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Articles on Seed Drying

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ARTICLES ON SEED DRYING 1/

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I. HOW DRY CAN YOU DRY SEEDS WITH NATURAL AIR?

When seeds are being dried, moisture is transferred from the seeds to the surrounding air. The moisture content to which seeds can be dried depends upon the temperature and the relative humidity of the air entering the mass of seed. The relative humidity is the major factor that influences seed moisture content. To determine whether any drying can be done on seeds in a drying bin, the air temperature, relative humidity, and equilibrium moisture content of the particular seed must be known. The two last terms will now be defined to help explain why seeds will reach a certain moisture content when placed in a given atmospheric condition.

Relative Humidity: This is defined as the ratio between the amount of water the air actually contains and the amount it would contain at the same temperature when fully saturated (100% R.H.) It is expressed as percentage. Let us now consider air at 70^{o}F. When saturated, it would contain .01576 pounds of water per pound of dry air. At 70% R.H. it would contain .01103 pounds of water and would be capable of holding .00483 pounds more. At 50% R.H. it would contain .00788 pounds of water, and could hold .00788 pounds more before reaching saturation. Thus, the rate of drying at a given temperature increases as the relative humidity at that temperature decreases. This is a major consideration in determining whether seeds can be dried quickly enough to safe storage levels using unheated air.

Equilibrium Moisture Content: Seeds, like any moisture containing material, have a certain ability to take up or give up moisture to the surrounding air. This exchange of moisture depends upon the difference in vapor pressure developed by the moisture inside the seeds and the surrounding air. If the vapor pressure inside the seeds is

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1/Reprinted from Seed Processor's Clinic, Seedsmen's Digest, September, October, November 1967.

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higher than the vapor pressure of the atmosphere, the seeds will lose moisture to the atmosphere. The opposite effect will occur if the vapor pressure of the atmosphere is greater than that inside the seeds. This exchange of moisture will continue until the seeds reach a moisture content that develops a vapor pressure equal to that of the atmosphere. As long as the vapor pressures are in equilibrium, there is no further change in the seed moisture content. Thus, the moisture content that seeds maintain in a given atmospheric condition is known as the equilibrium moisture content.

The equilibrium moisture contents for several different seeds and relative humidities at a constant temperature of 77°F. are shown in Table 1. For each 10°F., above or below 77°F., the moisture content will decrease or increase approximately 1%, respectively.

TABLE 1. Equilibrium Moisture Contents at Different Relative Humidities. (At approx. 77°F.)

Relative Humidity (Percent)	Moisture Content: (Wet Basis) in Percent					
	15	30	45	60	75	90
Barley	6.0	8.4	10.0	12.1	14.4	19.5
Corn, YD	6.4	8.4	10.5	12.9	14.8	19.1
Rice, Rough	5.6	7.9	9.8	11.8	14.0	17.6
Sorghum	6.4	8.6	10.5	12.0	15.2	18.8
Soybeans	-	6.2	7.4	9.7	13.2	-
Wheat, White	6.7	8.6	9.9	11.8	15.0	19.7

ASEA Yearbook, 1965

This table can be used to determine if drying can be done and to what moisture content seeds can be dried with air at a given temperature and relative humidity. Some typical examples showing the use of the table follow.

Example 1. Shelled yellow dent corn at 16% moisture is placed in a drying bin. The relative humidity is 67% and the temperature is 57°F. Can any drying be done?

Referring to the table we find the equilibrium moisture content for shelled YD corn at 77°F. is 12.9% at 60% R.H. and 14.8% at 75% R.H. Thus, 67% R.H. would be halfway between these two figures:

$14.8\% - 12.9\% = 1.9\% \times 1/2 = .95\%$
$12.9 + .95 = 13.85\%$ moisture content at 67% R.H. and 77°F.

Adding 1% moisture because the temperature is 10° below 77°F., the equilibrium moisture content of the corn would be 14.85%. Drying of the 15% corn will take place but at a rather slow rate.

Example 2. What would be the final moisture content of rough rice being dried with air at 80° F. and 60% R.H.?

At 77° F. and 60% R.H., the equilibrium moisture content of rough rice is 11.8%. Since the air temperature is only 3 degrees above the temperature on which the table is based, it is not necessary to make any corrections in the moisture content. Thus, the final moisture content of the rough rice after drying under the conditions indicated above would be around 11.8%.

These principles also hold true when heated air is used for drying. In the case of heated air, however, the possibilities for increasing rate and extent of drying are much greater than when natural (unheated) air is used. Heated air drying will be considered next.

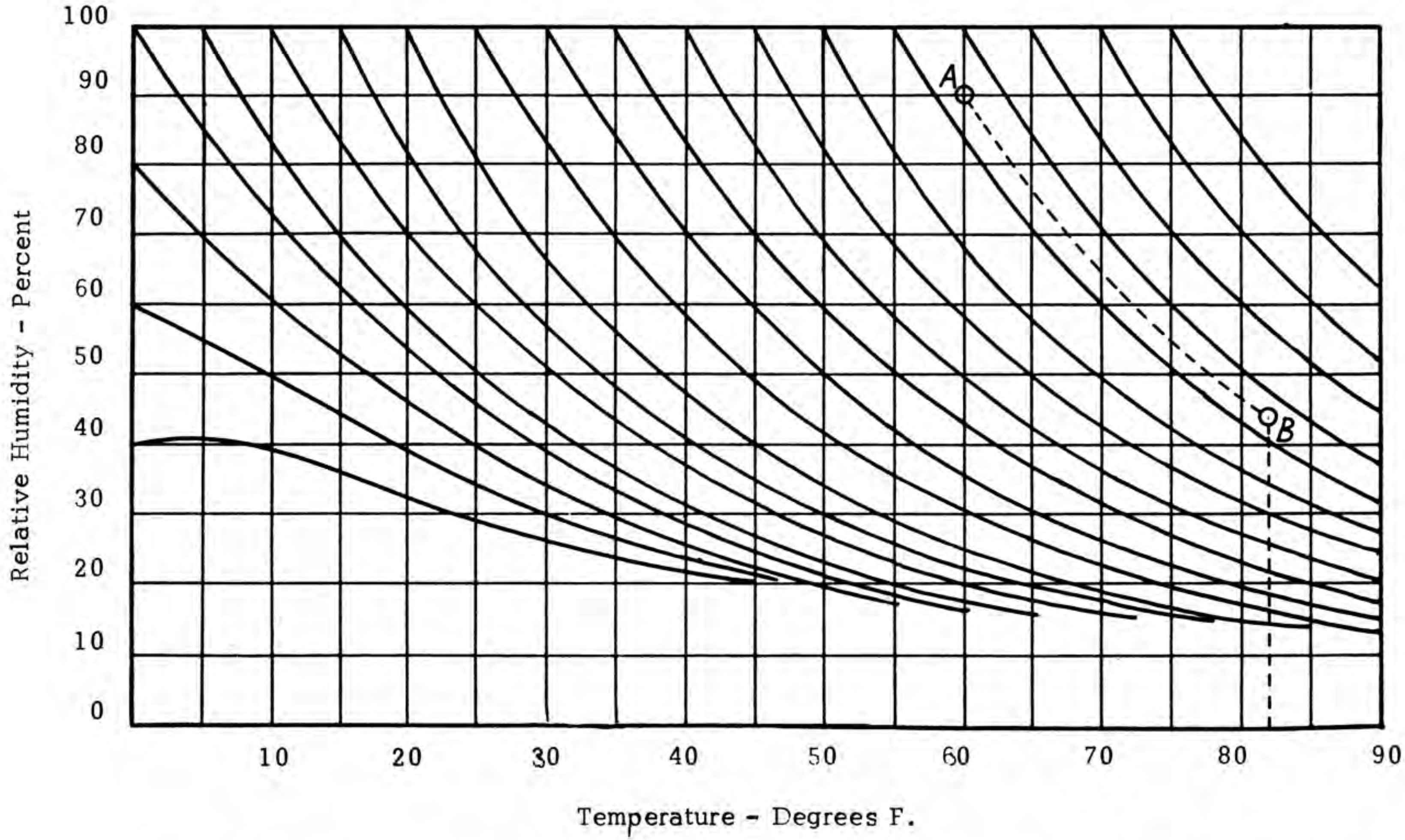
II. DRYING WITH SUPPLEMENTAL HEAT- WHEN AND HOW TO USE IT

QUESTION: What is the difference between drying with heated air and drying with supplemental heat?
ANSWER: The major difference is the increased temperature of the drying air. In heated air drying, a large amount of heat is added to increase the air temperature as much as 100°F. or more. This much heat is used mainly for drying grain to be used for purposes other than seed.

In drying seed with supplemental heat, a small amount of heat is added to increase the temperature of the air 10 - 20°F. before it enters the seed mass. The purpose of adding a small amount of heat to the drying air is to lower the relative humidity to approximately what it would be during the summer and early fall. Thus, the seed can be dried to a safe storage level more rapidly.

Drying with supplemental heat is particularly suited for drying seed when they are not heated enough to be injured.

Effect on Relative Humidity When Air is Heated by Direct Burning of L-P Gas. Products of Combustion into Heated Air.



Source: Chart by G. M. Petersen, Agricultural Engineering Department, University of Nebraska.

FIGURE 1

QUESTION: When should supplemental heat be used for drying grain or seed?
ANSWER: During periods of high relative humidity such as during the late fall, early winter, and rainy periods. By increasing the drying air temperature 10 to 20 degrees, the drying process can be carried on regardless of the weather conditions. Increasing the air temperature 20^{o}F will lower the relative humidity approximately 50%.

When drying with natural air, drying may become very slow after the seed reach 16% moisture. Raising the temperature of the air several degrees will reduce the time required for removing the last 3 to 4 percent moisture.
QUESTION: How is supplemental heat added to the airstream and how is it controlled?
ANSWER: Supplemental heat can be added to the drying air by placing a gas, oil or electric heater behind or in front of the drying fan. The manufacturers of drying fans also have heaters designed to attach directly to their fans.

The heater unit can be controlled by either a thermostat or a humidistat. The controlling device is placed in the airstream near where the air enters the seed.

The humidistat has a sensing element that responds to a change in relative humidity. It senses the relative humidity in the airstream and turns the heater on or off to maintain the relative humidity at the desired level for which the device is set. Once the humidistat is set, it does not have to be adjusted as the temperature of the atmospheric air fluctuates.

The thermostat controls the relative humidity by maintaining the airstream at a particular temperature corresponding to the desired relative humidity. It is sometimes necessary to change the thermostat setting as the temperature of the atmosphere fluctuates during the day.

QUESTION: When the heater is controlled by a thermostat, how can one determine the temperature required to give the desired relative humidity?
ANSWER: The temperature necessary to give the desired relative humidity can be estimated very easily by using the chart shown in Figure I. Let us take a typical example to illustrate its use.

EXAMPLE: Assume that the outside environment is 60^{o}F and 90% R.H. To what temperature must the drying air be heated to lower the relative humidity to 45%.

SOLUTION: Referring to Figure 1, follow the horizontal line representing 90% R. H. to the right until it intersects the vertical line representing 60^{o} F (point A). Then follow parallel to the nearest curved line to the horizontal line representing the desired relative humidity 45% (point B). From point B, draw a vertical line to intersect the temperature scale at the temperature necessary to give 45% relative humidity. In this case, the thermostat would be set at 82^{o}F.

Now let us consider the volume of air necessary to accomplish the desired drying.

III. AIR REQUIREMENTS AND FAN SELECTION FOR NATURAL AIR SEED DRYING

The function of the air used in drying seeds is to remove moisture evaporated from the seeds. As air moves through a mass of moist seeds, it picks up moisture from the seed. This causes an increase in relative humidity of the air. If the air flow rate is too low, the air can become saturated soon after it enters the seed mass and no further drying can be accomplished. Air flow rate, therefore, should always be high enough to insure that the air maintains its capacity to absorb moisture during its entire passage through the seed mass.

Recommended minimum air flow rates for several kinds of seeds at different moisture contents are shown in Table 2. Air flow rates of 3 to 5 cubic feet per minute (cfm) per cubic foot of seed are commonly used in calculating the air requirements for a drying system. Air flow rates from 6 to 8 cfm/cu.ft. are sometimes used when the seed moisture content is 24 percent higher. When seed moisture content is within 1 to 2 percent of the desired storage moisture content, air flow rates as low as 1 to 1.5 cfm/cu. ft. can be used.

Static Pressure and Depth of Seed

Static pressure is the force required to move air at a given rate through a given mass of seed. It is measured in inches of water column, and varies directly with the air flow rate and the depth of seed. The size of the seeds and the amount of foreign material mixed with the seeds also influence static pressure. For the same air flow rate, small seeds require a higher static pressure than large seeds.

Recommended maximum depths for drying seeds are also shown in Table 2. Greater depths can be used, although for most conditions it is best to limit the depths to those shown. The power required for a fan increases as the static pressure increases. Generally, static pressures above 3 inches requires too much fan horsepower for economical operation.

Fan Selection

To select the proper fan size for a drying system, the air flow rate in cfm and the static pressure required to move the air through the seeds must be known. When a fan is to be used for drying more than one crop, it should be selected to meet the requirements of the most difficult drying conditions encountered.1/ The following example illustrates the procedure for determining the proper fan size for a drying system.

Example:

2500 bushels of shelled corn at 20 percent moisture content are to be dried in a bin with a perforated floor. The corn is 9 feet deep. (A) Determine the minimum required air flow rate and the static pressure. (B) Select the minimum fan size needed for the drying system.

Solution:

I. Determine total rate of air flow required.
From Table 2, the minimum air flow for 20% moisture content corn is 3 cfm/cu. ft. The total flow rate required for the 2500 bushels would be:

$$2500 \times 3 = 7500 \text{ cfm.}$$

II. From figure 2 determine the static pressure for an air flow of 3 cfm/bu. through 9 feet of shelled corn.

Two important points should be noted in connection with using the graphs in Figure 2: (a) the air flow given along the vertical axis is measured in cfm/sq. ft., rather than in the customary cfm/bu.; and (b) one bushel of seed or grain occupies 1.25 cubic feet. Stated another way, one cubic foot would contain 0.8 bushel.

The cfm/sq. ft. can be calculated easily when the cfm/bu. and

1/ Combine run or uncleaned seed require approximately 30% fan capacity than clean seed when the foreign material is smaller than the seed being dried. (note lines 1 and 2 of figure 2)

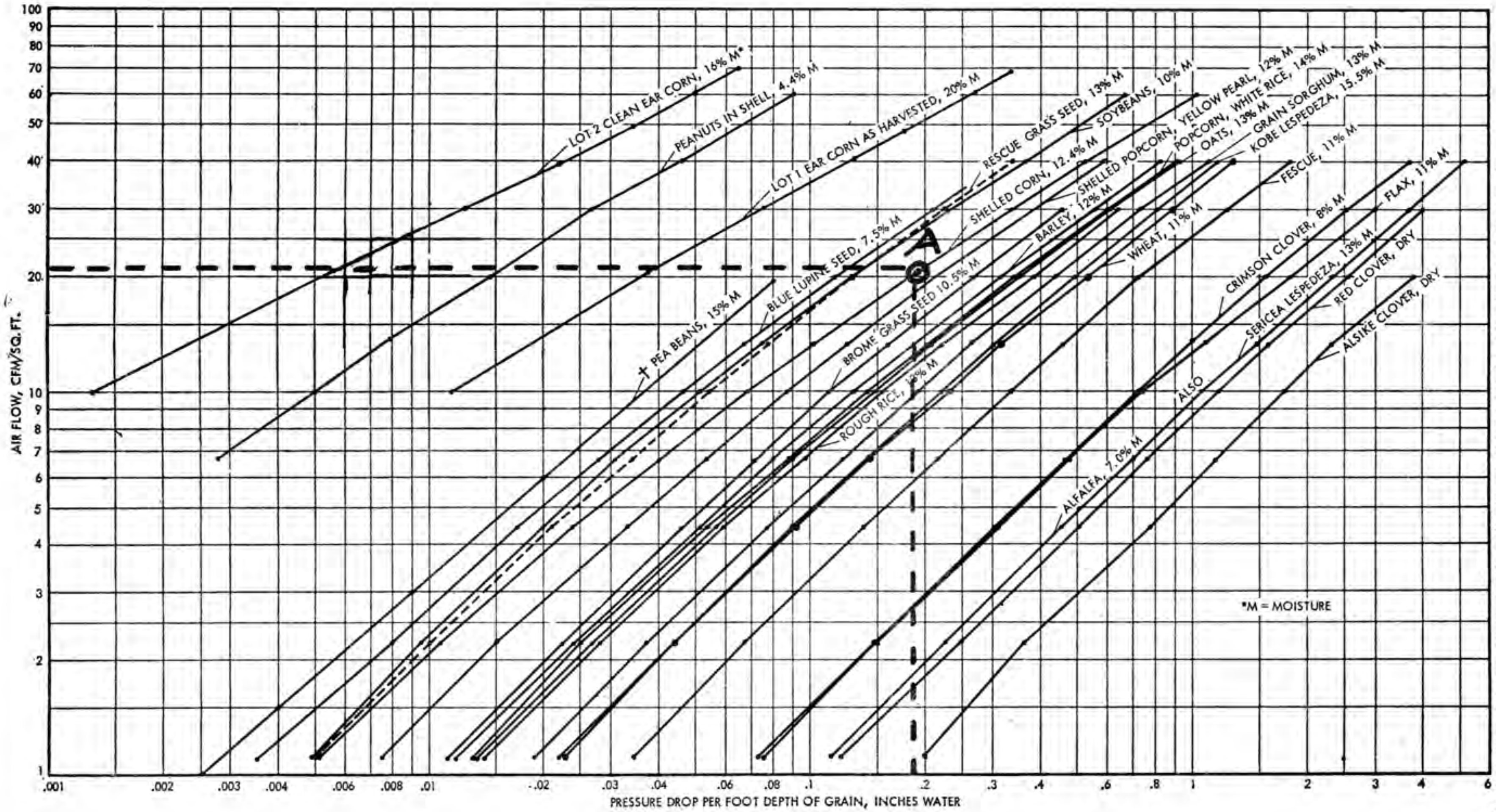
TABLE 2. USDA RECOMMENDED MAXIMUM DEPTHS AND MINIMUM AIR FLOWS FOR NATURAL AIR DRYING

Type of Grain	Grain Moisture Content Per Cent	Recommended Maximum Depth of Grain Feet	Recommended Minimum Air Flow cfm/cu. ft.
Wheat	20	8	3
	18	10	2
	16	12	1
Oats	25	8	3
	20	11	2
	18	12	1.5
	16	16	1
Shelled Corn	25	6.5	5
	20	10	3
	18	12	2
	16	16	1
Grain Sorghum	20	8	3
	18	10.5	2
	16	16	1
*Rice	22	6	4
	20	8	3
	18	8	2
Barley	20	8	3
	18	10	2
	16	14	1
Soybeans	20	10	3
	18	12	2
	16	16	1

*Based on recommendations by Texas A & M University.

Revised 1962; reconfirmed without change for one year by Committee EPP-03, December, 1966.

RESISTANCE OF GRAINS AND SEEDS TO AIR FLOW



NOTES: This chart gives values for a loose fill (not packed) of clean, relatively dry grain.

For a loose fill of clean grain having high moisture content (in equilibrium with relative humidities exceeding 85 percent), use only 80 percent of the indicated pressure drop for a given rate of air flow.

Packing of the grain in a bin may cause 50 percent higher resistance to air flow than the values shown.

When foreign material is mixed with grain no specific correction can be recommended. However, it should be noted that resistance to air flow is increased if the foreign material is finer than the grain, and resistance to air flow is decreased if the foreign material is coarser than the grain.

REFERENCE: Resistance of Grains and Seeds to Air Flow, C. K. Shedd, AGRICULTURAL ENGINEERING, vol. 34, September, 1953.

FIGURE 2

the depth of seed are known. Consider one square foot of floor area in the bin: since the seed are 9 feet deep, each square foot of floor area is supporting a column of seed one foot square and 9 feet high with a volume of 9 cubic feet. The total bushels of seed above each square foot of floor area can be obtained by the general formula: cfm/sq. ft. = depth of grain X desired cfm/bu. X0.8.

Substituting in the formula for our example, we have: cfm/sq. ft. = 9 X 3 X 0.8 = 21.6 cfm/sq. ft. air flow rate.

Referring to Figure 2, locate 21.6 on the vertical scale. Read across horizontally from this point to intersect the curved line labeled shelled corn (at point "A"). From point "A" extend a vertical line down to intersect the horizontal scale at 0.18. This is the pressure drop per foot of depth. The total pressure drop through the seed would be: 0.18 X 9 = 1.62 inches static pressure.

There is also a pressure loss due to resistance of the air duct and perforated floor. An allowance of 0.25 inch is usually sufficient for the duct and floor loss. The total static pressure is the sum of: 1.62 + 0.25 = 1.87 inches static pressure.

III. A hypothetical fan manufacturer's performance data for different models of fans are shown in Table 3. The chart shows the volume of air that different size fans will deliver against various static pressures. A similar chart from an actual potential supplier should be used to select a fan that will satisfy minimum requirements of 7500 cfm at 1.87 inches static pressure.

To select the proper fan size, read across the top line (Table 3) to the required static pressure. Since the table does not list 1.87 inch static pressure, use the next higher figure in the adjacent column which is 2 inches static pressure. Read down this column to the cfm rating closest to 7500 - in our case it is 7650. Reading horizontally to the left, we find that the Model "D" fan would have the required capacity. This is the size fan that should be purchased.

TABLE 3. VOLUME OF DRYING FAN OPERATING AT DIFFERENT STATIC PRESSURES

Fan Size	Horse Power	Static Pressure (inches of water) .5	1.0	1.5	2.0	2.5	3.0
		Cubic Feet Per Minute					
Model A 16"	1 1/2	3500	3200	2975	2400	1850	1400
Model B 18"	3	6600	6100	5700	5100	4700	4000
Model C 21"	3	8150	7400	6600	5900	5200	4600
Model D 21"	5	9300	8800	8100	7650	7000	7200
Model E 24"	5	12200	11300	10700	10000	9000	8100

Note: These are hypothetical data.