper part of the grain column. The more humid the air, the thicker the layer of undried grain. If air is overheated, the grain near the bottom of the column can overdry. Low-temperature drying systems balance these two extremes by heating the air sufficiently to allow drying but not heating too much to cause overdrying. Therefore, drying using low-temperature conditions is usually slow and must be carefully managed.

Mold growth occurs more rapidly in wet grain (greater than 20% moisture content) at temperatures above 60°F. Accordingly, low-temperature drying is suitable when outside air temperatures are below 50°F before adding the slight heating. The low-temperature rise prevents overdrying of lower grain layers, compared to normal or high-temperature drying, while reducing the likelihood of mold damage. Airflow rates are usually between 1 and 2 cubic feet per minute (CFM) per bushel for low-temperature drying. High airflow rates are desirable but are difficult to obtain in deeper grain depths in bins because of excessive fan horsepower requirements.

System Equipment Overview

A grain bin with a perforated floor, a grain spreader, an underfloor unloading auger and a sweep auger are normally associated with low-temperature drying. A fan, motor and the heating unit are also needed. A stirring device may also be added. Filling the bin may be accomplished by either a portable auger or a bucket elevator. It should be mentioned that a spreader and a stirrer are not commonly used when moisture and temperature cables are suspended from the bin roof. Farm bins are typically top loaded using grain augers.

Burners and Heaters

As mentioned earlier, the objective of adding heat in a low-temperature drying system is to reduce the relative humidity of incoming air, which allows the air to hold more water vapor so drying can occur. However, too much heat will cause the grain to overdry. Because overdrying should be avoided, the amount of heat to be added to outside air should vary with the condition of this air. A temperature rise of 7°F for outside air temperatures between 40°F and 50°F is recommended. Of this 7°F temperature rise, 2 degrees are provided with heat added by the fan and motor, so only a 5-degree temperature rise must be furnished by the gas or electric heater.

For gas heaters, the heater size in Btu/hour can be estimated by (Loewer, Overhults and Hamilton):

$$\text{Btu/hour} = 1.1 \times \text{temperature rise to be provided by the heater (°F)} \times \text{CFM of fan}$$

For electric heaters, the power requirement in kilowatts (KW) is:

$$\text{KW} = \frac{\text{CFM of fan} \times \text{temperature rise (°F)}}{3000}$$

Both gas burners and electric heaters specifically designed for low-temperature drying use are commercially available. Because of the low BTU/hour rating required in low-temperature drying, high output burners for high-temperature drying usually prove unsatisfactory. This problem may be solved, in some cases, by installing a time clock or thermostat that automatically turns the heater coil or burner on and off. However, this is not usually recommended because high temperatures (20° to 30°F temperature rise) can result over short periods of time, increasing the risk of overheating air, grain and equipment. Also, constantly cycling burners on and off reduces fuel use efficiency.

The location of the heater relative to the fan and bin varies with the manufacturer. Regardless of burner location, the heater casing should never restrict the airflow of the fan. The heater should be controlled with the fan to prevent continued operation if the fan stops. If the heater is operating without airflow from the fan, very high temperatures can result increasing the danger of a fire.

To determine if the fan is supplying sufficient air to the grain, first determine CFM/bushel using the following formula (Loewer, Overhults and Hamilton):

$$\text{CFM/bushel} = \frac{\text{hp of fan} \times 6356 \times \text{fan efficiency (\%)}}{\text{(Static pressure in inches of water} \times \text{bushels of grain in the bin)}}$$

If the CFM/bushel is less than three, reduce the height of the grain column in the bin and recalculate until CFM/bushel exceeds three. It should be mentioned that this value depends on the initial moisture content of the grain and grain type. Lowering the height of the grain column in the bin will reduce the static pressure required and increase CFM/bushel. To determine if the proper amount of heat is being added, a temperature sensor (such as a thermometer or thermocouple) measuring the air temperature before and after heating should be installed. By using temperature sensors, it is possible to monitor not only the temperature rise of the drying air but also fan output. The cost of the sensors is relatively low. Use of the sensors represents an easy and accurate method for monitoring the performance of the low-temperature drying system.

A humidistat may be added to sense the relative humidity of the air in the plenum before it enters the grain and may also be used to control the output of the heater and to prevent the lower layers of grain from overdrying. This device, in general, is set to control the relative humidity of the drying air at 55%. Under most dry weather conditions, it is advisable to operate the fans continuously through all types of weather until the grain is dry or until extremely low temperatures are encountered.

Advantages of Low-Temperature Drying

- Lower risk of spoilage than natural air-drying.
- Grain is dried and stored in the same bin, thus minimizing handling and labor costs. Additionally, it minimizes the amount of equipment and maintenance.
- In-bin low-temperature drying allows filling the bin as fast as the grain can be harvested, eliminating a possible "bottleneck" in the system created by low-capacity, portable dryers.
- Low-temperature drying does not require large amounts of fuel for short periods of time, as do other drying systems.
- The reduction in power demand allows for the use of electricity as an energy source to heat the air used for drying.
- When used properly, low-temperature drying causes less stress cracking and can result in a higher-quality grain. Stress cracking is associated with rapid moisture removal typical in high-temperature drying.
- Successful low-temperature drying has lower energy costs compared to most higher temperature methods. Total drying costs decrease because of decreased costs of heating the air. However, more energy is usually required to operate the drying fans because of higher airflow requirements of low-temperature drying.

Limitations of Low-Temperature Drying

- Low-temperature drying is restricted to conditions where grain harvest moisture content is relatively low.
- Low-temperature drying has little reserve capacity; that is, the system dries grain at a slow, steady rate which cannot be altered greatly.
- There is a greater risk of mold growth, spoilage and/or aflatoxin being produced than with higher air-temperature drying.
- Long drying periods are required to reach storage moisture content.
- The moisture content of the upper layers of grain decreases very slowly until the drying front moves through the lower layers. Some damage from mold growth could occur in the grain even during "safe" storage times.
- If electricity is used as a heat source, electrical power demand may limit the size of the heater unless the electrical configuration is designed to meet the required load.
- Low-temperature drying is a higher-risk drying method than high-temperature drying; the process requires a high level of management (continuously monitoring the grain temperature and moisture content) if the grain is to be dried successfully every year. The drying strategy required is dependent on the weather and initial grain moisture content, so the same drying strategy may not be used every year. Precautions should be taken to avoid aflatoxin contamination.
- Because natural gas is available in Arkansas in sufficient quantity and at a reasonable cost for drying, it would be preferable to use high-temperature drying methods rather than low-temperature drying techniques if the cost of the high-temperature dryer is affordable for the producer.

System Performance and Management

Important factors determining the performance of a low-temperature dryer include airflow rate, ambient air temperature, relative humidity, fill rate, initial grain moisture content, harvest damage and air temperature rise. Airflow rate is the most important factor (drying rate is directly proportional to airflow), but all other factors should be considered when designing a low-temperature dryer. One factor that can be controlled is the CFM of air applied. Fan horsepower requirements may be calculated by the following formula (Loewer, Overhults and Hamilton):

$$\text{hp} = \frac{\text{Total CFM} \times \text{static pressure in inches of water}}{6356 \times \text{fan efficiency (\%)}}$$

Although it would appear from the formula that doubling the CFM would double the fan horsepower, such is not the case. An increase in CFM also increases the static pressure required to push the air through the grain. For example, increasing the airflow rate from 1 to 2 CFM per bushel would increase the horsepower requirements by approximately a factor of five if the depth of grain remained the same. Some tips to aid in creating an exceptional management plan for using the low-temperature drying technique are as follows:

- Apply low-temperature drying if at least one of three basic conditions is met. (1) The air temperature must be relatively low (preferably 50°F or below), thereby extending the allowable storage duration. (2) The initial moisture content of the grain must be relatively low (under 22%), resulting in a shorter drying period. (3) High volumes of air must be applied (3 CFM per bushel or above) to increase the drying rate.
- Clean the wet grain being brought in from the field to remove any fines before placing grain in the drying bin. This reduces the chance of mold growth, allows air to circulate more uniformly throughout the bin and reduces the probability that grain will bridge across the bin.
- Use a spreader to reach a uniform height of grain in case the bin has no suspended cables. This will aid in applying uniform airflow throughout the bin.
- Reduce the depth of the grain layer in the bin to 4 to 6 feet so proper quantities of air can be provided. This may leave part of the bin empty but will decrease the chances of grain spoilage.
- Never load high-moisture content grain (above 22%) into the bin beyond half full. Wait until the upper layers dry to 22% before adding more grain.
- Develop a filling schedule to maximize the drying rate. This could be accomplished via single filling (fill the bin in one to three days), layer filling (grain is added in layers over a period; let the drying front come through before adding another layer) or controlled filling (similar to layer filling with the exception that drying front does not come through). This will reduce the chance of grain spoilage and aflatoxin contamination.
- Monitor the grain conditions, such as the moisture content (MC), by using moisture cables or by taking samples from the bin carefully as drying progresses. Check the amount of heat and air being supplied, and watch the grain for any indications of spoilage.
- Ensure proper venting on the roof is installed and maintained (not clogged) to prevent airflow reduction and reduce condensation on the roof, which will lower the amount of water that will drip onto the grain.
- Run the fans continuously, if your system has no automatic controller, once the grain is placed in a bin. Wait until either the grain is dry or the temperature of the drying air is too low.
- Use the highest possible airflow rate. The drying rate is directly related to the quantity of drying air. The higher the airflow rate, the faster the grain will dry and greater the chances that the system will produce high-quality grain.
- Manage the system properly by continuously monitoring the grain temperature and moisture content to reduce the chances of spoilage.
- Stop drying when the top layer of grain in the bin reaches the desired moisture content level.
- Close the hatches on the bin once the drying is complete.
- Aerate grain frequently if the air relative humidity is lower than the grain MC during storage to prevent moisture migration in the bin. Do not run the fan once the grain is cooled enough for winter holding.

Economic Considerations

Install a bin and drying system that is of sufficient capacity to handle current production and reasonable expansion needs. Low-temperature drying is most economical when using a single-bin drying-storage system. If multiple bins are required, then all drying accessories must be duplicated, which can eliminate economies of scale. Among artificial drying systems, successful low-temperature drying is second only to layer drying regarding maximizing energy efficiency and grain quality. The total comparative cost for drying is decreased by reducing the air heating energy, even though more energy is required to operate the drying fans. Thus, an effective low-temperature drying strategy can be more economical regarding energy costs when compared to higher temperature methods. Some of the cost advantages of low-temperature drying realized by energy efficiency are lost when electricity is used as the heat source. Electricity is usually more expensive per unit of energy than LP gas, especially if higher electricity costs are in effect because of the demand schedules. The major economic concern with low-temperature drying is whether or not it will work successfully to dry grain to proper storage moisture content without spoilage. The chances of spoilage and aflatoxin contamination when using low-temperature drying increase greatly with warmer outside air temperatures and high relative humidity during harvest. Nonmarketable grain represents the major expense of any unsuccessful drying system.

Summary

If fuel shortages exist or other drying methods cannot be used, low-temperature drying provides a means of drying grains to a safe storage level. Also, low-temperature drying could be recommended if grain is allowed to dry in the field to 22% or less, the average outside air temperature is 50°F or below and sufficient quantities of air are supplied. Good management is a necessity and depends on an understanding of the capabilities of the low-temperature drying strategy. Consequently, low-temperature drying is a relatively high-risk drying system requiring substantial management. It is preferable to natural air-drying, in that drying can occur in all types of weather. When used successfully, low-temperature drying results in a grain of high quality. However, its susceptibility to failure during high temperature, high relative humidity conditions at harvest limits its application to cooler regions.

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