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Seed Drying Principles

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SEED DRYING PRINCIPLES

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Introduction

Seed drying is a mass transfer process in which moisture is removed from the seed in a vapor form and is absorbed by surrounding air. Thus, the seed must be surrounded by an ample supply of dry air capable of absorbing the moisture given off by the seed. Since the moisture content of seed is greatly dependent upon the humidity of the air, knowing certain air properties will contribute to our understanding of the seed drying process. Drying of seed in a deep bed dryer is characterized by the establishment of a drying front which must move through the whole mass of seed to complete drying. Several factors including air relative humidity, temperature, air flow rate and permeability of the seed to internal moisture migration, affect the efficiency of drying.

Equilibrium Moisture Content

The colloidal nature of seed allows them to take up or give off moisture depending upon the relative humidity of the surrounding air. The moisture in the air is present in a gaseous form and excerpts pressure. The moisture in seed also excerpts a certain pressure. There is a continuous movement of moisture in the vapor form from the air into the seed and vice versa, but if the water vapor pressure in the air is grater than the water vapor pressure in the seed, eventually there will be an increase in the moisture content of the seed, Figure 1. On the contrary, if the water vapor pressure in the seed is greater than the water vapor pressure of the air, the seed will eventually loose moisture, until an equilibrium of vapor pressures is attained, Figure 1. At this point it is said that seed have reached their equilibrium moisture content. The equilibrium moiste content is determined to a great extent by the relative humidity of air. Oil seed tend to have a lower equilibrium moisture content than starchy seed, as shown in Table 1.

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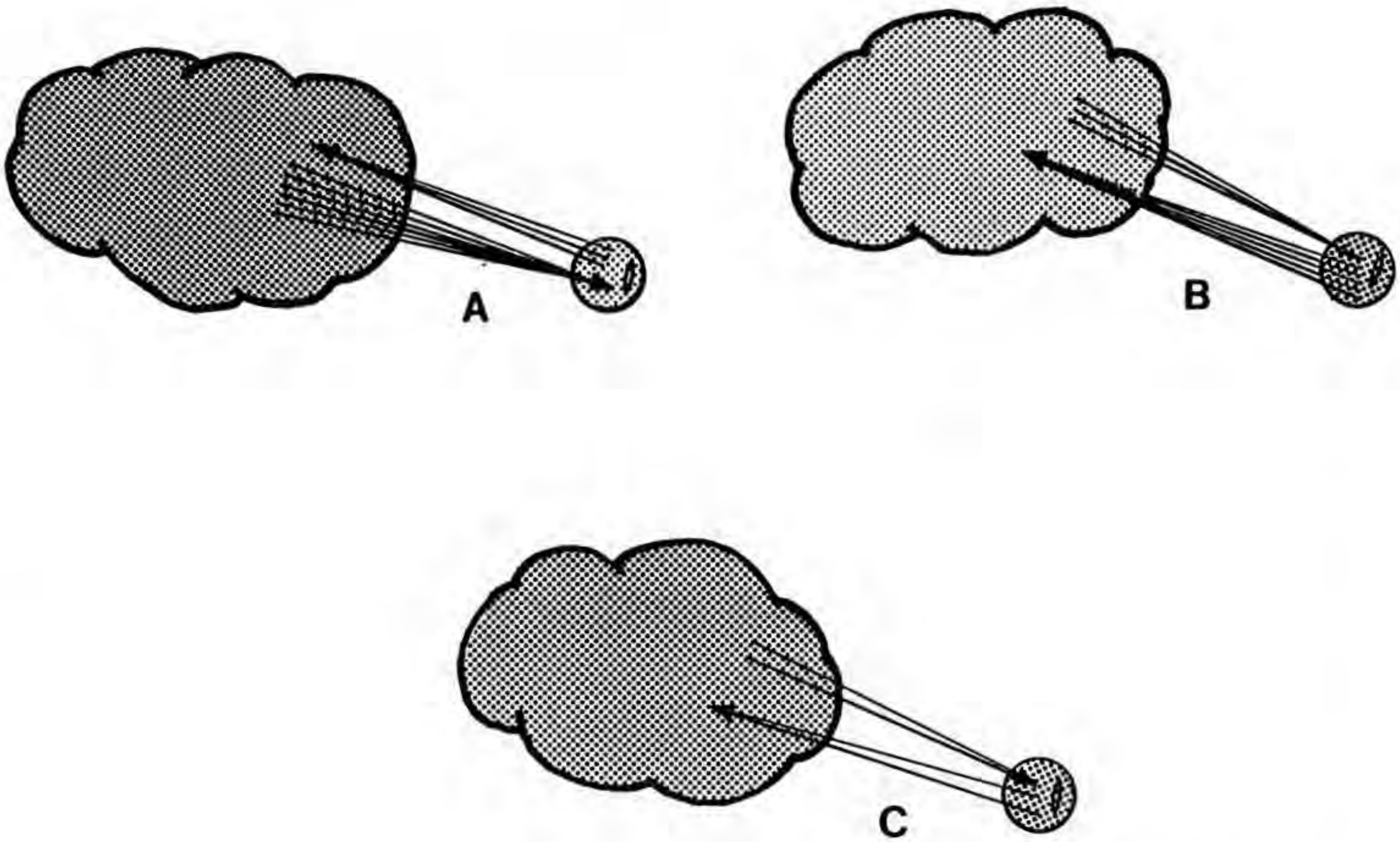

Figure 1. a) Water vapor pressure (wvp) in the air greater than wvp in seed.
b) wvp in seed greater than wvp in air.
c) Equilibrium moisture content attained.

Table 1. Equilibrium moisture content for seed of various crops at different relative humidity values (25C).

Crop	Relative Humidity					
	15	30	45	60	75	90
Alfalfa	-	6.4	7.4	8.6	13.0	18.0
Barley	6.0	8.4	10.0	12.1	14.4	19.5
Corn	6.4	8.4	10.5	12.9	14.8	19.1
Peanuts	**2.6**	**4.2**	**5.6**	**7.2**	**9.8**	**13.0**
Rye	7.0	8.7	10.5	12.2	14.8	20.6
Sorghum	6.4	8.6	10.5	12.0	15.2	18.8
Soybeans	**4.3**	**6.5**	**7.4**	**10.3**	**13.1**	**18.8**
Sunflower	-	**5.1**	**6.5**	**8.0**	**10.0**	**15.0**

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Air Properties

Air is used in drying because of its ability to remove moisture from seed. The functions of air during drying are a) to evaporate the moisture from the seed surface by creating a water vapor pressure differential and b) to carry the evaporated moisture away from the seed mass. Therefore, for drying to occur the air should be dryer than the seed.

Air can be naturally dry. In certain geographical areas the relative humidity (RH) of air is sufficiently low during the harvesting period that seed drying can be accomplished with natural air. Unfortunately this is not always the case and the relative humidity of the air must be reduced by mechanical means. Moist air can be dried by actually removing its moisture with a dehumidifier. This practice is very seldom used in commercial drying. Instead the air is heated to reduce its relative humidity. When heat is added to air, its water holding potential is increased. Figure 2 shows the water potential of air at 75F and 80% RH. Air under this conditions contains 0.015 lb of water/lb of air. If the temperature is increased to 99F, its water holding capacity is doubled.

The psychometric chart graphically represents air properties. Personnel dealing with seed drying should be acquainted with its use. Figure 3 illustrates how high the temperature rise of the drying air should be to lower the relative humidity of the previous example to 40%. Point A is 75 F-80% R.H. Point B is 99 F-40% R.H.

Relative humidity of ambient air can be determined with a sling psychrometer. A sling psychrometer consists of two regular thermometers mounted on a casing that can be slung by hand, Figure 4. The sensing bulb of one of the thermometers is covered by a wet sock or wick and measures the wet-bulb temperature, while the un-modified thermometer reads the dry-bulb temperature. These temperatures, when plotted in the psychometric chart allow you to determine the relative humidity as well as other properties of air.

Drying of Individual Seed

Two processes are involved in the removal of water from seed:

a) Moisture from the seed surface is evaporated

b) Moisture from within the seed is transferred to the surface.

When dry air surrounds the seed, water molecules from the seed surface move to the air, leaving the moisture level in the periphery of the seed lower than in the inside, and a moisture gradient is established within the seed. Water molecules, therefore, must move from the inside to the drier area of the seed to nullify the moisture gradient,

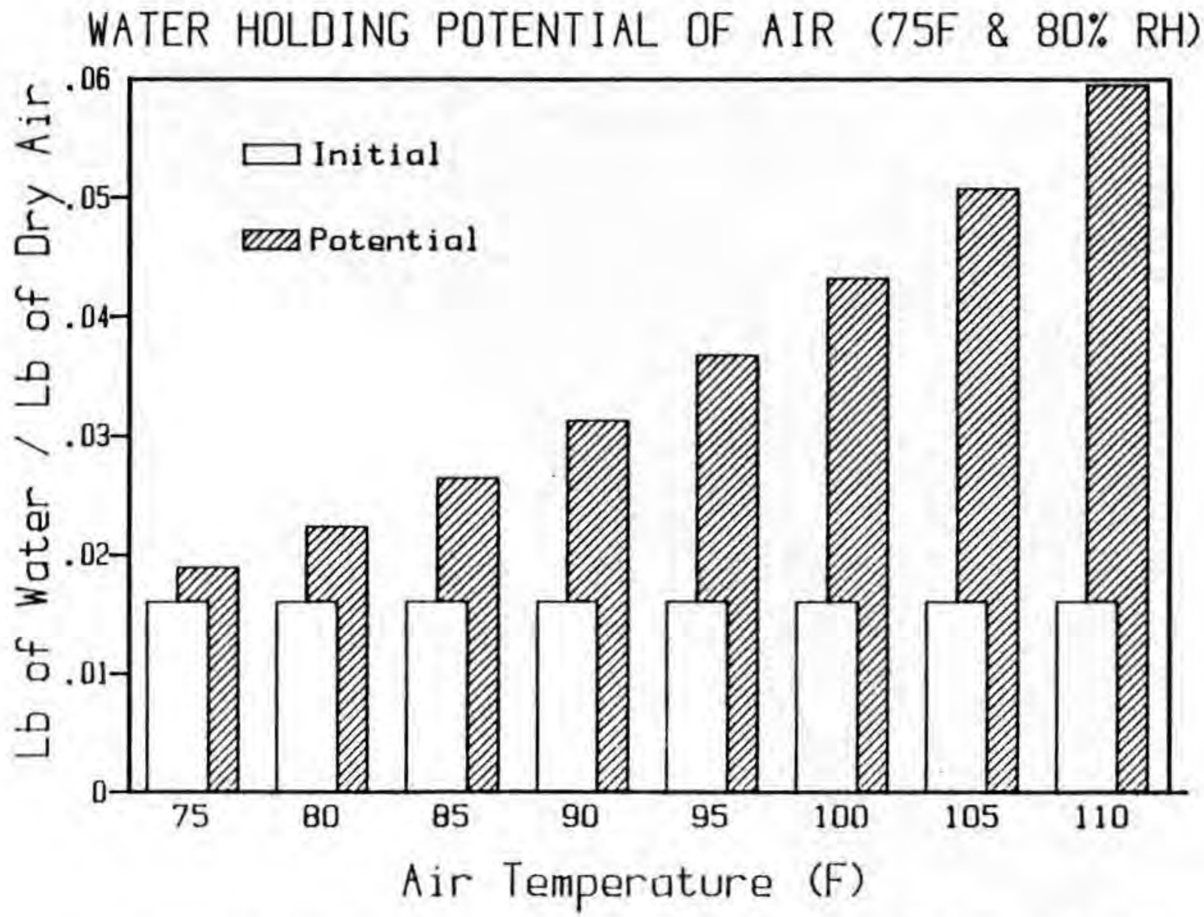

Figure 2. Water holding potential of air at 75F and 80% relative humidity compared to potential at higher temperature.

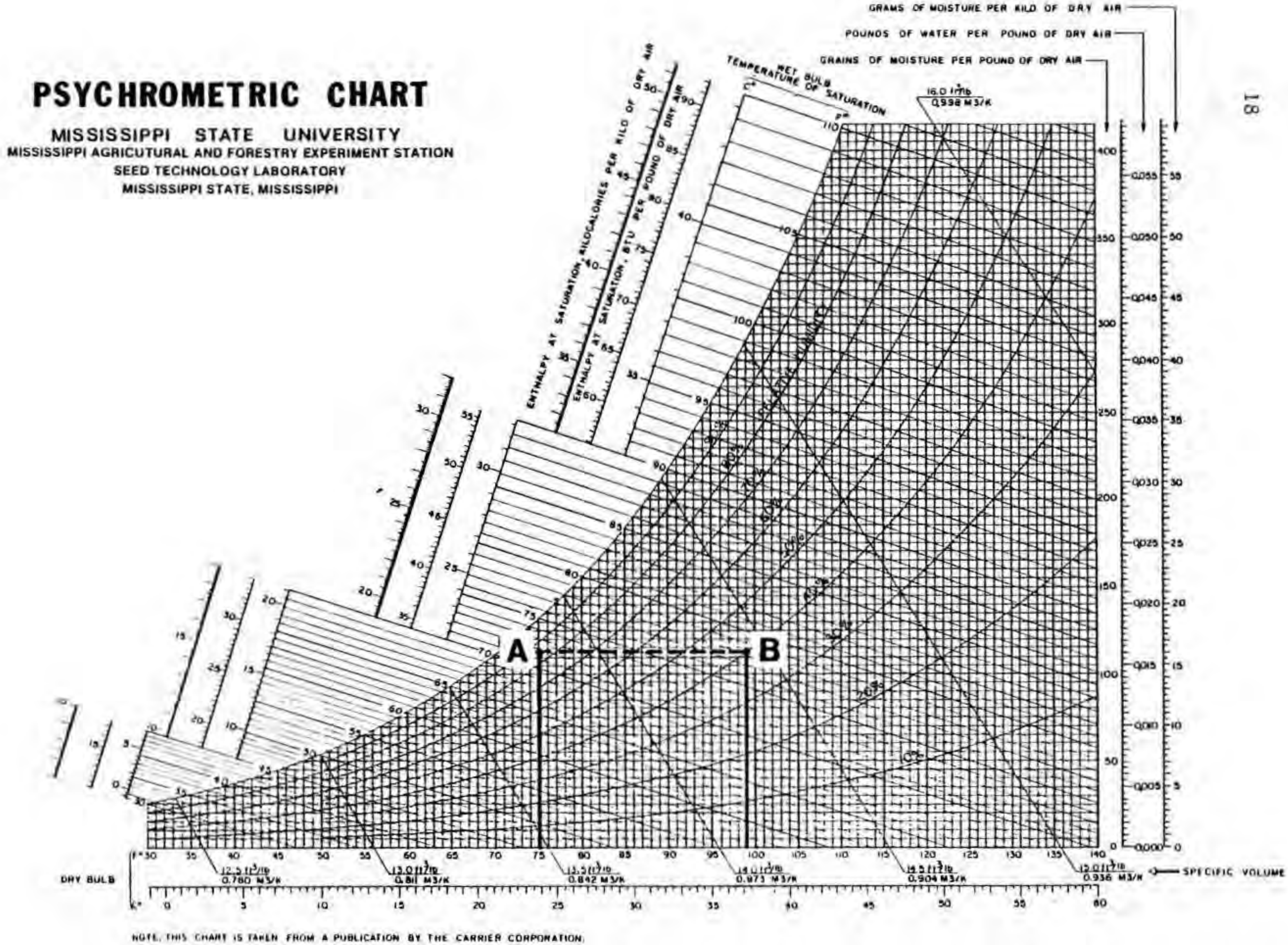

Figure 3. Psychrometric chart showing air properties. To lower the relative humidity (RH) of 75F and 85% RH air (point A) to 40%, the air should be heated up to 99F (point B).

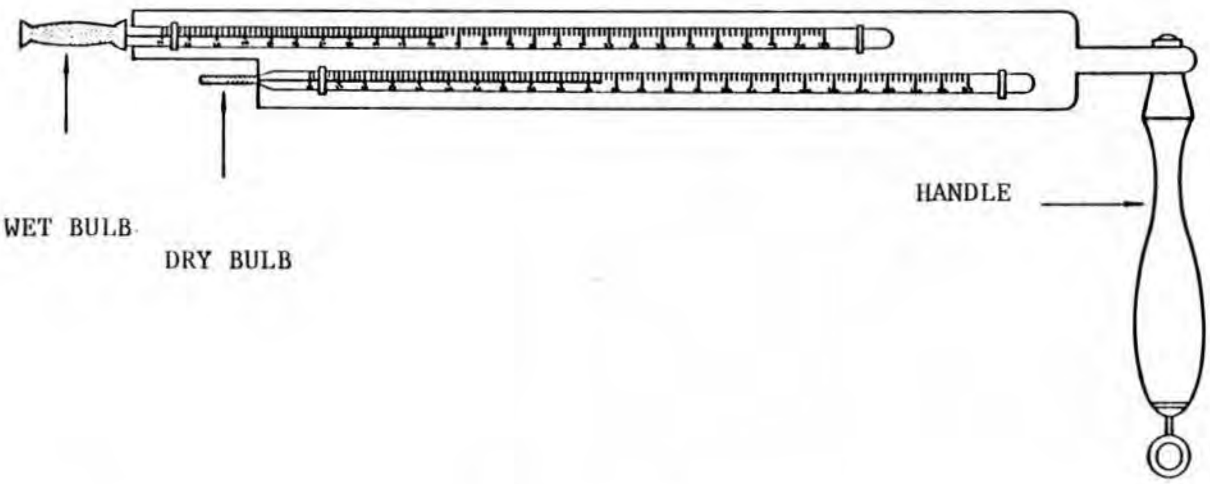

Figure 4. Sling psychrometer. Instrument is rotated about 2 to 3 times per second until readings attain constant valves

and can be evaporated. After this occurs an equilibrium is established between the water vapor pressure of the air and seed and no further drying takes place, Figure 5.

Drying in a Deep Bed Dryer

In deep bed drying, air is introduced in the plenum chamber and forced through the mass of seed to remove excess moisture. Drying, however, does not occur simultaneously in all seed at the same time, but rather a drying front is created and it moves slowly in the direction of the air flow until it reaches the top of the batch. An illustration of this process is shown in Figure 6. A few minutes after dry air begins to flow through the seed mass, a drying front is formed at the bottom of the batch. The drying front slowly moves up leading the drying zone. The drying zone consists of a few inches of seed next to and below the drying front and it is in this area where drying is actually taking place. The drying front can be rather easily identified. Seed temperature below the drying front approaches plenum air temperature, while seed temperature above the drying front is several degrees lower. The temperature of the exhaust air is several degrees lower than plenum air indicating the temperature drop due to evaporation. The relative humidity of exhaust air is higher than plenum air since it contains the moisture removed from seed. Figure 6 shows the theoretical changes of temperature and relative humidity that occur in a bin during drying.

Magnitude of Water Removed in Drying

The high volume of water removed by drying is frequently taken for granted. To dry 1000 bushels of rice seed that come from the field with 20% moisture down to 13%, 466 gallons of water must be removed. This is the equivalent of eight and one half 55-gallon drums, Figure 7. To calculate the loss of weight by drying the following formula can be applied:

$$FW = IW \times (100 - IM) / (100 - FM)$$

Where:

FW = final weight
IW = initial weight
IM = initial moisture percentage
FM = final moisture percentage

Example:

What is the final weight of 50,000 lb of corn harvested at 35% moisture and dried to 12%?

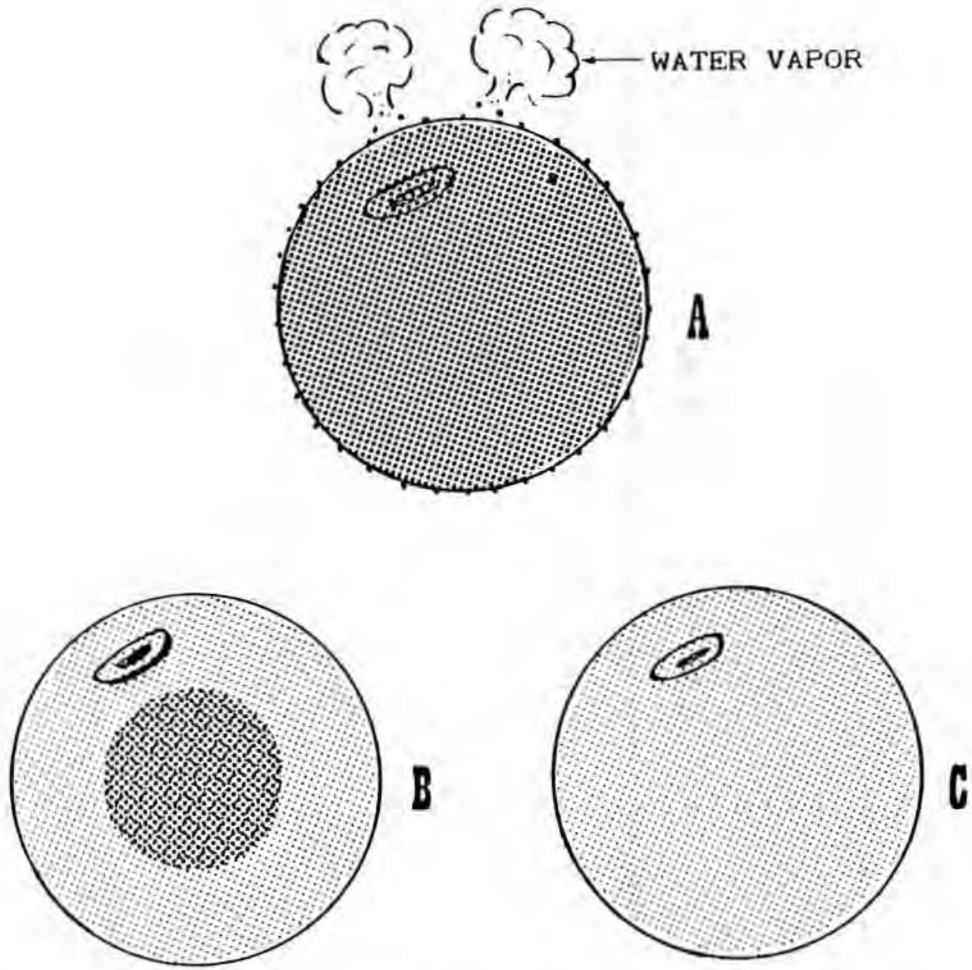

Figure 5. Drying of individual seed. a) Moisture from the seed surface is evaporated. b) Moisture from within the seed is transferred to the surface. c) Dried seed.

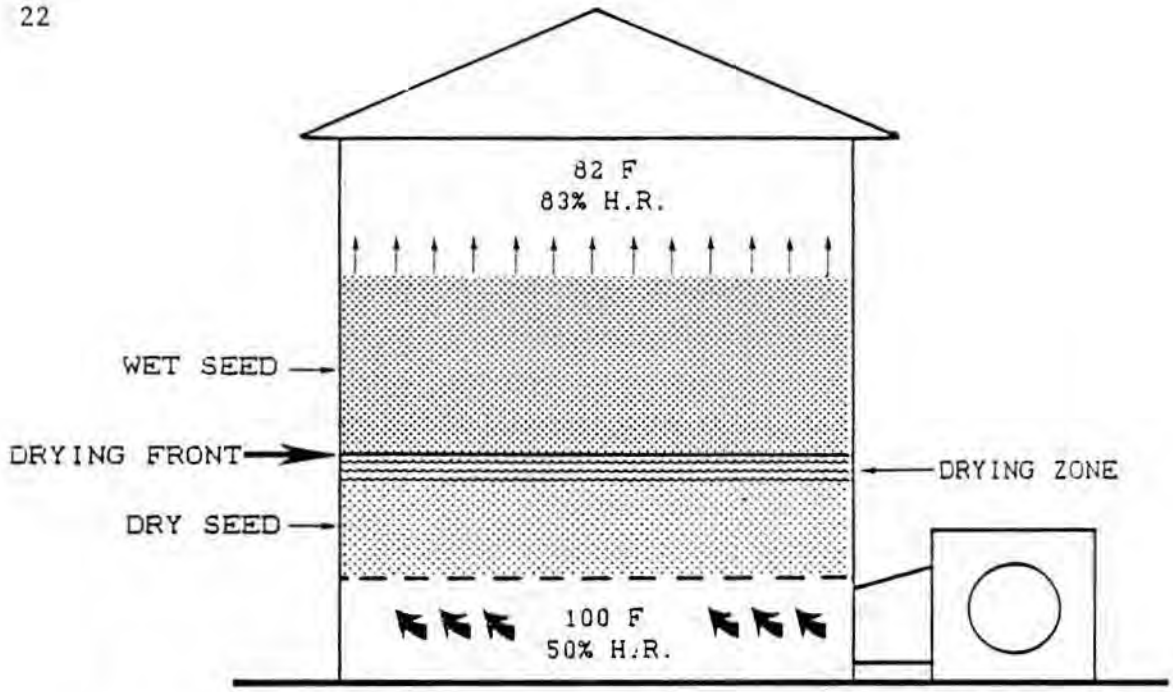

Figure 6. Drying in a deep bed dryer. Establishment of the drying front.

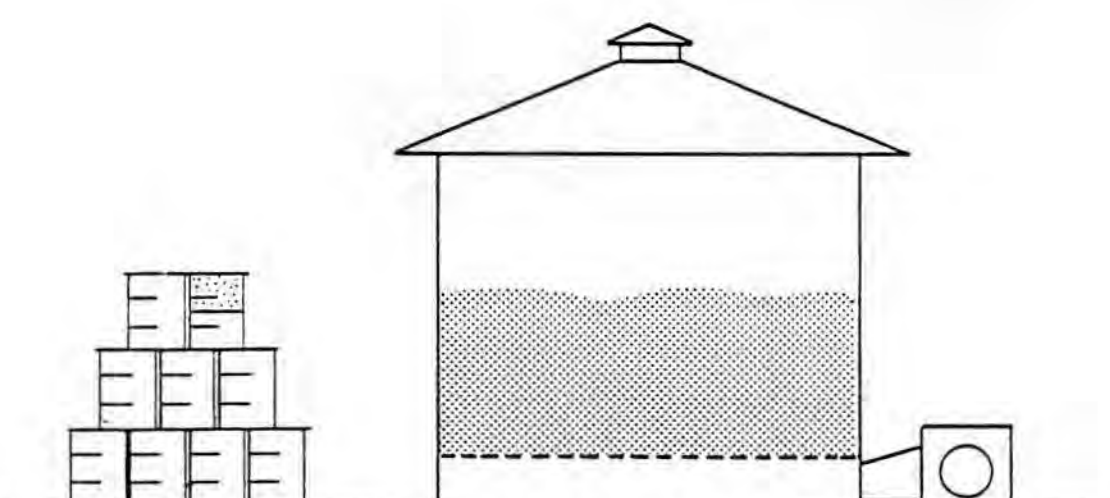

Figure 7. To dry 1000 bushels of rice seed from 20% to 13% moisture, 466 gallons of water must be removed.

FW = 50,000 lb X (100 - 35) / (100 - 12)

FW = 36,932 lb

The weight loss by drying is 13,068 lb.

Main Factors Affecting Seed Drying

Several factors influence the rate at which drying takes place; the most important, however, are described as follows:

1. Initial seed moisture content

The removal of water does not occur at the same rate during the drying process. Figure 8 shows the rate of moisture removal of one layer of high moisture seed. At high seed moisture levels water is removed more rapidly from seed. As seed moisture is reduced it becomes harder to remove. The lower the moisture level, the more tightly the remaining moisture is held by the seed and the more energy is required to remove it.

2. Relative humidity of the air

It was mentioned earlier on that dry air is required for seed drying. The lower the relative humidity of air, the faster drying will occur. It is possible thought, to remove water from high moisture seed (above 18% MC) using high relative humidity air (80% RH) down to about 15 - 16% in the case of cereals, but it will take a relatively long period of time. To accelerate drying, lower relative humidities are used and the equilibrium moisture content is not quite reached. In deep bed drying, relative humidities of 40 - 55% are commonly used. Because of this, over-drying of seed at the bottom of the bin is also common, since they are allowed to reach equilibrium moisture content due to the long exposure to dry air. Excessive drying can cause seed germination problem even physical damage without mechanical handling. Over-drying of seed in the lower section of a bin can be minimized with the use of stirring devices that slowly transfer the seed from the bottom to the upper part of the bin, Figure 9. Another practice is to invert the air flow when the drying front is located about half the way up the seed mass.

3. Temperature

In order to reduce relative humidity, the air is heated. Excessive temperature can have two detrimental effects on seed. Over-drying can occur by using excessively dry air, rendering the seed more susceptible to mechanical damage during handling and conditioning. But perhaps the greatest risk is to physiologically damage the seed with excessive temperature. Susceptibility of seed to high temperature varies with the species, but generally high moisture seed are more

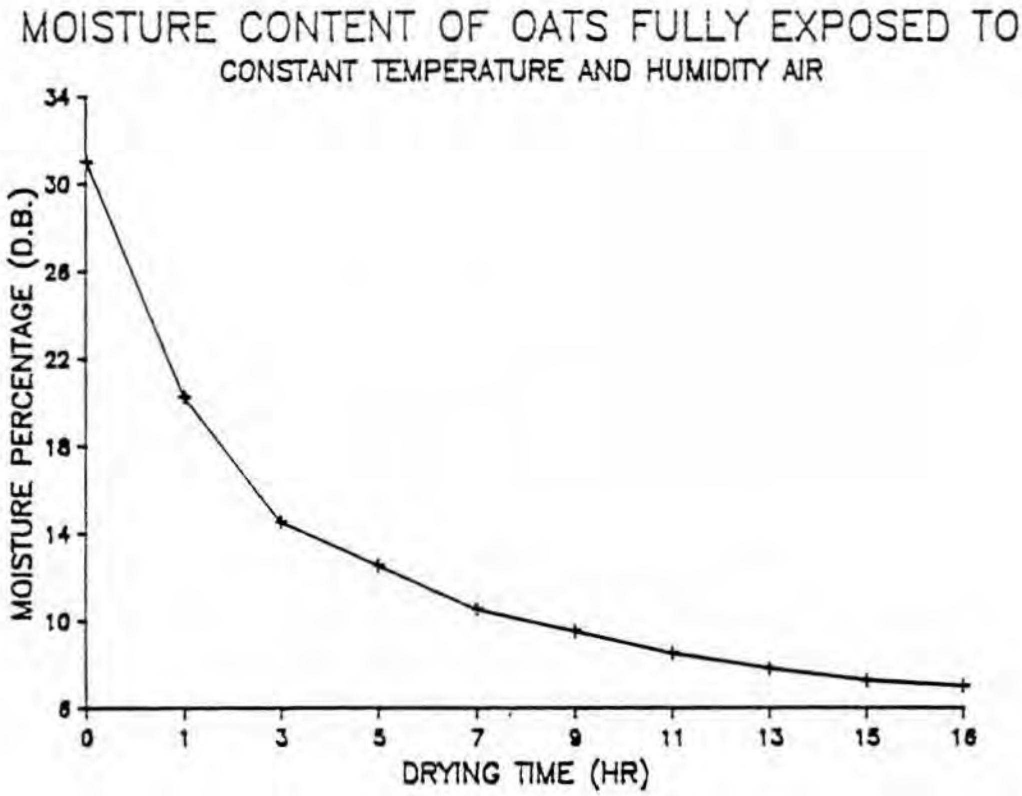

Figure 8. Rate of moisture removal in one layer of high moisture oat seed sample.

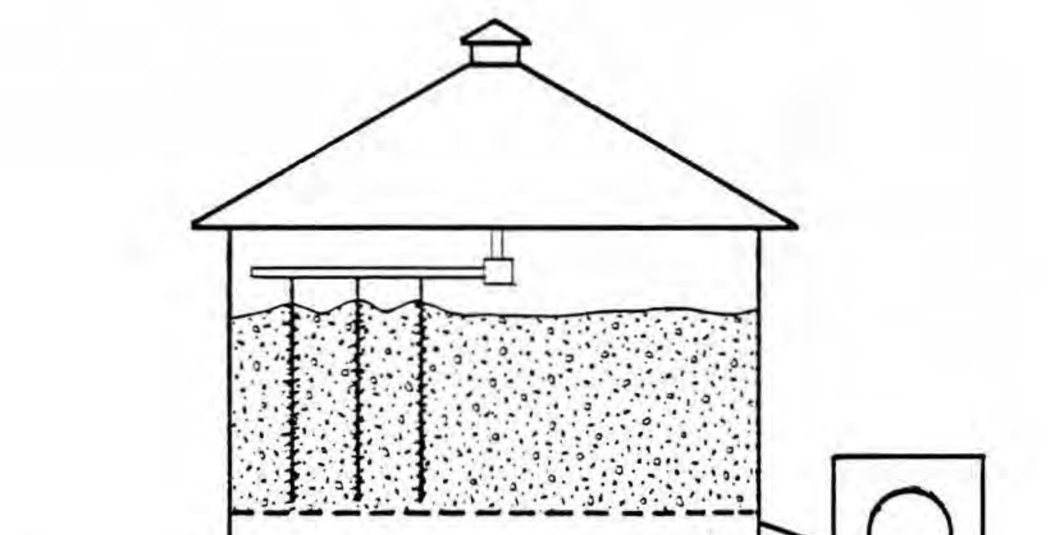

Figure 9. Stirring devices slowly move the seed from the bottom of the bin to the upper layer of seed.

susceptible, therefore, care should be exercised during the initial stages of drying not to use high temperatures. As drying advances and lower relative humidities might be needed, air temperature can be increased.

As a general rule, though, drying air should not exceed 110F.

4. Air flow rate

One of the functions of air during drying is to serve as a vehicle to remove the evaporated moisture from the seed mass. This implies the need of sufficient air volume to take-up and remove all this moisture. Airflow rates requirements will very according to seed kind, initial moisture level and seed depth. Table 2 shows the recommended air flow rates for different crops at different moisture levels and depths. These recommendations are applicable to relatively dry areas. Drying in the humid south requires the use of higher air flows in the order of 9 - 12 cubic feet of air per bushel per minute (cfm/bu/min). Using high airflow rates will also reduce over-drying in the bottom section of a batch, since drying time is reduced and exposure of seed to low relative humidity air is also decreased.

The air-flow delivered by a drying fan is dependent upon the size of the fan and the static pressure developed in the plenum chamber. Static pressure is defined as the pressure required to force a given air flow through the seed mass, Figure 10. For any given fan, the greater the static pressure the lower the airflow delivered, Figure 11. Several factors affect static pressure:

a. Seed size

The smaller the seed the greater the static pressure. Figure 12 shows the static pressure found in sorghum seed as compared to the static pressure in soybeans using the same air flow rate and at the same depth.

b. Seed depth

The greater the depth the greater the static pressure. It takes more pressure to force the air through a deeper layer of seed, regardless of the volume, Figure 13. The static pressure developed in soybean seed at different depths is shown in Figure 14. Note that as the seed depth is doubled the static pressure increases about four times.

c. Airflow rate

The higher the air flow rate the higher the static pressure. It takes more pressure to force a grater volume of air through the seed mass. Figure 15 illustrates the increase of static pressure as higher air flow rates are used in ear corn at various depths. The increase of

Table 2. USDA recommended maximum grain depths and minimum air flows for natural air drying.

Type of Grain	Grain Moisture Content %	Recommended Maximum Depth of Grain Feet	Minimum Air Flow cfm/bu.
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
	16	14	1
Soybeans	20	10	3
	18	12	2
	16	16	1

*Based on recommendations by Texas A&M University.

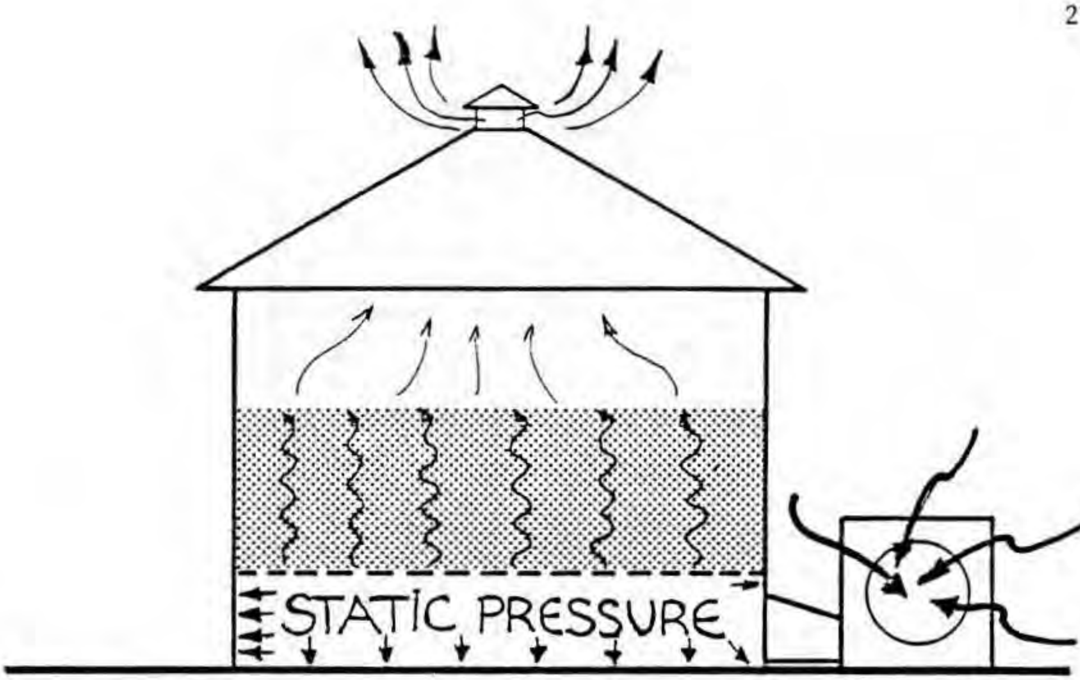

Figure 10. Static pressure in the plenum chamber of a drying bin.

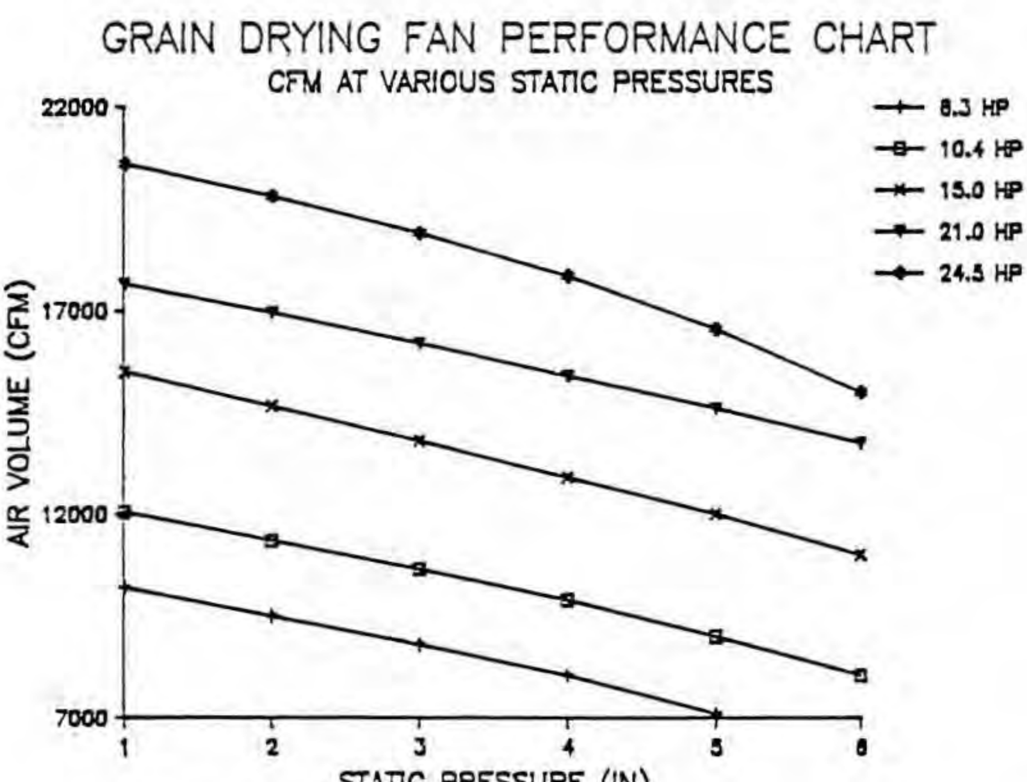

Figure 11. Air flow delivered by various sizes of centrifugal fans (expressed in maximum brake horse power) against different static pressures. Source: Combustion Equipment Company, Form 182-3MArg-JDM.

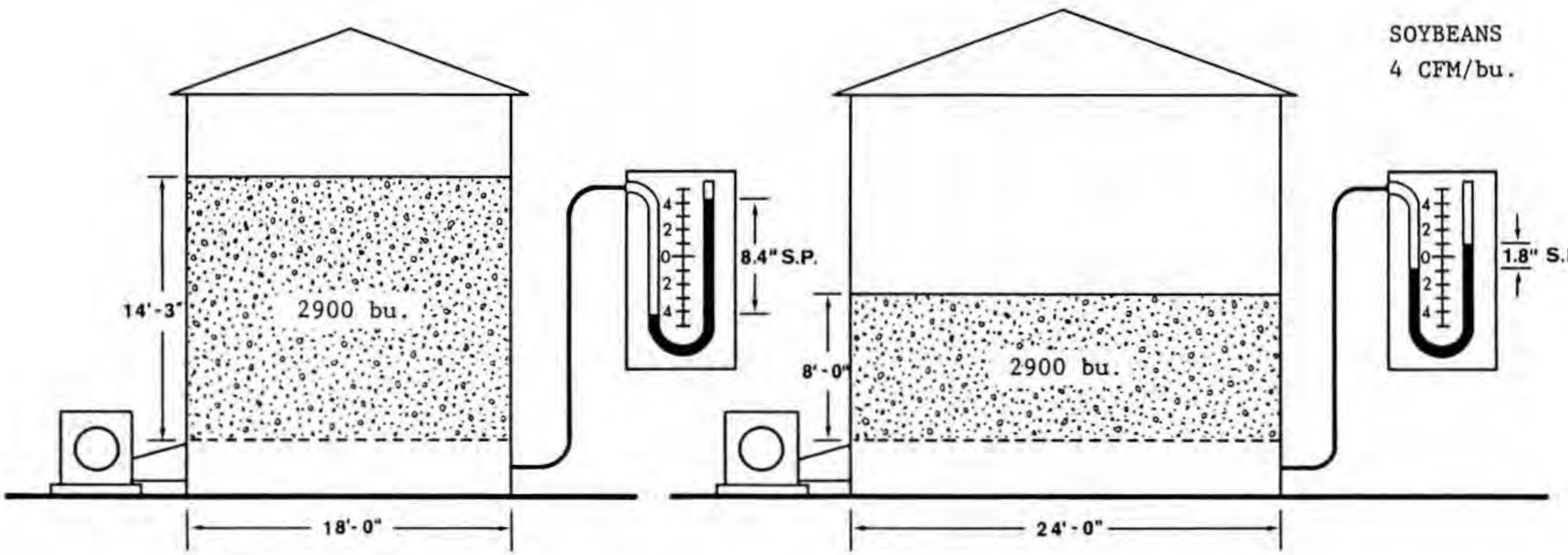

Figure 12. Static pressure developed when drying 2900 bushels of soybeans using 4 CFM/bu in 18 ft and 24 ft diameter bins.

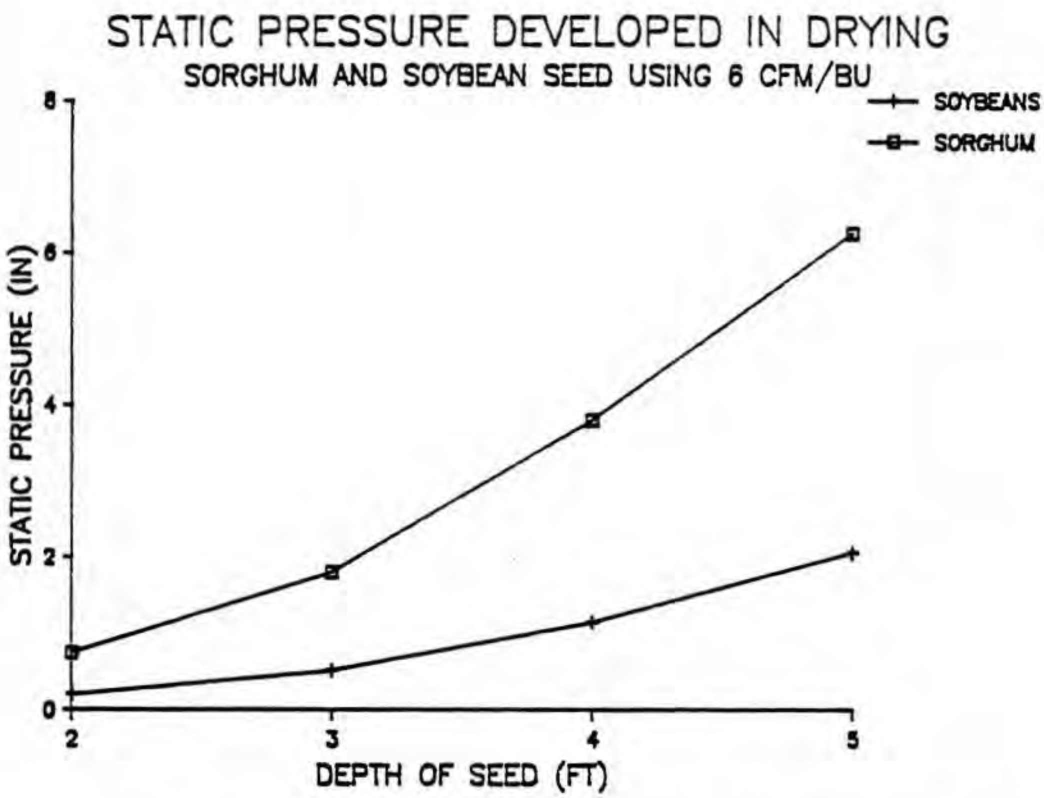

Figure 13. Influence of seed size on static pressure using 6 CFM/bu at several depths.

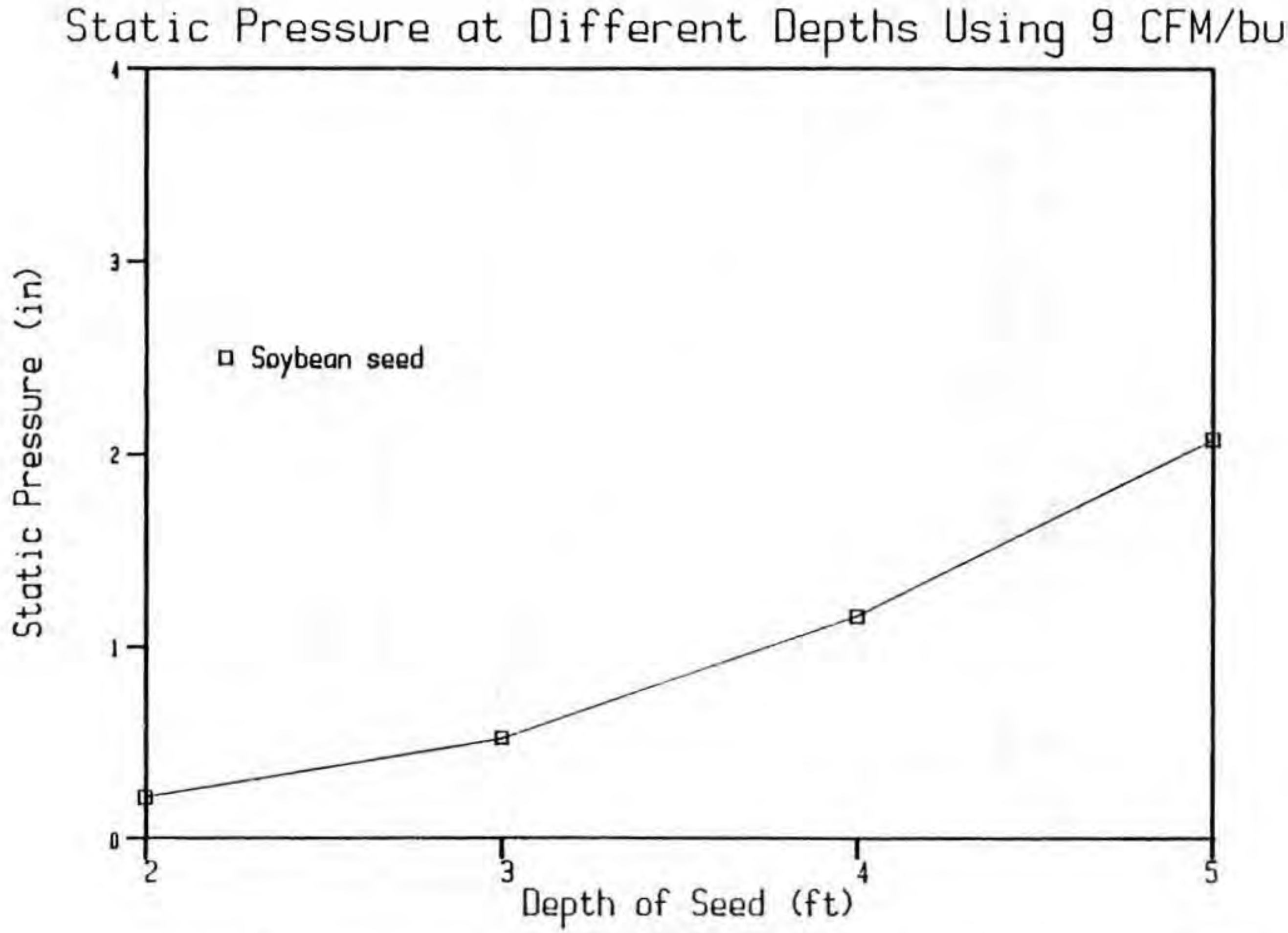

Figure 14. Effect of seed depth on static pressure when drying soybeans using 9 CFM/bu.

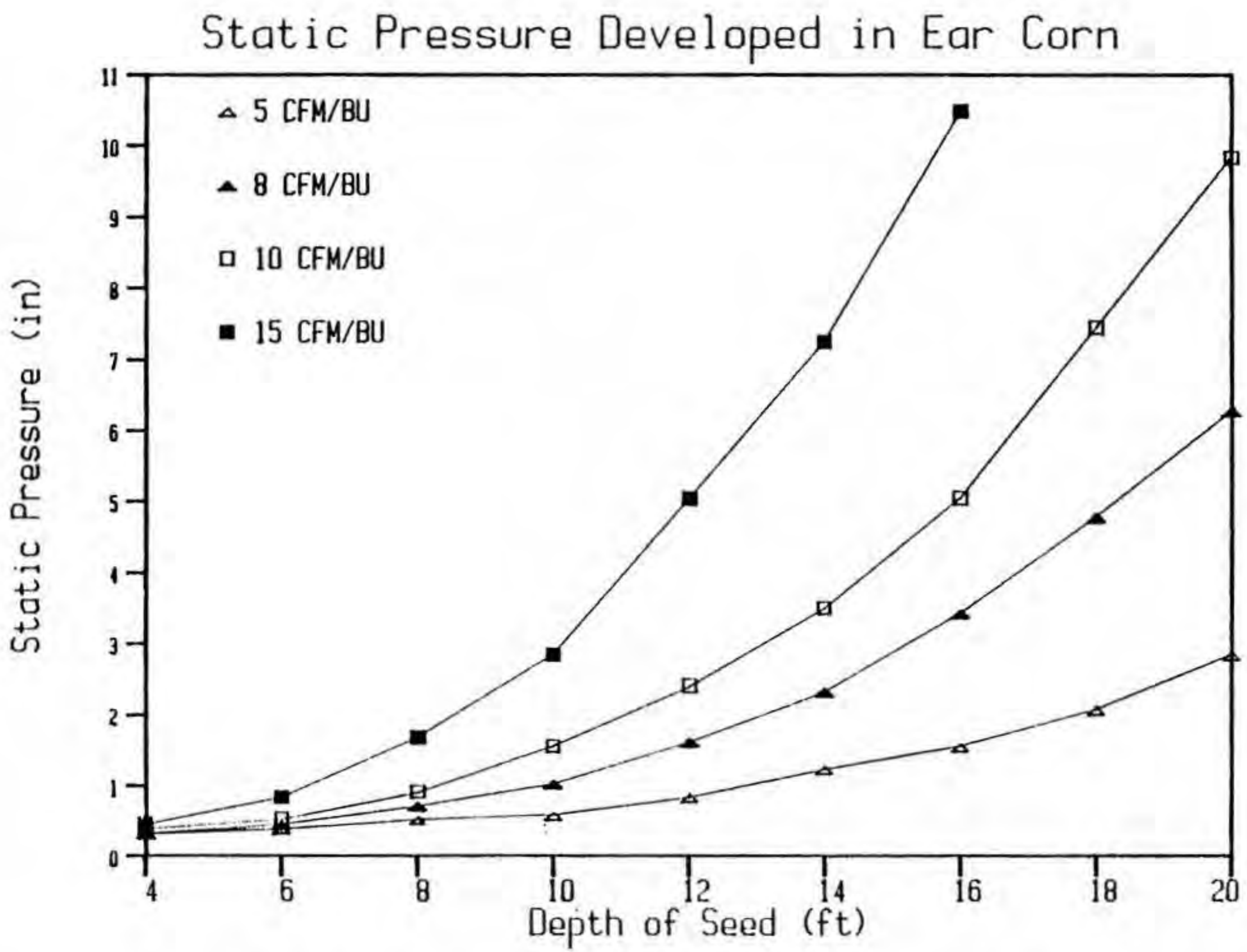

Figure 15. Static pressure developed in the plenum chamber when drying ear corn at different depths using several air flow rates.

static pressure is compounded when air flow rate and seed depth are increased.

d. Amount of trash in the seed

The presence of trash, including very fine material will increase the static pressure. In addition, trash may cause uneven movement of the drying front thereby resulting in a un-uniform drying.

e. Inadequate design of drying system

A minimum of 10% open area is required in the false floor to minimize static pressure. A general rule is to use transitions that will allow a maximum air velocity of 1250 feet per minute. Sufficient exhaust area is needed for the exit of humid air. The use of adequate number of "gooseneck" ventilators will permit free exhaust of the drying air.

5. Permeability of seed to moisture migration

The rate at which moisture moves from the inside to the periphery of the seed depends upon the permeability of the seed to moisture migration. When sufficiently high airflow is used, moisture transfer to the seed surface becomes the limiting factor. In rice seed the permeability to moisture movement is low. If drying is accelerated by using high temperature air a stress develops due to a difference of moisture within the seed and mechanical checking or cracking can occur. Rice drying requires sweating periods to allow the equalization of moisture within the seed.

Summary

1. In order to minimize seed quality losses in the field, seed are often harvested at high moisture content and dried down to levels safe for storage.

2. Seed drying requires large amounts of energy, therefore, understanding the processes involved during drying can help minimize costs.

3. Seed are hygroscopic. Their moisture content is a function of the relative humidity of the air. Drying usually involves removing the moisture of seed without quite reaching the equilibrium moisture content.

4. Drying of individual seed involves the evaporation of moisture on the surface of the seed and the movement of inside moisture to the periphery.

5. Air performs two functions in drying: provides the energy to evaporate moisture from the seed and removes the evaporated moisture away from the seed mass.

6. Drying in a deep bed drier occurs as a drying front moves in the direction of the air flow. The whole batch is not dried until the drying front has moved throughout the entire mass of seed.

7. The relative humidity of air can be reduced by heating. The relative humidity of drying air in normally between 40 - 55%.

8. High moisture seed are more susceptible to heat damage. Even at lower moisture levels temperatures higher than 110F should be avoided.

9. Airflow rate will be determined by fan size and static pressure. The greater the static pressure the lower the air flow delivered by a given fan.

10. The smaller the seed, the greater the depth, air flow rate and amount of trash, the greater the static pressure. Any obstruction to air flow in a drying system will also contribute to a greater static pressure.

11. The permeability of the seed to internal moisture movement can limit the rate of drying. Increasing drying rate by using high temperature can cause internal stress in the seed to the extent of creating fissures or cracks.