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Drying Soybeans with Heated and Unheated Air

Bruce A. McKenzie
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Soybeans do not usually require drying at harvest time as a regular practice. The crop does not adapt well to early harvest at high moisture contents until the plant has died from either complete maturity, or a killing frost or freeze. Prior to that time, the range in bean maturity from completely green and soft to fully mature and hard, presents problems in harvesting, and may affect yield.

The maturity spread problem has usually best been solved by letting the soybeans mature and field dry. Field and weather conditions in the Fall are usually such that field drying has worked well with little risk. There has been little pressure to develop forced drying procedures. Farmers have little experience, and there is very little technical information based on drying studies on soybeans. Most information is derived from experience with other crops.

In two of the last three years, however, in 1970 and again in 1972, there have been serious problems in getting the crop harvested. A number of producers are turning to drying as a way of increasing the number and length of available operating days, decreasing the potential field loss, and insuring the best possible quality of the harvested bean in the storage.

GENERAL DRYING REQUIREMENTS AND LIMITS

There is no doubt that drying as an emergency or continuing practice can aid in soybean harvesting and storage. Once the bean plants have matured or been frosted and have died, the immature beans shrivel and dry so that seed moisture is more uniform. Moisture content of beans standing in the field may swing from 16% in the morning from a heavy dew or rain to as low as 9 - 11% during the heat of the afternoon in good drying weather.

In periods of cold, wet, rainy weather such as the Fall of 1972, the moisture on the standing beans may hover around 16 - 20% and never approach safe storage levels. These high moisture beans can be very successfully harvested provided the soil conditions will support equipment, and the weather is favorable to dry the foliage.

Basically, all grain drying methods are adaptable to soybeans, with some restrictions on the use of heat, and on handling practices. The successful use of unheated air depends on the drying rate required and the conditions of the air available.
HEATED AIR DRYING

The use of too much heat in drying soybeans will cause excessive seed coat or pericarp cracking, resulting in splits. Some farmer experience suggests that with high heat, it is possible to develop almost 100% cracks in as short a time as 5 minutes of exposure.

Studies by Ohio State University Agricultural Engineers indicate that the key factor in avoiding seed coat cracking is to keep the drying air above 40% humidity. At 40% humidity, splits begin to develop, and increase rapidly as more heat is added to further lower the humidity.

A useful rule of thumb is that humidity is cut in half with each 20°F temperature increase. Thus, if the humidity was 80%, and you added 20°F of heat, the resulting air condition would be the minimum 40%. If the outside air was only 50°F, this would suggest that you dry with a maximum heat of 70°F. This is a severe restriction on heat input, and will limit capacity.

The soybean trade does not normally discount for splits. Recognize, however, that with incorrect procedures, you could wind up with 50 - 100% splits, and these may be severely discounted! Even if not discounted, the broken seed coat opens the seed to other damage, and will not store as well.

Commercial Soybeans. Most recommendations on drying of commercial soybeans suggest a maximum temperature of 130 - 140°F. In good drying weather, you may need to reduce these levels to control or eliminate cracking, since you do not need the extra capacity when conditions are favorable. You may want to run a check on cracks before and after drying, to judge the drying effect.

Soybeans for seed should not be dried at temperatures above 110°F, without prior experience covering several years. Splits on bean seed are critical. Handling should be minimized and impact drops avoided if at all possible, because they increase splits and drop germination.

UNHEATED AIR DRYING

Unheated air drying can be used on either seed or commercial beans if the weather conditions are favorable. In general, the air conditions should be above 60°F temperature and the humidity below 75%. If the air conditions are cold and damp, such ventilation is useless. In a year when drying is apt to be needed, harvest tends to run late into the Fall. More moldy and poor quality beans may be incoming, along with the less favorable conditions for natural air drying. Early in the season, unheated air offers an excellent system and performance.

Over-sizing the drying fan and motor and connecting it to an under-sized air distribution system, is a safe and easy way to add heat. The big fan beats the air, heating it with the added friction. A little temperature rise will help tremendously, and such a system can give 3 - 10° of usable heat, including that generated by the motor. See the section on emergency drying practices for more details.
DRIYING COSTS

Drying needs on commercial soybeans has not, in the past, generally justified investment in drying equipment. However, by spreading volume over both corn and soybeans, the cost should be in line with other crop drying experiences. Typically, ownership costs on drying equipment is 15 - 17% of new cost, per year. This cost, divided by the number of bushels dried, is the fixed or ownership cost per bushel. It usually runs 3.5 - 6¢ a bushel on well-designed and sized corn drying units.

In applying the above costs to drying systems in a grain bin, the 15 - 17% figure for fixed costs should be figured only on the pieces in the bin that make it a dryer (the false floor, fan, heater, sweep, distributor, wiring and grain stirring or blending device if used). The bin itself is not a drying cost, but a storage cost. A good rule is to figure the bin cost as you would build and equip it for storage only. Then add the cost of these items you must add to make it a dryer. It is this last group that is your investment in drying equipment and the basis for computing your ownership costs/year.

Operating costs or variable costs (primarily fuel and power) will probably be a little less than for corn, because the moisture is lower and the weather usually slightly more favorable. Typical costs are 2.5 - 4.5¢ a bushel for corn, removing 10 - 15 points of moisture.

On unheated air systems, you can estimate one kilowatt per horsepower per hour. Typical power cost in Indiana will run 1.25 - 2¢/kw-hr. Thus the total estimated fan time x the kw/hr x the cost/kw = the total cost. Dividing by the number of bushels is the cost/bushel for power. It will usually run 1 - 2¢/bushel on unheated air systems. Since unheated air equipment lasts longer than heated air units, fixed costs can be estimated at 12 - 15% of initial cost, per year. See Reference 1 for additional information on costs.

DRIYING WITH EXISTING EQUIPMENT AND SYSTEMS

By following the guidelines on drying temperature and humidity, any of the bin drying options plus mechanical batch and continuous systems should be workable. Caution should be applied in any system that involves manipulating the grain while in the dryer, such as recirculators or stirring devices. Damage from handling can be severe, especially as the moisture content drops to 12% and below. Over-drying should be avoided, because it adds to fuel and time costs, and further contributes to handling damage.

STORAGE AND CONDITIONING REQUIREMENTS

The safe storage moisture content for soybeans is 11%. This is lower than for corn, because the bean is 18% oil. The oil contains no water; hence, the water is all concentrated in the other 82% of the mass. Since the moisture content is figured on the total bean weight, but the water is in only a portion of the mass, the bean has to be lower in moisture to make sure the non-oil portion is not wet enough that it will spoil.
As in all grain, if the incoming quality from the field is poor (moldy, heavy damage, much fines, rotted or mushy grains, etc.), storage safety is increased by over-drying. At 9 - 10% moisture, it is more difficult for any organism or insect to exist and grow.

Soybeans should be managed in storage much like any other grain. Heat should be removed by proper aeration. Reducing temperature if the grain is heating should always take priority over drying. Cooling the grain reduces mold and insect activity and respiration. See Reference No. 2 for more information.

Short term storage of beans can be carried out at moistures above 11%. However, if the incoming quality is in any way less than that of a good year, the practice is risky. Remember that the product is worth over $2.50 per cubic foot. Marginal practices may not be worth the risk.

PLANNING AND PERFORMANCE DATA - EMERGENCY DRYING SYSTEMS

Air Flow Requirements and Characteristics

Table 1. Static Pressures Required to Force Air Through Soybeans

<table>
<thead>
<tr>
<th>Air Flow Per Bushel</th>
<th>1'</th>
<th>2'</th>
<th>3'</th>
<th>6'</th>
<th>8'</th>
<th>10'</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>0.8</td>
<td>1.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.7</td>
<td>1.2</td>
<td>1.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.0</td>
<td>1.7</td>
<td>2.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.3</td>
<td>2.2</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.3</td>
<td>0.7</td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.4</td>
<td>1.2</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.5</td>
<td>1.7</td>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.6</td>
<td>2.3</td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Static Pressure includes 0.25 inch for Duct Friction Loss

AIR DISTRIBUTION SYSTEMS

The ideal air distribution system is a full perforated floor under the grain. However, duct systems have been used for years in grain drying systems, and if correctly designed, will do an excellent job. They are well adapted to emergency installation in an existing flat bottom bin with no air distribution facilities. They are also adapted to small bins used infrequently and in such small quantities that more sophisticated methods are not justified.
Figure 1, below, illustrates two types of home made ducts that can be built. In addition to the units shown, a number of perforated galvanized metal ducts are available from your local bin equipment dealer. These ducts are offered in either full round tube, or half round (arch) designs.

![Diagram of lateral duct systems for grain drying](image)

Many bin equipment dealers also have sheet stock, such as corrugated, perforated materials, for use in duct or full floor air distribution systems. The perforated sheets may be placed over concrete block spacers as in Figure 1, or can be supported on the edges by 2' lumber sides. These solid sides should be blocked off the floor with 2" material spaced much like the blocks under the "V" ducts of Figure 1, to let air enter the grain along the sides of the duct.

For bins built on a wood floor supported by joists, such as in overhead bins in a double crib, the floor can be sawed out between every other joist space. The bottom of the joist is sealed with an air tight cover, and the cut-out floor section covered with perforated metal sheet material. A fan can then be connected to the open ends of the ducts, formed by the joists sealed on the bottom.

On a bin with a solid floor, 2" x 6" or 2" x 8" joists can be laid on the floor, and a perforated metal floor installed over the joists. The joists form air cells or ducts under the floor, that run to the side of the bin, where they can be connected to a fan duct to introduce air.

Another totally home-made duct can be made like the concrete block and board unit in Figure 1, except the entire board top and block sides are covered with hardware cloth, and if need be, fly screen. When using concrete blocks to support grain weight, use one concrete block for each 50 bushels of grain.
Duct Size and Spacing. For uniform air distribution, fill the bin with grain to a depth of at least 3 feet. Space the ducts so that the distance between them (center to center) is not more than one-half the depth of grain to be dried. Depths shallower than 3' can be dried on full perforated floors, or on duct systems if the spacing is reduced.

The width of the base of each duct should be at least twice the clearance of the duct above the floor. The total area for air passage under all the lateral ducts (height from the floor to bottom of lateral times length of both sides) should equal at least one-fourth of the bin floor area. If perforated material is used to cover the laterals, the perforation should total at least 10% of the sheet area.

Allow 1 square foot of cross section area for each 1500 cfm of air flow from the fan. For instance, if the air flow chosen from Table 1 was 2 cfm/bu and you are drying 3000 bushels, the total air flow required is 6000 cfm. This will require a main duct with 4 square foot cross section area. If all the ducts or laterals are the same length, divide the number of ducts into 4 square feet, and this is the area for each.

The previous calculation can be carried out in reverse if you have the ducts and want to determine the main duct and fan size for which they are suited.
SIZING THE FAN

Fan horsepower can be estimated on the following basis:

1 horsepower will deliver 3000 cfm of air at 1" static pressure

Thus, 1 hp = 3000 cfm @ 1"
     = 1500 cfm @ 2"
     = 750 cfm @ 4", etc.

Again, considering the 3000 bushels of soybeans dried using 2 cfm/bushel, the total air flow would be 6000 cfm, as before. If the beans are 6' deep, the static pressure should be 0.5" (from Table I). Based on the above horsepower/airflow relationship, 1 hp should give 6000 cfm @ 1/2" static pressure. Hence, a 1 horsepower fan is sufficient.

USING THE FAN AS A HEAT SOURCE

By designing an inefficient air system, the fan will produce heat that is added to the air. The heat comes from the friction and resistance in the system. Thus, a 5 or 7-1/2 hp motor may be connected to an entrance and duct system under the grain that is only sized for a 1 or 2 hp system. The big fan beats the air to try to force it through the undersized ducts, and the resultant is a temperature rise of 3 to 10° of usable heat.

This approach to the addition of supplemental heat is simple, safe, and often easy to arrange. A number of dealers have older style bin dryers in the 3, 5, and 7-1/2 hp sizes that may be readily adaptable. The fan should be arranged so that the heat from the motor also flows through the grain. A 5 hp motor developing 5 hp but only succeeding in getting an air flow equivalent to a 1 hp motor through the grain, should be delivering the other 4 horsepower in the form of heat. We saw earlier that 4 hp is equal to 4 kw-hrs; thus, we effectively have a 1 hp fan with a 4 kw heater.

The reader is cautioned that if a large fan is used on a reasonably adequate duct system, the air flow per bushel may be quite high. Be careful as the grain dries down because the high airflow can rewet it quickly. In all unheated or low heat systems, choose your days to operate more critically, as the grain moisture drops.
OTHER HEAT SOURCES

The use of external or auxiliary heat sources on drying systems in adapted bins should be done with caution, unless the bin is metal and separate from any other buildings. Separate burners are not usually controlled by the fan, such that they go off if the fan should stop or fail. Too, most dryer fires are caused by trash that is sucked into the fan, through the flame and deposited, still glowing, into the grain mass. The use of temporary burners on fans in wood bins inside existing buildings, with dry shucks, chaff, etc., floating around is very risky.

The introduction of electric drying heat units over the past several years may offer a good possibility for small drying units on seed or commercial beans. However, the same trash-ignition problems apply to these heat elements, although probably not quite as likely as with an open flame covering the entire air stream.

The use of homemade, temporary mounted electric heat elements is doubly dangerous. Electrical interlock with the fan is important to shut the elements down with a fan stoppage. Temporary mountings may fail under the continuous vibration and contact a combustible surface or material.

The use of portable space heaters seems equally risky, again from the lack of safety inter-lock and the possibility of inspired tinder-dry material. However, heat might be drawn from a shop or utility area that has a space heater, if the fan happens to be close enough to make this practical.

ESTIMATING DRYING CAPACITY

Table 2 indicates the water in soybeans at various moisture levels. The pounds of water to be removed per bushel can be determined by simply subtracting the water at the initial and final moisture content.

Table 2. Amount of Water in a Bushel of Soybeans at Various Moisture Contents

<table>
<thead>
<tr>
<th>Percent Moisture Content</th>
<th>Pounds of Water/Bu.* Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>16.5</td>
</tr>
<tr>
<td>22</td>
<td>14.7</td>
</tr>
<tr>
<td>20</td>
<td>13.1</td>
</tr>
<tr>
<td>18</td>
<td>11.5</td>
</tr>
<tr>
<td>16</td>
<td>9.9</td>
</tr>
<tr>
<td>14</td>
<td>8.5</td>
</tr>
<tr>
<td>13</td>
<td>7.8</td>
</tr>
<tr>
<td>12</td>
<td>7.1</td>
</tr>
<tr>
<td>10</td>
<td>6.8</td>
</tr>
</tbody>
</table>

*The weights per bushel in this table are based on a bushel of grain at 13% moisture content.
In most drying processes, it requires roughly 2000 BTU's of heat to evaporate one pound of water. Thus, assuming we are drying beans from 16% to 12%, the pounds of water to be evaporated per bushel is 2.8 pounds. 2.8 pounds of water per bushel x 2000 BTU's/pound = 5600 BTU/bushel of grain dried.

Another useful approximation formula is as follows:

\[ \text{Air flow (cfm)} \times \text{temperature rise (°F)} = \text{BTU/hour} \]

Returning to the example used earlier, an air flow of 6000 cfm heated 10°F would be as follows:

\[ 6000 \text{ cfm} \times 10^\circ \text{F} = 60,000 \text{ BTU/s/hour} \]

From our calculation above, drying beans from 16% to 12%, it will require 5600 BTU's/bushel. Dividing 60,000 BTU/hour input by 5600 BTU/bushel, the capacity should be 10-1/2 bu/hour.

This may seem slow, but remember that the air is working on a large part of the grain at the same time, not just 10 bushels being dried completely every hour. By working the moisture downward before mold growth can develop, the process is successful.

The above procedure can be used to estimate capacity on any dryer, if the temperature rise, air flow and moisture to be removed per bushel is known. Or, if fuel input and temperature rise is known, air flow can be estimated. LP gas can be figured at 90,000 BTU/gallon; electricity at 3413 BTU/kw-hr; oil at 120,000 BTU/gallon.

STRUCTURAL SUPPORT

Tables 3 and 4 list some information that may be useful on sidewall framing and covering for temporary or permanent bins. (See next page for tables)

REFERENCES

1. AE-67, "Selecting a Grain Drying Method"
2. AE-71, "Aeration for Safe Grain Storage"

Copies of the above publications are available from your county and area Cooperative Extension Offices, or from the Mailing Room, AGAD Building, Purdue University, Lafayette, Indiana 47907.
Table 3. Safe Depth of Wheat, Rye, Shelled Corn, Grain Sorghum or Soybeans in Bins with Studs of Common Sizes and Spacings.

<table>
<thead>
<tr>
<th>Size of Studs Inches</th>
<th>Spacing Center to Center Inches</th>
<th>Length of Stud Feet</th>
<th>Depth of Grain Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 4</td>
<td>24&quot;</td>
<td>8'</td>
<td>5'</td>
</tr>
<tr>
<td>2 x 4</td>
<td>16&quot;</td>
<td>8'</td>
<td>6'</td>
</tr>
<tr>
<td>2 x 4</td>
<td>12&quot;</td>
<td>8'</td>
<td>7-1/2'</td>
</tr>
<tr>
<td>2 x 6</td>
<td>24&quot;</td>
<td>8'</td>
<td>8'</td>
</tr>
<tr>
<td>2 x 6</td>
<td>16&quot;</td>
<td>10'</td>
<td>9'</td>
</tr>
<tr>
<td>2 x 6</td>
<td>24&quot;</td>
<td>10'</td>
<td>8'</td>
</tr>
</tbody>
</table>

1/ This table is based on ordinary commercial sizes of lumber. If the studs are full size rather than nominal, the depth of grain can be increased 1/3. If large knots occur in any of the studs, or if the lumber is soft and lightweight, ties should be used across the bin. Studs should be well-fastened to the floor system.


Table 4. Maximum Girt or Stud Spacing Permitted by Strength of Lining Material (Inches).

<table>
<thead>
<tr>
<th>Grain Depth (Feet)</th>
<th>3/8&quot;</th>
<th>1/2&quot;</th>
<th>5/8&quot;</th>
<th>3/4&quot;</th>
<th>1-1/4&quot;</th>
<th>1&quot; Corrugated steel, 28 ga.</th>
<th>2-1/2&quot; Corrugated steel, 28 ga.</th>
</tr>
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<tbody>
<tr>
<td>8 - 12</td>
<td>14</td>
<td>18</td>
<td>21</td>
<td>24</td>
<td>31</td>
<td>15</td>
<td>21</td>
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<td>12 - 16</td>
<td>13</td>
<td>16</td>
<td>19</td>
<td>22</td>
<td>28</td>
<td>13</td>
<td>19</td>
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<td>10 - 20</td>
<td>12</td>
<td>15</td>
<td>18</td>
<td>20</td>
<td>26</td>
<td>13</td>
<td>18</td>
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</tbody>
</table>

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