A Vacuum Cleaner Seed Dryer

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Introduction
High seed moisture is the greatest single cause of losses in viability and vigor; therefore, it is of paramount importance that seed moisture content after harvest be rapidly and safely reduced to 12% or less for the cereals and 11% or less for oil seed.

The fundamental factors necessary for drying seed are heat to evaporate the moisture and air to remove the moisture from the vicinity of the seed. How the air is heated or by what mechanism it is forced through the seed is immaterial to the drying process. It has been shown that the maximum allowable temperature for drying seed without decreasing the viability is from 85° to 110°F depending upon the type of seed, the moisture content of the seed and the relative humidity of the drying air.

There are many occasions when a small batch dryer is needed for drying seeds on an experiment station or for a plant breeder who deals with small seed lots from 3 to 10 bushels. For small seed lots of this size, it is possible to use an enclosed industrial-type vacuum cleaner to dry the seed.

Nearly all seed processing facilities have an industrial-type vacuum cleaner available for cleaning the floor in seed work rooms and cleaning the processing machinery either by normal vacuuming or high velocity air when the air hose is attached to the exhaust port. If the vacuum cleaner is constructed in such a manner that the incoming air passes the motor to provide cooling, the heat absorbed by the air is sufficient for drying seed.

The blower in most vacuum cleaners has the capability of developing a static pressure of 6 inches water column. Thus, an industrial-type vacuum cleaner has the capability of providing the two necessary components for drying seed: heat and air flow.

Characteristics of An Industrial-Type Vacuum Cleaner
The industrial-type vacuum cleaner used in this study was a Gustafson Booster Power Model. (Note: Trade names are used strictly for the purpose of giving a better description of the equipment used and in no way are meant as recommendations). This model has twin electric motors (575 watts each) with attached blowers: an upper motor and a lower motor. The two motors permit a high and low speed.

Essentially, the electrical input of the motor is converted to heat that raises the temperature of the air, except for a small amount of kinetic energy associated with the moving air and the heat loss in the hose from vacuum cleaner to the plenum chamber. Since the air moving through the seed is normally less than 30 cm, see the kinetic energy is small, and since a short rubber hose is used from the vacuum cleaner to the plenum this heat loss is small. Since both of these quantities amount to a reduction of energy heating the air, the maximum temperature rise with one or two
motors can be determined.

The heat input (BTU/Hr) can be approximated by multiplying the air flow (CFM) by the temperature rise (°F) of the incoming air. Since 3.413 BTU/Hr is equal to 1 watt, the 575 watts of one motor is equal to 1963 BTU/Hr. Therefore, the temperature rise (°F) is approximately 1963 BTU/Hr divided by the air flow (CFM).

For the recommended minimum air flow of 10 CFM bushel using one motor of the vacuum cleaner there is sufficient heat energy to raise the temperature of the ambient air 60°F for drying 3 bushels of seed or 30°F for drying 6 bushels of seed. When using two motors there is sufficient heat energy for raising the temperature of the ambient air 30°F for drying 12 bushels of seed.

Experiment Vacuum Cleaner Dryer

Feasibility tests were conducted with an experimental seed dryer which consisted of the Gustafson Booster Power Model Vacuum Cleaner and a 12 x 12 x 48 inch high seed bin fitted with perforated metal flooring. Three of the bin walls were constructed of ¼ in. plywood and the remaining wall was made of ¼ in. plexiglass to permit visual observation of the seed during the drying operation. The bin was attached to a plenum chamber which was 24 x 24 x 5 inches deep. A 2-inch aluminum pipe 8 inches long was fitted into an opening in the middle of the bottom of the plenum chamber to provide a means of connecting the vacuum cleaner hose.

Two tests were run using the experiment vacuum cleaner dryer to dry rice seed. One hundred forty pounds of rice seed at 17.7% (wet basis) moisture were placed in the seed bin filling it to a depth of 42 inches. One motor was used on the vacuum cleaner.

Seed moisture content was reduced in 12 hours from 17.7% to a range of 8.8% to 12.3% at the 6 to 38 inch seed depths, respectively (Figure 1). Thereafter, drying progressed slowly and at the end of the 48-hour drying test the final moisture contents were 7.0 and 8.0% at the 6 and 36 inch depths, respectively.

Temperatures developed in the drying system during the drying period are shown in Figure 2. The temperature was always highest in the plenum where the air entered the seed mass, and decreased from the bottom to the top of the bin. Over-all temperatures in the system increased as seed moisture content decreased and as ambient temperature increased. Maximum temperature rise over the ambient condition was 25-30°F and was achieved without supplemental heat. The temperature rise was very uniform.

The second drying test using the experimental dryer was conducted with rice seed having 20.7% initial moisture content. The atmospheric conditions during this period were characterized by high relative humidity averaging above 80%. Results of this test (Figure 3) were similar to those of the first test. The more frequent sampling interval (2 hrs. for the first 8 hours) revealed that the most rapid rate of drying occurred during the first 6 hours, and also that the maximum difference in moisture content of the seed from bottom to top of the bin (approximately 8%) was attained at 8 hours. This indicated that drying has occurred in the lower portion of the seed bed but no drying has occurred in the top layer of seed. This test demonstrated that the vacuum cleaner dryer was effective in drying rice seed even under relatively adverse drying conditions (70°F, 80% RH).

Operational Small Batch Seed Dryer

Based on the feasibility studies using the experimental dryer and availability of materials an operational small batch
seed dryer to be used with the industrial type vacuum cleaner was constructed and tested.

**Construction of Dryer**
A 55-gallon drum with an open top (Figure 4 and 5) is used for the seed container. A perforated false floor is constructed 6 inches above the bottom of the barrel to form a plenum chamber underneath. A hole is cut in the side of the barrel below the false floor, and a short length of pipe is welded to the outside. This pipe is used for attaching the vacuum cleaner hose to the seed container.

The drum is suspended in an A-frame to allow the seed to be removed easily after drying. The frame is constructed of 1½ inch angle iron. A ¾ inch steel rod is placed horizontally through the center of the drum 1/3 the distance from the top. This rod is welded to the sides of the drum and extends approximately 8 inches on either side providing points of support on the A-frame. When the barrel is filled with seed the location of the rod causes the seed above the rod to act as a counter balance which aids in pivoting the barrel for removing the seed.

**Evaluation of the Seed Dryer**
Drying tests were run to evaluate the operational vacuum cleaner seed dryer. The temperatures during the drying tests were measured by a Digital Thermometer Model 501N - United Systems Corporation. The temperature was determined for the ambient air, the incoming drying air and the exhaust air from the seed bed.

The static pressure was measured with a Dwyer-Manometer 1215-24, F.W. Dwyer, M.F.G., Co.

The relative humidity during the drying time was measured at one-hour intervals by a Bacharach-Pittsburg sling psychrometer.

During the drying period, samples of 30-50 grams were taken at three different levels at one hour intervals using a trier which was inserted into the mass of seeds from the top to bottom. The air oven method was used to determine the moisture content of the samples. The temperature in the oven was set at 105°C and the sample was dried for 24 hours. The moisture content determinations were on the wet basis.

The first six tests were run to study the temperature rise and the static pressure developed in the dryer. It was established that only one motor would be necessary to dry one barrel of seed (approximately 4½ bushels).

One test was run using both motors of the vacuum cleaner to dry one barrel of seed. During this test the drying air temperatures exceeded 130°F which was approximately a 50°F temperature rise from ambient conditions. Another test was run using both motors on two barrels of seed and the drying air temperature exceeded 117°F. Therefore, since 110°F is the maximum temperature at which the seed can be dried safely, both motors should not be used unless more than two barrels of seed are being dried or ambient temperatures are less than 60°F.

The remaining tests were run using one barrel of seed at a depth of approximately 20 inches and one motor on the vacuum cleaner. Typical temperatures developed during the drying tests are shown in Figure 6. The temperature rise was very uniform and ranged from 20 to 30°F. The static pressure ranged from 0.10 to 0.35 inches of water column. From Figure 6 it is noted that the temperature estimated by dividing the 1963 BTU/Hr of heat energy produced by one motor of the vacuum cleaner by the 22°F temperature rise. This equals to
approximately 90 CFM.

One barrel holds approximately 4½ bushels of seeds; therefore, the specific air flow is 20 CFM/bu which is well above the minimum 10 CFM/Bu recommended for drying (2, 12).

The last four drying tests were run to determine if the vacuum cleaner dryer could be used to dry several different types of seed in a reasonable period of time. Ear corn, soybeans, wheat and rice were dried and the graphs (Figures 7, 8, 9 and 10) indicate that the decrease in moisture content of all the seeds is sufficient to warrant the conclusion that the dryer can be used to satisfactorily dry up to 4½ bushels of seed. Similar tests indicate that 9 bushels of seed can be dried using two seed containers (55 gallon drums) and the high speed (2 motors) or low speed (1 motor) on the industrial-type vacuum cleaner depending upon the ambient temperature.

General Discussion

Evaluation of the vacuum cleaner seed dryer indicated that it is a very efficient heat and air source for drying small batches of seed. Vacuum cleaners of the type used are readily available for seed and plant laboratories and they are quite durable.

In the evaluation tests, the vacuum cleaner was operated with one motor. Nevertheless, it dried the seed very efficiently and built up a very high static pressure of about 6.5 inches in the experimental dryer having a one-square foot cross-sectional area and a 36 inch depth of rice. In the operational seed dryer 4½ bushels (one barrel) of various types of seed were dried satisfactorily using one motor of the vacuum cleaner and nine bushels (two barrels) of seed were also dried satisfactorily using one motor of the vacuum cleaner. It appears that 12-15 bushels of seed could be dried using both motors of the vacuum cleaner. Temperature measurements taken during drying showed that temperature rise in the system was on the order of 25-30°F over the ambient temperature. Since 110°F is the maximum temperature for seed drying, use of the vacuum cleaner at ambient temperatures above 70-75°F could be detrimental to viability of seed. If the drying air temperature exceeds 110°F it can be reduced by increasing the air flow through the vacuum cleaner. A reduction of the resistance to the air flow through the seed will result in an increased air flow, and this can be accomplished by reducing the depth of the seed or by increasing the cross-sectional area through which the air moves. This can be done by adding another barrel to the exhaust hose of the vacuum cleaner.

Obviously if one is interested in using a vacuum cleaner it will be necessary to run sufficient evaluation tests to determine the volume of seed and the depth of seed which can be dried using your particular vacuum cleaner. The best indication of how effective a drying system is can be determined by measuring the reduction of moisture content in the top layer of seed in the dryer. This layer should be reduced to a satisfactory storage moisture content in at least a 48 hour drying period.
Figure 1. Drying rate of rice in the first test using the experimental dryer.
Figure 2. Temperature of rice versus time in the first test using the experimental dryer.
Figure 3. Drying rate of rice in the second test using the experimental dryer.
Figure 4. Construction detail of the seed container of the small batch seed dryer.
Figure 5. General arrangement of the small batch seed dryer.
Figure 6. Temperature versus time for seed dried in the small batch dryer.
Figure 7. Drying rate of ear corn in the small batch dryer.
Figure 8. Drying rate of soybeans in the small batch dryer.
Figure 9. Drying rate of wheat in the small batch dryer.
Figure 10. Drying rate of rice in the small batch dryer.