Seed Cleaning by Electrostatic Separation

When devices, depending upon size, shape, length, specific gravity, coat texture, terminal velocity or color of matter, fail to separate similar seed varieties, the seed’s own ability to conduct electricity distinguishes it from other species.

The production of field crop seeds is an important industry in the United States. Approximately 150 kinds of agricultural seeds are produced which are valued at more than $300 million annually. This does not include vegetable crops and flower seeds. In addition, the United States imports another $15 million worth of crop seeds. The commercial value of seed is a function of its grade and quality. Consequently seed cleaning is a very important phase in the over-all production of field crop seeds.

Seed cleaning involves the removal of contaminating material from the crop seed. The presence of such things as weed seed, rocks, chaff, clods, insect and animal excreta, or other crop seed can definitely reduce the quality of a seed lot. For example, planting seed containing weeds can result in reduced yields and increased production costs. The far-reaching effects of the weed seed do not end here, however. Land values may be reduced because of infestation with certain weeds. Even the health of man and animals may be affected by the presence of some weeds. Also to be considered is the reduction in quality of any products that are manufactured from the seed produced. Federal and state seed laws specify the permissible tolerances for contaminating materials in crop seeds that may be transported and marketed. Some weeds are so objectionable that not even one weed seed is permitted.

Some sort of cleaning operation is usually required for a seed lot to meet minimum standards. New and improved techniques for seed cleaning are constantly in demand. The commonly used methods of cleaning are based on physical differences between the crop seed and the contaminating material. Commercial seed cleaners are available that make separations based on size, shape, length, specific gravity, seed coat texture, terminal velocity, and color. The greater the difference between particular properties of a crop seed and its contaminant, the easier will be the separation. Unfortunately there is not enough difference in physical characteristics of seeds in some mixtures for existing machines to make a separation. Therefore, some other physical property of the seed must be utilized in order to effect a separation of these mixtures. With small seeds, electrostatic separation is essentially independent of such things as size, shape, weight, and surface texture. It depends upon the ability of a seed to conduct an electrical charge.

The principle employed in the electrostatic separation process was known to man as early as 600 B.C. The Greeks discovered that lightweight materials, such as strands of hair and dust particles, could be attracted to a piece of amber which had been rubbed with fur. The amber, thus treated, was charged with static electricity. It was not until 1600 A.D. that it was discovered that materials other than amber had the ability to accumulate a static charge (9)*. Not until the latter part of the nineteenth century do the records show that man made practical use of this phenomenon.

The first commercial electrostatic separator was developed and patented by Thomas B. Osborne of New Haven, Conn., in 1880. It is interesting to note that Osborne’s machine was made specifically for processing an agricultural commodity. The function of this machine was to remove chaff and other lightweight material which reduced the quality of flour. The contaminating material was attracted or “lifted” out of the flour by a charged, hard-rubber roll. The electric charge was produced in this machine, as it was in most early electrostatic separators, by friction (11). In 1881, the first commercial electrostatic minerals separator was patented. Since that time, electrostatic separation has been used primarily in the mining industry. Today there are more than 200 United States patents on electrostatic separators of one kind or another. Only a few of these were designed specifically for seed cleaning. At present, there are several makes of electrostatic seed separators receiving limited use by the seed industry.

Very little publicity has been given to the application of electrostatic separation in the cleaning of agricultural seeds; however, some of the successful electrostatic separations of agricultural products on record are shown in Table 1.

*Numbers in parentheses refer to the appended references.
Research on electrostatic separation has been carried on mainly by individuals connected with the mining industry and by the U.S. Bureau of Mines at its College Park, Md., station. There is still much to be learned about the phenomena involved in electrostatic separation. This is evidenced by its rather limited use. However, because of the strict requirements of the seed trade, no separation method may be overlooked. The great possibilities offered by electrostatic separation for cleaning hard-to-handle seed mixtures warrant further study.

To investigate electrostatic seed-cleaning applications, an experimental machine has been developed at Oregon State College, Corvallis. Design, construction and testing of the unit has taken place through the cooperation of the Oregon Agricultural Experiment Station and the Small Seed Harvesting and Processing Investigations, Agricultural Engineering Research Division, U.S. Department of Agriculture. The unit consists essentially of a feed hopper, a conveyor belt, a 25,000-volt, direct-current power unit rated at 90 microamperes, a beam-type electrode, and adjustable dividers (Fig. 1). The electrode is made up of a 3/4-in. diameter aluminum tube and a 0.012-in. diameter tungsten wire which are parallel to each other and in electrical contact.

In operation, seeds are metered from the hopper to the belt and are conveyed into an electric field surrounding the electrode where they become charged. A given seed tends to stick to the moving belt for a short time. In other cases, the forces present in the field deflect the seeds toward the electrode.

When the electrode is rotated so that the wire is between the tube and the belt, a discharging or "pinning" field is created (5). Seeds passing through this field are sprayed with electrons and become negatively charged by conduction as shown in Fig. 2. The better conductors of a seed mixture will lose their charge and fall in a normal discharge pattern from the belt. Seeds that are relatively poor conductors will adhere to the belt, as shown, until their charge is neutralized.

If the electrode is positioned with the tube between the wire and the belt, a static or "lifting" field is produced. When seeds pass through this field, they receive a positive charge by induction (Fig. 3). With seeds that are good conductors, the positive and negative charges already present tend to migrate on the seed surface as shown. Positive charges assume a position nearest the negative electrode, and negative charges (electrons) accumulate at or near the seed surface contacting the belt. Free electrons of the seed move to the belt, leaving the seed with a net positive charge. A force of attraction then exists between the seed and the electrode causing the trajectory of the seed to be shifted toward the electrode. Poor conductors, because they resist the charge migration, are relatively unaffected and drop normally from the belt.

With the proper combination of such variables as field characteristics, voltages, divider positions, and feed rates, many seed types can be separated according to their electrical conductivities. Fortunately, from a separation standpoint, no two seeds are exactly alike. There may be slight differences in surface texture, shape, weight, or appendages. Even though no physical differences are apparent, there still may be variations in chemical makeup. Any of these factors may affect electrical characteristics of seed and therefore influence separation possibilities.

Electrostatic seed separation research at Oregon State College has had several objectives. They are: (a) determining the effect of high voltage exposure upon seed germination, (b) studying the influence of seed moisture content upon seed separation, (c) investigating electrical field characteristics for several electrode positions, (d) adding to the list of seed mixtures that can be separated electrostatically, and (e) measuring electrical conductivity of seeds as a means of predicting separation possibilities.

### Table 1. Electrostatic Separations

<table>
<thead>
<tr>
<th>Cleaned Product</th>
<th>Contaminating Material Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alta fescue</td>
<td>Cheat, ryegrass bachelor's button (3,7)</td>
</tr>
<tr>
<td>Bentgrass</td>
<td>Ergot (12)</td>
</tr>
<tr>
<td>Bluegrass</td>
<td>Canadian thistle</td>
</tr>
<tr>
<td>Brome</td>
<td>Wild oats (7)</td>
</tr>
<tr>
<td>Clover</td>
<td>Curly dock, lambsquarter, pigweed, sheep sorrel (7)</td>
</tr>
<tr>
<td>Coffee, ground and roasted</td>
<td>Chaff (4)</td>
</tr>
<tr>
<td>Cocoa nibs</td>
<td>Shells and bark (4)</td>
</tr>
<tr>
<td>Corn</td>
<td>Insect and animal excreta, chaff (1)</td>
</tr>
<tr>
<td>Mustard seed</td>
<td>Insect and animal excreta (10)</td>
</tr>
<tr>
<td>Raisins</td>
<td>Leaf and stem material (2)</td>
</tr>
<tr>
<td>Rice</td>
<td>Water cress (2)</td>
</tr>
<tr>
<td>Ryegrass, common</td>
<td>Bachelor's button (3)</td>
</tr>
<tr>
<td>Ryegrass, perennial</td>
<td>Bachelor's button (3)</td>
</tr>
<tr>
<td>Vetch</td>
<td>Wild garlic</td>
</tr>
</tbody>
</table>

![Fig. 2 Discharging field in which seeds receive a charge by conduction](image1.png)

![Fig. 3 Static field in which seeds receive a charge by induction](image2.png)
High-voltage exposure was studied by subjecting Chewings fescue, ryegrass and subterranean clover to voltages ranging from 10,000 to 45,000 volts in 5,000-volt increments (6). In another test, samples of seed were exposed fifty or more times to voltages up to 25,000 volts. The seeds tested were bachelor's button, ladino clover, red clover, Dutch white clover, alfalfa, common and perennial ryegrass, creeping red fescue, and alta fescue. All exposed seed lots and untreated control samples were then germinated in an official seed testing laboratory. A statistical analysis showed no significant differences between the germination results of exposed and control samples.

To determine the influence of seed moisture content upon seed separation, tests were carried out in a room with controlled temperature and humidity. It was found that an increase or decrease in moisture content of 3 percent (dry basis) definitely reduced separation efficiency. Even though seed moisture is influential, there is some evidence that moisture changes can be compensated for, to some extent, by varying the voltage, electrode position, or divider settings.

Since the electric field surrounding the energized electrode is of basic importance in electrostatic separations, an analog field plotter was used to obtain two-dimensional plots of fields for various electrode positions. Figs. 4, 5, and 6 show, respectively, field patterns for the lifting, pinning, and combination positions (3). As determined by experiment, any of these positions or other intermediate electrode rotations may be required for optimum separating results.

As indicated in Table 1, various electrostatic separations of agricultural products are now on record. Attempts have been made, in the Oregon State College research, to duplicate some of the separations and to enlarge this list. Separations that have shown promise are curly dock from red clover, bachelor’s button from common and perennial ryegrass, sheep sorrel from alsike clover, sandbur from alfalfa, bachelor’s button from alta fescue and crested wheatgrass, chervil from ryegrass, wild radish from crimson clover, and red clover from lotus.

Preliminary investigations have indicated that two seeds may be separated when there is a substantial difference between the index numbers of the two seeds.

Preliminary studies have been carried out to obtain some knowledge of relative electrical conductivities of seeds (8). This information should be of value since the electrostatic phenomenon is a function of electric charge which, in turn, is related to seed conductivity. Parallel, horizontal, charged plates were arranged so that the distance between them could be readily changed. Seeds were placed on the bottom plate, and the top plate was lowered until the electrical force of attraction lifted the seeds off the bottom plate. The distance separating the plates at this time was taken as an index of the relative inductive capacities of the seeds and therefore their conductivities. On this basis, curly dock, vetchling, and alfalfa showed low values indicating a short distance between plates. On the other hand, Reed’s canary grass, bentgrass, and perennial ryegrass were high in comparison. Preliminary investigations have indicated that two seeds may be separated when there is a substantial difference between the index numbers of the two seeds.

The charged plate data were also used in another phase of the work. The voltage and distance separating the plates were determined at the time the electrical force of attraction was sufficient to overcome the weight of a given seed. By making the necessary substitutions in a capacitance equation, this information and seed dimensions permitted the calculation of the induced electrostatic charge on the seed at the time of lifting.

In other tests, the time was determined for a seed to lose a given charge and assume one of opposite polarity. Single seeds were exposed, first, to a discharging field and, next, to a static field. The time required for a seed to lose its initial charge and receive an induced one was taken as another index of seed conductivity.

Since the first commercial machine, much progress has been made in the use of electrostatic separation for cleaning agricultural products. However, more basic knowledge of electrostatic response of seed is needed. With additional
research, it is possible that electrostatic separation can realize its full capability; that is, processing seed mixtures which are difficult or impossible to separate with existing equipment.

References

9 Johnson, Herbert B. Electrostatic separation, its development as revealed by forty years of patent history. Engineering and Mining Journal 139(9):37-41, 51.