Surface Texture Separators

Section F
Figure F. Laboratory model electro-magnetic separator used in teaching and for small lots of seed.
ROLL MILL

The "roll mill", "velvet roll mill", or "velvet roll separator", is widely used in seed processing. It is most commonly called the "dodder mill" because it was originally designed to remove dodder from clover and alfalfa.

Roll mills are finishing machines and should only be used on seed that have already been processed on an air-screen cleaner and/or other machines. They are used to clean smooth seed such as clovers, alfalfa and beans that are contaminated with: (1) seeds that have a rough seed coat such as dodder; (2) seeds that are irregular in shape or have sharp angles such as dock; (3) immature seeds that are wrinkled or shriveled; (4) broken, chipped or damaged seed that have irregular surfaces; and (5) rough and irregularly shaped inert material.

Examples of some separations made on the roll mill are:

<table>
<thead>
<tr>
<th>Crop Seed</th>
<th>Contaminant Removed by Roll Mill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crimson Clover</td>
<td>Cutleaf Cranesbill, Dock</td>
</tr>
<tr>
<td>Alsike Clover</td>
<td>Timothy</td>
</tr>
<tr>
<td>Whole Seed Beans</td>
<td>Broken Seed</td>
</tr>
<tr>
<td>Vetch</td>
<td>Dirt Clods</td>
</tr>
<tr>
<td>Hulled Lespedeza</td>
<td>Wild Winter Peas</td>
</tr>
<tr>
<td>Clovers</td>
<td>Unhulled Lespedeza</td>
</tr>
<tr>
<td></td>
<td>Sorrel, Peppergrass, Foxtail</td>
</tr>
<tr>
<td></td>
<td>Catchfly, Mustard, Cockle, Wild Carrot</td>
</tr>
</tbody>
</table>

Parts of the Machine

A roll mill consists of two basic components: the feed unit and the separating unit.

Feed Unit

The gravity-type feed unit feeds the seed mixture into the separating units. It consists of a small hopper which acts as a funneling device on the feed end of the machine. Connected to one side of the vertical shaft is a slide gate which can be raised or lowered to increase or decrease the rate of seed flow through openings in the side of the vertical shaft. Seed flow from these openings into troughs which convey the seed onto the velvet-covered rolls of the separating units. The
Figure Fl. Ten unit roll mill. The feed hopper, vertical feed shaft and troughs used for metering seed to each pair of rolls are on the left.
number of openings and troughs is determined by the number of pairs of rolls in the machine. On most machines a clean-out pull slide is located in the base of the vertical shaft.

**Separating Unit**

The separating unit is composed of two parts: a pair of velvet-covered rolls with a shield or baffle mounted directly over them. The velvet-covered rolls are always arranged in pairs and mounted with one end higher than the other. The rolls in each pair contact each other along their full length, and rotate outwardly in opposite directions. In machines that have more than one pair of rolls, the rolls are mounted in parallel planes, one above the other. Multiple pairs of rolls increase a machine's capacity; they have no influence on the effectiveness of separation. Machine size varies from a small machine with a single pair of rolls for laboratory use, up to machines with ten pairs of rolls. Commercial size machines usually have 5 or 10 pairs of rolls. Length and diameters of rolls also vary with the different types and models of machines.

**Principles of Operation**

The roll mill will separate mixtures of crop seed and contaminants that differ in surface texture. Rough-surfaced, irregular contaminants - seed or inert material - are separated from the mass of smooth surfaced, regular shaped crop seed.

The mixture of seed (and inert material) to be separated is introduced onto the upper or high end of each pair of rolls. As they move downhill in the trough formed by the two rolls, rough seed are caught by the nap of the velvet fabric cover of each revolving roll and thrown against the shield above the rolls. The rough seed strike the shield at an angle and are deflected back toward the roll at an opposite but equal angle. Thus, they contact the velvet roll at a higher level along its upper arc. Repeated action of this type causes the rough seed to move in steps across the upper arc of the roll until they finally fall over the outer edge of the roll. The bulk of the smooth and regular-shaped seed are not affected by the nap of the fabric and continue to slide downhill until they discharge at the low end of the machine.

Since seed are separated along the entire length of the rolls, several grades of seed are produced (usually four). The very roughest seed are the first to be separated and drop into a hopper positioned beneath the upper one-third of the length of the rolls. A second hopper beneath the middle third of the rolls catches seed that are a mixture of predominately rough but with a small percentage of smooth seed. The
Figure Fl. Ten unit roll mill. The feed hopper, vertical feed shaft and troughs used for metering seed to each pair of rolls are on the left.
Figure F2. Schematic drawing of roll mill showing principles of separation and operation.

Hopper beneath the lower third of the rolls catches seed that are predominantly smooth, but with a small percentage of rough seed. Essentially, pure smooth seed are discharged off the lower end of the rolls. Seed discharged into the hopper along the lowest section of the rolls (bottom one-third) are usually re-run to recover the large percentage of smooth good seed or to remove the small percentage of rough undesirable seed.

Adjustments

A roll mill requires a minimum of attention to keep it operating once it is properly adjusted. However, its effectiveness depends upon roll speed, rate of feed, clearance between the rolls and shield, and angle of incline of the rolls.

Roll Speed

The most important adjustment is roll speed. A variable speed drive mechanism permits revolution of the rolls at any desired speed from zero to approximately 350 rpm. A single adjustment changes the speed of all rolls. In general, higher roll speeds remove more material and result in cleaner seed. However, excessive speed results in unnecessary throw-over of good seed. If excessive quantities of smooth seed
are thrown out with the rough seed, roll speed should be reduced. Likewise, if too many rough seed are left in the clean seed, roll speed should be increased.

An accompanying illustration shows the results of test conducted by the Agricultural Research Service of the United States Department of Agriculture on the effect of roll speed in removing dodder from red clover. At 70 rpm about 7.5 percent of the dodder remained in the clover. As roll speed increased, the dodder remaining in the mixture decreased to less than 0.5 percent at 260 rpm.

To adjust roll speed, start with a minimum speed and a feed setting of about one-half inch. If the clean seed product is not free of all objectionable seed or material, roll speed should be increased until the product is clean.

Feed Rate

Rate of feed is a critical adjustment. A single adjustment controls the rate of seed flow from the vertical shaft to each pair of rolls. The slide gate mechanism insures a uniform seed flow to each pair of rolls.

Rate of feed must be closely controlled for two reasons. First, the effectiveness of the separation is determined by the rate of feed,
since each seed must contact the velvet so all rough seed can be bounced out of the mixture. Over-feeding will flood the rolls, or crowd the space between the rolls and the shield and interfere with free movement of individual particles. This reduces the percentage of rough seed removed.

A second reason for close control of the feed rate is that it directly influences capacity. An average starting feed setting for most clovers is a feed-hole opening of one-half inch. It should, however, be remembered that the percentage of contamination will influence the final setting.

Shield Clearance

Clearance between the shield and the rolls, termed "shield-clearance", also influences the separation. This should be adjusted according to seed size, and the range of separations desired.

All machines come equipped with a mechanism for independently raising or lowering the baffles at either end. The clearance usually is slightly greater at the feed end of the machine. A rule of thumb for determining the correct setting is to provide a clearance equal to one and one-half times the diameter of the seed being cleaned. However,
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this adjustment is usually not critical if the seed has sufficient clearance to permit it to leave the roller after contact, strike the shield, and be deflected back onto the roller. This ricocheting action is essential for proper separation; rough seed must be bounced over the rollers and out of the mixture. If clearance is too great, rough seed fail to contact the shield, and repeatedly fall back into the smooth seed. If the clearance is inadequate, both smooth and rough seed will be pressed into the velvet, carried around the roller and dropped into the reject hoppers. For most cleaning operations, a clearance of approximately 1/4-inch at the feed end of the machine is usually adequate.

Elevation

Angle of incline of the rolls; or "elevation", is the least used adjustment on the roll mill. It is seldom altered once an operator has established the best elevation for the particular kind of seed being processed.

The elevation mechanism is located under the feed end of the machine. On some machines it is a hand-wheel screw; on others it is a combination lever-screw device. Usually, an incline range from approximately 7 to 13 degrees, or from 13 to 19 inches, may be obtained. The full range of roll inclination usually has little significant effect on the percentage of rough seed removed. However, the steeper the angle, the faster the seed travel from the feed end to the discharge end of the machine.

Changing elevation has the effect of lengthening or shortening the length of the rolls. Capacity and length of exposure of seed to the rolls can be varied somewhat by increasing or decreasing the angle of inclination. Decreasing the elevation of the feed end of the machine has the effect of lengthening the rolls, because seed will remain on the rolls longer. Conversely, increasing the tilt has the effect of shortening the rolls. As previously mentioned, roller length has little effect on separation, but an increase in elevation may slightly reduce throw-over, because as the speed of flow increases the width of the stream decreases. The most commonly-used tilt is approximately 17.5 inches.

When adjusting a roll mill only one adjustment should be made at a time. The machine should be run several minutes, then the results observed. If additional changes are necessary, they should be made and results checked again. Changes in adjustments should be gradual unless results indicate that a drastic change is needed.
Summary

The roll mill is a finishing machine that effectively separates irregular rough surface seed from smooth seed. It is a relatively easy machine to operate, and requires a minimum of adjustment and attention.
MAGNETIC SEPARATORS

The magnetic separator has been used for many years in industrial applications ranging from removal of tramp iron from coal to the purification of pharmaceuticals. The most common uses are separation of ores and removal of tramp iron from non-ferrous materials.

The first use of the magnetic process in seed separations was made in England some 30 to 40 years ago. Iron oxide was mixed with red clover containing dodder, and the mixture was passed through a magnetic field. The results were not satisfactory because the red clover was badly discolored and the dodder was not completely removed. Since then, several machines have been designed specifically for seed cleaning by United States, English, and German firms.

General types of separators available include the drum or cylinder, induced roll, and crossbelt types. The induced roll and crossbelt separators were originally designed for industrial use and have been adapted for seed separation. The revolving cylinder or drum is the most common type of separating device used for seed. Regardless of the make or type, the principles of operation are the same.

The basic requirement for magnetic cleaning is that the seeds and other material to be separated must differ in seed coat characteristics. Generally, the "good" seed must have a smooth seed coat, while contaminating seed or inert matter must have a rough, gelatinous, or granular surface that will retain a dusting of fine iron powder when pretreated with water or a combination of oil and water. (The iron powder, water and/or oil are called "dosage materials"). The effectiveness of separation depends largely upon the magnitude of difference in seed coat texture between the good and undesirable seed and the thoroughness with which the seed and dosage materials are mixed. If the dosage materials are not applied to the seed mixture thoroughly, uniformly, and in correct proportion, some undesirable seed will not be coated with the iron and will not be separated.

Parts of the Machine

A magnetic separating system consists of three units: the feeding unit, the mixing unit, and the separating unit. Automated systems also include a panel with controls for the machine.

Feeding Unit

The feeding unit consists of a hopper with a device for controlling the rate of feed. The feed hopper may be located differently on different
Figure F5. Wemag magnetic seed separator.
machines. Some machines have a feeding unit for correctly metering the seed into the mixer, and one for metering the seed over the magnetized rolls or drum.

Mixing Unit

The mixer uniformly distributes a specific amount of dosage material (water and/or oil, and iron powder) throughout the seed lot. The amount of each varies with the kinds of seed being cleaned and other factors.

Two systems for mixing seed and dosage materials are used. One is the batch type in which measured amounts of dosage materials are added to a given quantity of seed in a bin or drum and they are mixed for a specific time. The seed are then transferred to the separating unit.

The second type of mixer is the continuous-flow type in which a continuous stream of seed are passed through a series of auger-type mixing chambers. At different points in the system the dosage materials are metered into the seed stream where they become thoroughly mixed with the seed as they travel to the separating unit. The effectiveness of magnetic separators is greatly influenced by the mixing operations.

Separating Unit

Magnetized rollers, cylinders or drums, are the effective separating units in the magnetic separator. A revolving cylinder or drum is the most common separating device used. The drum may be an electromagnet whose magnetism or "pulling power" can be controlled, or it may contain permanent magnets with constant magnetism, or the magnetism may be induced by stationary electric poles. A second type of separating unit consists of a flat revolving belt driven by a magnetized roller or pulley.

Automatic Control Unit

Some systems are equipped with a control system that automatically regulates the dosage of water and iron powder, and the duration of the mixing cycle. The control cabinet is actuated by a signal button. All steps in the process are indicated by control lights or accoustical signals.

Principles of Operation

The general principles of seed separation are the same for all magnetic cleaners. Iron powder is introduced into the seed mixture that
Figure F6. Gompper magnetic seed cleaning machine.
The two-drum cleaner is on the left; the mixing chamber is on the right.
has been slightly moistened, after which the mass is agitated in the mixing apparatus. Rough textured seed, seed with gelatinous coats, and irregular foreign material retain iron powder whereas the "good" seed with smooth seed coats do not. The seed are then passed over the magnetized rolls. Contaminating seeds and inert material with iron powder adhering to them are held on the surface of the drum by magnetic force. Seed clinging to the drum either fall off due to gravity or are brushed off by stationary or rotating brushes into spouts provided for rejected material. Ordinarily, there is no re-run of the rejects. Those seed to which iron powder did not adhere pass over the drum and are discharged as clean seed.

Factors Affecting Magnetic Cleaning of Seed

Condition of the Crop Seed

High crop seed losses that sometimes occur during magnetic cleaning can usually be attributed to the treatment the seed received during harvesting and other processing operations. Crop seed that have received careful treatment are likely to have fewer damaged and broken seed than those that were improperly harvested and roughly handled. Cleaning losses are higher with scarified and damaged crop seed because their cracked and chipped seed coats collect more iron powder than non-scarified or undamaged seed. In some respects, this is an advantage because removal of damaged crop seed upgrade germination and storability of the seed.

The magnetic separator is a finishing machine. It is not intended make separations that can be made on basic cleaning equipment. Indeed, the effectiveness and efficiency of magnetic separators is greatly influenced by the amount of contaminating material in the seed mixture. Generally, the seed mixture should be cleaned as close as possible, with other machines and only brought to the magnetic separator to effect a final separation of specific contaminants.

Kind of Crop Seed

Not all crop seeds that can be cleaned with a magnetic separator respond equally to similar dosage applications. Seeds with extremely hard and smooth seed coats such as Sericea lespedeza take up less iron powder than do seeds with slightly roughened or irregular seed coats such as alfalfa and red clover. Seed of sweet clover will take up even more iron powder than alfalfa or red clover because they have a still rougher seed coat. As a general rule, the harder and smoother the coat of the crop seed, the lesser will be the amount of dosage material required, the lower will be the percentage of seed lost, and the greater will be the effectiveness of separation.
Figure F7. Diagram of two-drum magnetic seed separator. Rough seed that retain a coating of iron powder are brushed off the magnetic drums and discharge through spouts 2 and 3. Smooth seed pass over both rolls and discharge into spout 1.

Kind and Concentration of Weed Seed and Inert Material

An ideal mixture is one in which the seed and other material to be separated differ widely in textural characteristics. Some separations are not possible because of the similarities in seed coat texture of the weed and crop seed in the mixture. In mixtures where a separation is possible, the relative amounts of water, oil, and iron powder required must be considered. A seed lot containing a high concentration of weed seed requires a higher dosage than a lot with a lower weed seed concentration. Since the gelatinous seed coat of buckhorn plantain absorbs water quite readily, the water requirement of a mixture containing this weed seed is higher than for a lot of the same crop seed contaminated with a similar amount of dodder.

Dirt, sticks, straw, leaves and other debris in a seed lot require a higher dosage for effective cleaning. Inert material competes with weed seed for the dosage materials, and enough dosage must be applied to coat both the weed seed and inert material. This may also increase the loss of crop seed because the increased dosage might cause some of the crop seed to be coated with the iron powder and they will be lost with the rejects.

Iron Powder

Iron powders available for use with the magnetic separator are
similar in that each contains a high percentage of iron, but they differ in importance aspects such as particle size, shape, density, and color. The better powders are effective on most seed lots that can be magnetically cleaned, but in some instances certain powders are somewhat specific. That is, one powder might adhere to a particular species of weed seed better than another. Experimentation will determine the proper powder to use.

There is some question as to whether the iron powder should be salvaged or re-used in future cleaning operations. It is generally believed that enough properties of the powder may have been changed or altered to render the powder ineffective for use a second time. The iron powder is relatively inexpensive; enough to treat 100 pounds of seed costs approximately $30 cents.

Adjustments

The magnetic separator is a relatively simple machine to operate. There are few adjustments once the correct proportions of dosage material have been determined. However, these few are extremely important.

Dosage Materials

Mixing the proper proportion of iron powder and liquids uniformly with the seed lot is the most important operation in magnetic seed cleaning. Too little liquid results in inadequate coverage by the iron powder and poor cleaning results. Excessive liquid and powder causes discoloration of the crop seed and excessive cleaning loss. Soft water and warm water (room temperature) gives better results than hard water and/or cold water. Hard water may be softened with any commercial water softener. Distilled water may be purchased and used as the moistening agent. Some machines have electric radiators to control the temperature of both water and seed during operation.

Mixing Time

This adjustment is very important. An incorrect mixing time will result in ineffective separation. Too long a mixing time allows the water to evaporate and the iron powder will be rubbed off the seeds. Too short a mixing time will not permit thorough coverage of the weed seed with the iron powder.

Some units with "batch" type mixers are equipped with automatic controls pre-set for given quantities of water and iron powder and duration of the mixing cycle.
The mixing time for magnetic separators using a "continuous flow" mechanism is determined by the rate of feed. The higher the rate of feed, the shorter the mixing time. Rate of feed and mixing time go hand in hand and are determined by the results shown at the clean seed discharge spout. If weed seed are in the clean seed, then the rate of feed should be decreased to increase the mixing time.

Rate of Feed

The rate of feed must be adjusted and controlled properly. An incorrect feed adjustment will cause either a loss of capacity or ineffective cleaning, depending upon whether the rate is too slow or too fast. For efficient cleaning, the seed should not be more than one seed thick on the magnetized drums. This enables every seed or particle to contact the magnetized drum.

Intensity of Magnetism

The intensity of magnetism can be adjusted on systems equipped with an electro-magnet and a variable transformer. This is advantageous since over- or under-dosage can be partially compensated for by varying the intensity or "pulling power" of the magnet.

Capacity

Capacities of magnetic separators range from 250 to 2,000 pounds of seed per hour, depending upon make and type of machine and the seed being cleaned.

Summary

The magnetic separator is a finishing machine. It effects a rather specific separation of rough textured undesirable seed from crop seed with smooth coats. Seed that are to be finished on a magnetic separator should first be cleaned over basic cleaning equipment. The most general application of magnetic separators is for removal of contaminating weed seed from seed of the clovers, alfalfa, trefoils, and vetch.
INCLINED DRAPER

The inclined draper separates seed by differences in their ability to roll or slide down an inclined surface. The inclined draper utilizes the same principle of operation as the spiral separator, but offers more flexibility. It can be used to separate smooth or round seed from rough, flat or elongated seed. The draper is a finishing machine and should be used after the seed have been processed over other basic cleaning machines.

Parts of the Machine

The draper is composed of four basic components: a feed hopper, one or more inclined belts, a tilt mechanism, and a variable speed control mechanism.

Feed Hopper

As with all cleaning machines, a single feed hopper is provided for all draper belts in a single machine. From the feed hopper, seeds flow into metering devices that distribute them uniformly to each belt for cleaning.

Inclined Belt(s)

The draper belts are the seed separating parts of the machine. Each draper is a specially-made endless belt mounted in an inclined position. It moves, or travels, in an up-hill direction. Belt surfaces are usually made of plastic or canvas, but can be constructed of materials with varying degrees of surface roughness.

Tilt Mechanism

The tilt mechanism allows the operator to adjust the angle of inclination or slope of the draper belt.

Variable Speed Mechanism

The speed of the draper belt can be controlled by the variable speed mechanism. This permits adjustment of belt speed to particular characteristics of seed mixtures separated.

Principles of Operation

In operation, the seed mixture feeds from the feed hopper to the
metering device which distributes seed in a thin layer across the width of the moving inclined draper belt at a point near the center of its long dimension. As the belt travels up-hill, the round or smooth seed roll or slide down the draper faster than the draper is traveling upward. These seed eventually roll off the lower end of the draper into a discharge spout. Flat, rough, or elongated seed do not readily roll, lie flat on the belt and are carried to the top of the incline and discharge off the belt into a separate spout.

Adjustments

Rate of Feed

The rate of feed may be varied by adjusting the opening on the feed hopper. The rate of feed should allow each seed on the belt to act individually. Round and smooth surface-textured seed should not be restricted from rolling or sliding down the inclined plane by a mass of immobile rough-textured seed. Likewise, rough textured seed should not be forced to move down the inclined plane by a mass of rolling or sliding seed.
Belt Types

Belts with varying degrees of surface roughness are available. The best belt for any particular separation depends on the characteristics of the seed mixture. Smooth plastic belts permit a more precise separation and should be used when a sliding action is desired for seed coming off the low end. Use a rough-surfaced belt, such as canvas, when rolling tendencies predominate in seed discharged at the low end.

Angle of Incline

The angle of inclination, or slope, of the draper belt can be varied to facilitate rolling or sliding the desired low-end separate. When properly adjusted, none of the rolling or sliding seed in the mixture should be carried to the top of the slope and discharged.

Belt Speed

The speed of the draper belt can be varied to simulate a longer or shorter inclined plane. When properly adjusted, none of the flat or elongated seed (upper fraction) should discharge off the lower end of the belt.

Initial Adjustments

To adjust the machine for a given separation, start with a low rate of feed, slow draper speed, and slight angle of inclination or slope. Then increase the slope until none of the rolling or sliding seed of the mixture are carried over the top. Next, increase the speed of the draper until none of the flat or elongated seed fall off the lower end. Finally, increase the rate of feed to the point where each seed on the belt can still act individually, but minimum free space is left on the belt.

To gain capacity in commercial operations, many belts are used, one above another in a single machine. Each belt is a separate cleaning unit, but all have the same slope and belt speed.

Typical separations made by the inclined draper include crimson clover from grass seed, vetch from oats, or any other spherical or smooth seed from flat, rough, or elongated seed.

Summary

The inclined draper is a special purpose finishing machine. It is used to separate seed that differ in capability to roll or slide.
Figure F9. Multiple-belt inclined draper in seed plant.
Air Separators

Section G
Figure G. A pneumatic separator (seed blower) used in seed testing to separate inert material from pure seed.
AIR SEPARATORS

Air separators are widely used in seed processing as separate systems or structurally incorporated in other cleaning devices. Indeed, air separation systems have been so well integrated in other separators that they have almost lost their identity. The basic seed cleaner - the air-screen machine - has one, two, three or more air systems that assist in the separations made on the machine.

An air separation was the first seed cleaning method used by man. The proverbial "separation of the chaff from the grain" was accomplished by winnowing - a type of air separation. A mixture of grain and chaff was thrown into the air - the heavy grain fell almost straight back onto the reed tray, while the light chaff was moved laterally by the wind beyond the rim of the tray and fell to the ground. Since the wind was not a dependable source of moving air, winnowing was later mechanized by manual fanning. In many parts of the world today, fanning mills powered by a hand crank or small engine are still the primary - and in many cases the only - means of seed and grain cleaning.

As previously stated, air systems are widely used in seed processing. In addition to their incorporation in air-screen machines, air systems are an essential feature of gravity separators, stoners, huller-scarifiers, and many scalpers. They are often combined with dimensional sizing equipment, electric color sorters, conveying equipment, electrostatic separators, debearders and other equipment to remove dust and light material. The features and functions of air systems incorporated in the other processing machines or used in combination with them are described in detail in the chapters on the various machines. This section, therefore, will only consider those processing machines in which air is the primary - and often only - means of effecting separations.

Air separators - as considered here - can be classified as pneumatic separators, aspirators, and scalping aspirators. Although these three types of air separators are different in appearance, they utilize the same principle of separation.

Principle of Separation

All seed separators are designed to effect separations based on differences in some property or characteristic between the crop seed and undesirable contaminants. In air separations the pertinent property or characteristic is called Terminal Velocity. Thus, aspirators and pneumatic separators can properly be called Terminal Velocity Separators.
Terminal velocity is a fancy name for a simple phenomenon. It is the maximum or terminal speed a seed will attain in free-fall before air resistance will keep it from falling faster. If a handful of various seed is dropped from a great height, some seed will fall faster than others because they are more streamlined (have less air resistance) in relation to their weight. Reversal of the process has much the same effect: when air is blown up through a mass of seed, those seed with a high air resistance in relation to their weight will rise at a lower air velocity than seeds that have less air resistance. Put still another way, the terminal velocity of a seed is equivalent to that velocity of air required to suspend the seed in a confined, rising column of air. If the velocity of air in the column is adjusted to a certain level, and a mixture of seed is dropped into the column, each seed which has a terminal velocity less than the velocity of the air will be lifted. Conversely, each seed which has a terminal velocity greater than the velocity of the air will drop or fall against the rising air column. The rate of descent or ascent of a seed in a rising column of air is determined by the magnitude of the difference between its terminal velocity and the velocity of the air.

Streamlining has already been mentioned as one factor influencing the terminal velocity of seed or any particle. There are many others: shape, specific gravity, cubic volume, surface texture, amount of exposed surface, frontal area, and gross dimensions. In the context of seed separations, however, the determining factors are usually weight of the individual seed in relation to its air resistance. Thus, when the individual seeds in a mixture are of the same shape and volume but differ in density or specific gravity, air can be used to separate the light from the heavy seed. On the other hand, if the seed in the mixture are all of equal density but differ in shape, air can be used to separate seed with the greatest surface area from those with the least surface area, e.g., irregularly shaped seed from spherical seed.

Uses of Air Separators

Air separators are used in three different and distinct ways. These are;

1. **General cleaning.** Air separators are widely used to clean seed by removing dust, chaffy inert material, pieces of broken seed, immature and shriveled seed, and other light contaminating material. Air systems in an air-screen cleaner perform this type of general cleaning operation.

2. **Close grading.** Air separators are used to "grade" seed for density or volume weight. Removal of light seed or insect damaged seed from grass, grain, vetch or cottonseed increases
bushel weight (volume weight) and may upgrade germination. The effectiveness of this separation depends on the purity of the seed to be upgraded. For best results the seed should be thoroughly cleaned on other machines before the final air separation is attempted.

(3) **Specific separations.** In some cases an air separator can be used to remove a specific contaminant that was not removed in previous cleaning operations. The seed mixture should be closely pre-sized before the air separation is attempted.

**Types of Air Separators**

Air separators can be rather arbitrarily classified into three general types: (1) pneumatic separators; (2) aspirators; and (3) scalping aspirators.

**Pneumatic Separators**

In pneumatic separators the fan is located near the air intake where it creates a pressure greater than atmospheric causing air to be forced through the separating column under positive pressure.
Two-way separation by the SORTEX Air Separator is shown in the above diagram. The unsorted product is fed by a vibrator into two FEED channels serving Sections A and B. In channel C, a continuous, regulated stream of air lifts lighter particles (halves, broken pieces, hulls, etc.) to the top of the SPLITS AND REJECTS outlet. Heavier WHOLE product slides gently down the channel to the proper outlet. Using this same system, a product containing no reject matter can be efficiently separated into HALVES and WHOLE product.

Three-way separation by the SORTEX Air Separator is shown in the above diagram. First, the top outlet of Section B is swiveled to a position where it can feed into the feed channel of Section A. The unsorted product is first fed by a vibrator into Section B ONLY. A continuous, regulated stream of air lifts lighter particles to the top of Section B where they are directed into the feed channel of Section A. Whole product continues to the proper outlet of Section B, SPLITS AND REJECTS feed into Section A's Channel C. There a continuous regulated stream of air lifts lighter particles to the top of the REJECTS outlet while SPLITS slide through the proper outlet of Section A.

Figure G2. Two and three-way separation with Sormex dual column pneumatic separator.
**Operation:** Seed are fed into the moving vertical column of air through a feed chute. When the seed mixture encounters the air stream, those seed and other contaminants with a terminal velocity less than the air velocity (light seed) are lifted and rise through the column toward the top where they are deflected into a discharge spout. Seed with a terminal velocity greater than the air velocity (heavy seed) fall through the column of air until they reach an inclined screen positioned across the column. The seed are then deflected by the screen into the heavy seed discharge spout.

In pneumatic separators with a single air column, only a two-way separation is possible - light from heavy material. When two air columns are combined in the same machine, however, a three-way separation is also possible: the mixture is fed into one of the columns where the heavy seed or product falls through the air column and is separated; the lifted material - consisting of dust, chaff, light particles, splits and other seed fragments - is deflected into a second air column where the light, worthless material is lifted and separated from the splits and seed fragments which can then be salvaged for feed or industrial uses. In a three-way separation the air velocity in the first separating column must be set higher than that in the second column.

**Adjustments:** There are only two adjustments on pneumatic separators: rate of feed and air volume (velocity).

1. Rate of feed -- the rate of feed is controllable and determines capacity. It should be adjusted so that each seed reacts individually on the basis of its own terminal velocity. Generally, rate of feed should be as high as possible without affecting effectiveness of the separation.

2. Volume of air -- the volume or velocity of air blown through the separating column is controlled by adjusting the opening of the air intake. Since the column housing is inelastic, the greater the volume of air blown through the column the higher its velocity. Air velocity should be adjusted so that the desired separation is made. This can be achieved by slowly opening the air intake and periodically checking on the separation until the desired results are obtained.

**Aspirators**

Aspirators differ from pneumatic separators in that the fan is positioned at the discharge end of the separator. Operation of the fan induces a vacuum (reduced pressure) in the separator causing the outside air under normal pressure to rush through the separator.
Figure G3. Fractionating aspirator, cross-section view. A, feed hopper; B, air column through which heavy seeds fall against air flow; C, column into which lighter seeds and chaff are lifted; D, section that receives heaviest liftings; E, section that receives second heaviest fraction; F, section into which extremely light waste materials are delivered.
The principal type of aspirator cleaner used is the fractionating aspirator. It is called a fractionating aspirator because four separates or "fractions" ranging from light to heavy are produced.

**Operation:** The seed mixture is metered into the rising column of air by a feed roll. The heaviest seed fall against the air flow and are discharged out the air inlet. The remaining mixture of lighter material is lifted by the rising air. The cross section area of the separating section gradually increases in size reducing the velocity of the air and causing the lifted particles to fall "out" of the stream in order of their decreasing terminal velocity. Thus, in addition to the "heavies" or primary separate which fall through the air column, three other fractions are produced - each differing in terminal velocity (or weight). The first fraction (second separate) is usually the second highest grade of seed, the second fraction is the third highest grade, and the third fraction is usually worthless or near worthless dust, chaff, and other extremely light material. The second and third fractions are often called "intermediate liftings".

The primary fraction (heavies) fall through the air column, are discharged and can be spouted or conveyed away from the separator. The other three fractions fall into three chambers fitted with rotary air locks through which the seed are discharged. Thus, the fractionating aspirator produces graded fractions from a seed lot in a continuous operation.

**Adjustments:** The essential adjustments on the fractionating aspirator are rate of feed and rate of air flow.

(1) **Rate of Feed** -- the rate of feed should be adjusted so that a uniform flow of seed is dropped into the air stream. It should not be so fast that the independent action of the particles is prevented.

(2) **Air flow** -- the air flow (volume and velocity) is primarily controlled by an adjustable damper in the fan discharge pipe and/or a variable speed electrical motor powering the fan. However, another important adjustment that influences air velocity is the adjustable air vane. The vane is located in the section of the separator above the point where the seed first enter the air stream. The vane can be adjusted to restrict or enlarge that section of the separator with the consequence that air velocity is increased (when cross section is restricted) or decreased (when cross section is enlarged). The adjustable vane is used to control the proportions of the liftings directed to the three settling chambers.
Scalping Aspirators

Scalping aspirators are used in much the same manner as other types of scalpers. They may "scalp" off impurities solely by air or - more often - by air in combination with a scalping reel (cylindrical screen with large openings).

**Operation:** In a reel type aspirating scalper the material is fed at a regulated rate to a revolving cylindrical reel or screen with rather large openings. Sticks, straw, leaves and other large roughage can not drop through the openings in the reel and are carried over to the scalpings discharge. Seed and other small material pass through the revolving reel to the aspirating chamber. The screenings consisting of shriveled and insect damaged seed, broken seed, light weed seed, dust and fine chaff are lifted by the air and carried to a large chamber where they settle out and are discharged or conveyed away by an auger. Very fine and light material pass through the fan and are exhausted in a dust collector. The heavy screenings consisting mainly of good seed, but also containing other crop seed, weed seed, and some inert material fall against the air in the aspirating column and are discharged. They are then conveyed to an air-screen cleaner and/or other machines for final cleaning.
Material enters the Scalperator at (A). The flow of material at the feed roll (B) is regulated by a feed control (D). The material is fed at required capacity to the squirrel cage scalping reel (C) which scalps off the sticks, straws, nails, and other roughage. The material is then aspirated at (E) where the material leaves the seal gate in an evenly spread stream through which a uniform current of air is drawn. The air liftings or light screenings are carried up the air passage (F). This deep passage allows the heavier particles to drop back into the main stream, thus effectively removing light screenings without loss of good material. On leaving the air passage screenings are thrown by centrifugal force against the outside wall of the settling chamber (G). Screenings drop to the bottom where they are discharged by a screw conveyor (H). Very light foreign materials such as dust and chaff are drawn into the fans and exhausted into a dust collector.

Figure G5. Section view of a scalping aspirator (Scalperator).
Aspirators that scalp solely by air operate in much the same manner as pneumatic separators. In one type, the rough seed are fed through a feed inlet into the separator where they are distributed over a floating drum and subjected to a rising column of air. The air lifts the light material and moves it to a cyclone or dust bin. The heavy seed fall through the air column and are discharged through the bottom outlet. They can then be conveyed to storage or to other cleaning machines.

Adjustments: The main adjustments on scalping aspirators are rate of feed and air velocity. Both can be easily adjusted to obtain the desired results.

Summary

Air separators separate seed and other particles on the basis of differences in terminal velocity of the individual particles. The terminal velocity of a particle is equivalent to the air velocity required to suspend it in a confined, rising air current. It is influenced by such characteristics as specific gravity, shape, surface texture, all of which affect the particle's resistance to air flow.

Air separation systems are incorporated as integral features of basic seed processing machines such as the air-screen cleaner. Machines in which air is the primary separating medium are classified as pneumatic separators, aspirators, and scalping aspirators.

Air separators are used as general cleaners and scalpers, as close graders, and as precision separators.
Electronic Separators

Section H
Figure H. Sortex G423 MK II electric sorting machine. This model sorts two independent seed streams.
ELECTRIC COLOR SORTERS

The basis for the electric sorting machine was laid just before the turn of the century when researchers found that a strip of oxidized selenium would change its electrical conductivity as the amount of light falling on it changed. The first practical photocell using this discovery was produced in 1935, and the first electric sorting machine appeared two years later.

The light we see is only a small part of the electromagnetic spectrum, and the human eye does not see all of the visible parts of the spectrum equally well. Electric sorting machines are not limited to this narrow visible spectrum, since they provide their own light source. Sensing materials are available which respond to a wide range of the electro-magnetic spectrum from infra-red through ultraviolet and even into the x-rays. Therefore, the machines are capable of "seeing" things we cannot see.

Materials sorted with visible light include such diverse products as vegetable seed, peanuts, edible beans, tomatoes, vitamin pills, cherries, pearls, and buttons. White stones are removed from white beans with ultraviolet light which causes the minerals of the stones to fluoresce. Beans infected with halo blight disease can be removed by the same method, as can pecan worms from shelled pecans.

Almost any granular or particulate product can be sorted by an electronic machine. Whether or not it is practical depends on the value of the product and the cost of hand sorting. Hand sorting is a very boring job and work efficiency varies with the mood and alertness of the worker. Chief advantages of a sorting machine are consistent accuracy, greater sensitivity and lack of work interruptions.

As a seed processing machine, the electronic sorting machine should be used as a specialized finishing machine. Cleaning and grading by conventional machines should be done before using the color sorters so as to provide it with a more uniform product for handling and reduce the number of particles the machine must view.

Parts of the Machine

Photoelectric Cells

A photoelectric cell is a device which changes its electrical characteristics in relation to the amount of light or radiant energy falling on the cell. The three basic types of photoelectric cells are photconductive, photovoltaic and photoemissive. The photoelectric cell may
Figure H1. Mandrel electric sorting machine, Model Selexso 10.

Figure H2. Mandrel electric sorting machine, Model B350.
Figure H3. Schematic diagram of the mechanical and electrical systems in the Sortex G414 and G415 machines.
be sensitive to the wavelength of the radiation striking it as well as the amount. By varying construction materials, tubes can be built so that they are sensitive to a particular color of light. Phototubes can also be made more specific for color by placing filters in front of them so that light of only the desired wavelength reaches the tube. The differences in electric current will be extremely small, usually measured in millivolts, and must be amplified by other circuits to a much larger and usable amount.

Light reflected from a background of known color enters the phototube and causes a constant and steady flow of electrons through the phototube. If a seed of a different color or brightness from that of the background passes between the background and the phototube, then the different quality of quantity of light reflected into the phototube will cause a change in the amount of electrons flowing in the phototube. This small pulse is amplified and fed to a rejection system.

Rejection Systems

In the case of systems using the cathode ray tube, each color and/or shade is manifested as a trace of light at a different position on the face of the cathode ray tube. By determining the position of the traces for components of the product within "acceptable limits" and cutting a paper mask to cover this area of the cathode ray tube, leaving the rest uncovered, the unwanted components of the product can be rejected.

After the paper mask or pattern of the cathode ray tube is cut and positioned, a mirror is positioned over the face of the tube so that it reflects any trace of light from the tube face into a photomultiplier. Through its amplifier tubes, this photomultiplier places a charge on the condenser in a timer. This holds the charge until the object passes out of the viewing area and over the reject chute. At this point, a pickup brush accepts the charge from the timer condenser and activates a small electromagnet which opens an air valve to eject the unwanted seed into the reject chute. These actions are very rapid since electrical impulses move at the speed of light.

Another commonly-used system does not use the cathode ray tube, but feeds the pulses of electricity into a discriminator system which uses the background color as a standard. It can be set by controls to activate the ejector circuit when an electrical pulse is either larger or weaker than the standard. In the case of separations of color when the relative brightness is the same, the light is reflected into two photocells, one sensitive to red and the other sensitive to blue. Since the blue-sensitive cell measures the blue content of the product and the
Figure H4. General scheme used to sort for color in an air ejector nozzle sorting machine. Note use of blue-sensitive and red-sensitive photo tubes.

Figure H5. General scheme used to sort for relative "brightness" in an air ejector nozzle sorting machine. Note use of only one photo tube.
red-sensitive cell the red, it is possible for the discriminator to be adjusted to weigh the amount of each and an excess of one or the other will cause the air ejector to act. Block diagrams of both types of rejection systems are shown.

Color

Visible light is radiant energy of a wavelength that the human eye can detect. Any object receiving this radiant energy absorbs some of it along with a corresponding amount of heat, and reflects the rest. The reflected portion of this energy determines the object's color as we see it.

Colors of visible spectrum and their wavelengths in millimicrons

<table>
<thead>
<tr>
<th>Color</th>
<th>Wavelength (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>750</td>
</tr>
<tr>
<td>Orange</td>
<td>590</td>
</tr>
<tr>
<td>Yellow</td>
<td>570</td>
</tr>
<tr>
<td>Green</td>
<td>500</td>
</tr>
<tr>
<td>Blue</td>
<td>460</td>
</tr>
<tr>
<td>Violet</td>
<td>400</td>
</tr>
</tbody>
</table>
Reflected radiation or color is determined by surface texture, or the presence of pigments. A pigment has the power of selective absorption of light rays, and determines the color of things such as leaves, flowers, seeds, and fabrics.

An object that absorbs most of the yellow and red rays and reflects or transmits most of the blue rays appears blue. Intensity of the hue depends on the amount of light of the wavelength that is reflected. The chroma or purity of the hue is determined by adulteration or mixture with other colors or shades of gray.

Gray is considered a mixture of black and white, but can also be a mixture of complementary colors such as red and green or orange and blue. This makes it possible to use filters over the phototubes. A red filter will block out blues, greens and yellows; a blue filter will block out greens, yellows, and reds. A filter then takes advantage of the presence or absence of a certain pigment and makes the photoelectric circuit "see" only that portion of the spectrum where there is a difference between seeds sorted. It will be "blind" to the portion where the seeds are nearly the same color. Filters are available in a wide range of colors from ultra-violet to infra-red.

Principles of Operation

Electronic Sorting Machine (Selexso Series)

Seed are fed by a vibratory feeder into a revolving bowl where centrifugal force moves them to the outer edge of the bowl. A photoelectric cell prevents overfeeding by shutting off the feed when the seed in the bowl reach a predetermined level.

A revolving drum picks seeds from the edge of the bowl one at a time on vacuum ferrules and conveys them through an optic box containing lights, the background, and lenses or viewing "eyes". Two complete channels view the seed from both sides. When the drum turns about one-fourth of a revolution, the seed passes the ejector. If the seed is rejected, the timer activates the ejector. Compressed air ejects the seed off the drum into a reject chute. If the seed is not rejected, it passes the ejector and goes on over a shoe riding the inside of the drum. This shoe cuts off the vacuum from that part of the drum and the accepted seed is discharged into the accept chute.

A relay in the optic box lamp circuit cuts off the vibratory feeder if a bulb burns out to prevent accepting bad seed because of insufficient light.
Figure H7. Schematic diagram of electrical and mechanical systems of an ESM electric sorting machine.

The Selexso 10 Sorter requires an air compressor, vacuum pump, and 220-volt AC current for machine and pumps. It should be installed on a solid foundation away from heavy equipment to minimize vibration. The power source should be as stable as possible.

Sortex Color Sorter

Seed are fed from a vibratory feed onto a belt with a U-shaped groove, where they assemble in single file. Seed leave the belt at a point above the optical box in such a manner that the natural trajectory of the stream of seeds is through a viewing area formed by four lenses. These lenses are positioned slightly above an air ejector. If not interrupted, this stream drops into the accept spout. The unwanted particles will be ejected by a blast of air emitted from the ejector nozzle and drop into the reject spout.

The Sortex machine requires an air compressor and 220-volt AC current. It should not be installed facing a strong light source. Seed discharge out the front, either onto conveyor belts or into elevators.

Color sorters are usually operated in groups so a common conveyor belt can be installed to receive accepted seed from all units. Rejects can either be discharged onto a belt or collected under each machine.
Since color sorters are installed in fixed positions, conveying equipment must also be installed to feed seed to them from other machines.

Utilizing the combination of electronics and color, the uses of electric color sorters are limited only by one's skill and imagination.
ELECTROSTATIC SEPARATORS

Seed separation by electrostatic devices makes use of electrical phenomena known to man for more than twenty-five centuries. In the sixth century B.C., Thales, one of the seven wise men of Greece, discovered that amber, when rubbed with silk, acquired the property of attracting bits of paper and other light materials. This attraction took place because the electric charge induced on the amber was different from that on the paper or other materials. This phenomenon observed by Thales, and greatly refined by the use of generators, transformers, and rectifiers, is used today in the electrostatic separator, which produces controlled electrical fields for separating mixtures of materials differing in electrical properties.

Electrostatic separation is the process of separating one material from another with charged electrodes. In the case of seeds, the separator utilizes differences in the natural or induced electrical properties of seed to effect separations that cannot be made with conventional seed cleaning equipment. The degree of separation possible depends upon the natural charges on the various seed in the mixture and their relative ability to conduct electricity or retain an induced surface charge.

Parts of the Machine

A complete electrostatic separator is composed of three integrated systems: (1) A power unit and electrode assembly that creates the desired field conditions; (2) a feed and conveying system that delivers the seed into the high voltage field created by the charged electrode; and (3) a dividing and receiving system that separates the seed stream into desired components and receives the resultant separates. Individual components of the three systems and their functions are given below.

Feed hopper: The feed hopper serves as a temporary storage bin for seed conveyed to the machine and facilitates control of the flow of seed through the machine.

Vibrating or belt conveyor: Seed are transported from the feed hopper to a grounded revolving cylinder (or belt pulley) by a vibrating conveyor or endless belt. The speed of the belt or the vibrating conveyor can be regulated.

Grounded rotor or belt: The revolving cylinder or endless belt reinforces the forward motion of the seed and discharges them into the electrical field.
Figure H8. Carpco Laboratory Model high tension electrostatic separator.
Figure H9. Schematic diagram of Carpco Laboratory Model electrostatic separator showing major components and features of the machine.
Power supply: The power supply consists of a rectifier and transformer that can provide field strengths up to 50,000 volts, DC.

Electrode assembly: When energized the electrode assembly creates the electrical field in which the seed are separated. The assembly consists of a wire or sharp edge electrode and a large, rod electrode. They are adjustable in both the vertical and horizontal planes.

Adjustable splitters or dividers: The dividers or splitters are positioned in the drop path of the seed and can be adjusted to collect any fraction of the seed stream.

Principles of Separation

Three different field conditions can be obtained with the electrode assembly to produce a lifting effect, pinning effect, or a combination lifting and pinning effect. These field conditions and their effects are described below.

Static or non-discharging field-lifting effect: A static, non-discharging, low intensity field is produced when the large, rod
Figure H11. Schematic diagram of an electrostatic separator set up to produce a static, non-discharging field. Pigweed seed are "lifted" out of the white clover seed.
electrode is energized and brought into play. Separation of seeds in this type of field is dependent upon polarity of the charge on the individual seeds. As the seed to be cleaned pass through the field, those with a charge opposite to that of the electrode are attracted toward the electrode and lifted away from the normal path of fall. They can then be separated from the remainder of the seed stream by means of the adjustable splitters. Separations can also be effected when the components in the seed mixture differ in magnitude of charge by differences in the extent to which they are attracted to and lifted toward the charged electrode. Seed with the greater charge are attracted more strongly and can be separated from the lesser charged seed by the adjustable splitters. The low intensity method is a direct example of the phenomenon of static electricity, since little or no flow of current takes place. Changing the polarity - plus or minus - of the charge to the electrode may facilitate a separation with this method.

Discharging, high intensity field-pinning effect: The wire or sharp edge portion of the electrode assembly creates a discharging, high intensity field when energized. A relatively strong, concentrated electrical discharge to the grounded rotor is produced. Seed passing through the field are subjected to a spray of electrons which induces a high surface charge on the seed. Since the induced charge is of the same polarity as the discharging electrode, the seed are repelled toward the grounded rotor producing a pinning effect. The length of time the seed are repelled or pinned toward the grounded rotor depends on the length of time the induced charge is retained on the surface of the seed. Seed that are relatively good conductors rapidly disperse the induced charge to the grounded rotor and fall freely. Relatively poor conductors retain the charge much longer and tend to remain pinned to the rotor. As the rotor revolves they fall off or are brushed off into a different spout. Moderate conductors react immediately to the other two classes and their fall pattern is determined largely by the speed of the rotor. Polarity of charge is of little importance in the high intensity method since the charge induced on the seed is opposite to that of the rotor. Differences in conductivity of the different kinds of seed in the mixture determine the effectiveness of the separation.

Combination field-lifting and pinning effect: A third field condition for electrostatic separation is a combination static and discharging field (or low intensity and high intensity field) that produces both a "pinning" and "lifting" effect. This is achieved by bringing both components (wire and rod) of the electrode
assembly into play. The wire or thin band electrode produces a "pinning" effect for poor and non-conductors while the large rod electrode gives a "lifting" effect to the good conductors, thus, the seed stream is "fanned" to its maximum and a sharper separation can be made.

Factors Affecting Electrostatic Separations

The electrostatic separator has been used only in a very limited way as a seed cleaner. Its limited application in the seed industry can probably be attributed to the extreme inconsistencies and variations in the separations it produces.

Many factors appear to influence the results obtained with the electrostatic separator - so many, in fact, that precise control of all of them has not yet been possible. Indeed, it has become increasingly evident that all factors influencing the separation have not yet been identified. Those that have been identified can be classified into three groups: environmental conditions, condition of the seed mixture, and mechanical factors.

Environmental conditions: Relative humidity and temperature of the atmosphere around the separator greatly influence the separations obtained with the electrostatic separator. Best separations are made when the relative humidity of the air is low. Thus, it is advantageous to install the separator in an area where the relative humidity can be controlled during the processing season. Other factors being favorable, operation of the separator in an air temperature of 70 to 80 degrees F. gives the best results. Slight heating of the seed immediately prior to separation tends to counteract the effects of low air temperature.

Condition of the seed: Moisture content of the seed plays a most important part in electrostatic separations. Since the ability of a seed to conduct electricity is related to seed moisture content, changes in moisture content as small as 1 percent can impair, if not economically prevent, effective separations.

Best separations occur when seed moisture is below that necessary for ordinary safe storage. Excessive moisture content can be compensated for - to some extent - by proper adjustment of voltage, electrical field conditions, other machine settings, and pre-drying of the seed.

Seed temperature has little effect on the performance of the electrostatic separator as long as it is constant.
Figure H12. Schematic diagram of an electrostatic separator set up to produce a discharging, high intensity field. Seed that are poor conductors stay pinned to the rotor, while good conductors, are pinned only momentarily, then continue free fall.
Mechanical factors: Several mechanical factors affect separations in the electrostatic separator. Variables such as position of the electrode, field condition, voltage, polarity, and position of the adjustable splitters must be set at optimum levels by trial and error since the other factors are so difficult to control. The rate of feed is constant since the material on the rotor should never be more than one seed deep.

Uses of the Electrostatic Separator

Although much research has been done on electrostatic separation of seed, the separator must still be classed as an experimental machine. Considerable research is still being done on the separator because in spite of discouraging results it holds the potential of effecting some seed separations that cannot be made by other means.

Separations that can sometimes be effected include watercress seed from rice, ergot from bentgrass, Johnsongrass from sesame, pigweed from white clover, and dock from crimson clover.

The electrostatic separator is a finishing machine and separations should only be attempted on seed that has been thoroughly cleaned on other machines. Dust and chaff are particularly troublesome as they cause arcing.

Summary

The electrostatic separator separates seed on the basis of differences in their natural charges or in their ability to disperse an induced charge. Separations are extremely complex and inconsistent because many variables influence the separations and it is difficult to control all of them.

Although the electrostatic separator is described in some detail here, it is only because it has such vast potential as a separator and not because it is in current wide-spread use. Realistically, it must still be classified as an experimental separator.
Miscellaneous Cleaning Equipment
Figure 1. Battery of spiral seed separators installed in a large seed processing plant.
MISCELLANEOUS EQUIPMENT

SPIRAL SEPARATOR

Some seeds such as vetch and wheat differ so little in thickness and length that they cannot be separated satisfactorily with an air-screen machine or length separator. Since seeds of vetch are rounder than those of wheat and roll more readily, a separation can be made with a spiral separator. The spiral separator separates seeds according to shape, density, and degree of roundness or ability to roll.

The spiral separator basically consists of one or more sheet-metal flights spirally wound around a central tube or axis. The unit somewhat resembles an open screw conveyor standing in a vertical position.

Parts of the Machine

Feed Hopper

A feed hopper is as essential on the spiral separator as on other types of machines. Usually a single hopper serves all the spirals that may be combined into a single unit. The seeds flow onto the spirals through openings in the hopper bottom. A disc with a series of different size openings is attached to the underside of the hopper. These discs are attached in such a way that they can be hand-rotated across the openings in the hopper through which the seed pass. The size of the disc opening positioned under the hopper opening controls the rate of feed.

Cone Divider

A cone divider directly under the hopper opening at the top of each spiral disperses the seed evenly over all flights of the spiral.

Spiral

The spiral is the effective part of the machine. It is a series of inner flights onto which seed are fed, and an outer housing flight. The amount of decline in the spirals and the banking angle of the flights are predetermined and fixed by the manufacturer.
Figure II. Krussow double spiral seed separators.
Principles of Operation

In operation, the seed mixture is fed onto the inner spiral flights from the feed hopper. Rate of feed is regulated by the size of the opening in the disc attached under the hopper. As the seed move down the inclined inner flights, spherical seed roll readily and attain a higher velocity than non-spherical seed, which tend to slide or tumble. The orbit of the round seed on the flights around the axis increases as velocity increases until the seed roll over the edge of the inner flight, drop onto the outer housing flight and discharge through a spout in the bottom of the machine. In contrast, the non-spherical or irregular shaped seed do not attain sufficient velocity to roll over the edge of the inner flight and continue to slide toward the bottom of the machine where they discharge through another spout. Some spirals have multiple inner flights arranged in order of increasing size. These units grade the seed in the mixture according to shape and density ranging from low-density flat seed on the inner unit flight to high-density round seed on the larger outer flight. Each flight terminates in a different discharge spout.

Adjustments on Spiral Separator

Rate of Feed

The rate of feed is the only significant adjustment on the spiral separator. The disc that contains the various size holes is rotated until the desired size is directly under the opening in the bottom of the hopper and directly above the cone divider.

Use of Spiral Separator

The spiral is used to separate round seed, such as rape, vetch and soybeans, from irregularly shaped seeds like wheat, oats, ryegrass, and morning glory. It also separates whole vetch seed from broken vetch seed, and crimson clover from rape or mustard seed. Large seeds require a different flight size than small seeds; so several spirals may be needed to process a range of seed sizes.

The need for spirals is diminishing because of the increasing use of such machines as the disc and cylinder separators, which effect many of the same separations more efficiently. Although they are very economical, simple to operate and require no power, spirals have two major disadvantages: lack of flexibility in adjustment and very low capacities. For example, a spiral designed for small seed cannot be used effectively with large seed because the angle of bank and the size of the flights are
fixed. Also, capacities are in the range of only 200 to 700 pounds per hour, depending on the seed being separated and the percentage of round seed in the mixture.

Spirals do, however, offer certain advantages. In addition to being economical to install and operate, they are light in weight, consequently, easy to move. This is a distinct advantage in that when the spiral is not being used it can be stored away. Also, it can be shifted from one location to another within the plant easily and quickly.

POLISHERS

Bean and pea seed may be dusty, dirty, and have a dull appearance even after processing. Popcorn seed may retain light dusty chaff after it has been processed.

The lustre and appearance of large seed such as beans, peas, and popcorn can be greatly improved by polishing machines which remove dust, dirt, and grime.

Types of Polishers

Polishers are of two general types: one uses a polishing agent such as sawdust, bran, or wheat shorts to remove discolorations. The other type of polisher subjects the seed to a mild mechanical brushing or rubbing action.

Polishing-Agent Machines

When a polishing agent is used, it is mixed with the seed and the mixture is sent into a chamber where the polishing action takes place. The mixture is turned and agitated by a conveyor or by a revolving drum. After the seeds have been polished, the mixture is passed over a screen to separate the seed from the polishing agent. The polishing agent can be recirculated through the machine until it accumulates so much dust that its effectiveness is reduced.

Brushing Polishers

Brushing polishers subject the seed to a mild mechanical brushing or rubbing action. The seed are introduced into a cylinder containing a revolving cylindrical brush. The brushes remove dust and other material and convey the seed to the discharge spout. A screen
Figure 12. Crippen polisher, Model E-44-B. This machine uses brushes to polish seed and grain.

and a suction fan may be incorporated into the polisher to remove dust taken off the seed.

Beans are often polished before they are sent to electronic color sorters where off-color seed are removed. The polishing action allows a closer color comparison, and prevents loss of good seed that are discolored by dust.

PICKER BELTS

Separations that cannot be made by machines may be made by hand on hand-picker belts. A picker belt consists of a feed hopper with an adjustable gate, and a horizontal endless belt.

Principles of Operation

Seed or other material are fed onto one end of the moving belt. Operators examine the seed (or ears) as they move across the belt, and remove by hand undesirable material. The good seed discharge from the end of the belt into a hopper or spout. The operator drops undesirable material into containers or pockets at the side of the belt.
Figure 13. A picker belt installed near receiving bins in seed plant.

Sizes

Picker belts are available in a wide range of sizes. The smallest model is built for a single operator, who stands or sits at the discharge end of the belt. The operator removes undesirable material as the belt moves toward him. Larger models require up to 10 or 20 operators, who stand along the sides of the belt and remove undesirable material as the belt moves past.

The separation made on the picker belt depends upon visual examination of material by the pickers. They must be alert and conscientious. The only adjustments on the machine are the speed of the belt, and the rate of feed.

Uses

Picker belts are widely used to remove off type, rotten, or insect-damaged ears of corn, cockleburs from cottonseed, pods from shelled peanuts, and other specific contaminants from seed.
TIMOTHY BUMPER MILL

The bumper mill is a special machine developed to remove weed seeds from timothy. It effects separations on basis of differences in shape, surface texture, and weight of seeds.

Parts of the Machine

The machine consists of two sets of identical, superimposed decks suspended in a rigid frame and connected by a linkage. A small electric motor drives a cam that rocks the decks back and forth and bumps them simultaneously against adjustable rubber stops mounted on the rigid frame between the two batteries of decks. All decks of a battery are at the same inclination at any one time, and this inclination within the suspended frame can be varied by adjustment screws. Each deck is divided into 3 inch x 9 inch plates, and a feeder is positioned to supply seed continuously to each plate.

Principle of Operation

As the rocking deck battery bumps the rubber cushion, all seeds are given an uphill motion. The plump timothy seed have a tendency to
Figure I5. Vibratory seed separator with single deck.

Roll downhill between each bumping cycle, and will travel uphill a shorter distance than irregularly-shaped seed. By the time the seeds move from the feed end to the discharge end of the metal plate, the seed types have migrated far enough apart to be discharged into separate spouts.

Uses

When this machine is properly adjusted in deck angle, rate of feed, and intensity of stroke, it will separate alsike clover, Canada thistle, sorrel, ryegrass, buckhorn and other seeds from timothy seed.

VIBRATORY SEPARATOR

The vibratory separator is a special finishing machine designed to separate seeds on the basis of differences in shape and surface texture. Basically, the unit consists of an inclined deck, which is activated by an electromagnetic vibrator, with an adjustable stroke. The entire assembly can be tilted sideways and forward to provide a wide range of deck inclination.
Multiple decks may be mounted in a rigid frame so that a single vibrator will power the whole battery. The decks may be of varying textures ranging from smooth metal to rough sandpaper, depending upon the seed components being separated. The vibration intensity can be regulated by a rheostat controller in the electrical circuit.

Principle of Operation

In operation, a seed mixture is introduced near the center of the upper edge of the inclined deck. The action of the vibrator causes flat or rough seeds to climb the incline, while the more spherical seeds travel a shorter distance up the incline or roll to the low side of the deck. The forward deck inclination causes gradually widening bands of different seed fractions to travel over the deck from the feed to the discharge edge, where dividers isolate these fractions.

Uses of Vibratory Separator

With the proper deck surface, inclination, and vibration intensity, the vibrator cleaner can make many difficult separations. It will remove curly dock from crimson clover, dogfennel from timothy, and plantain and ergot from bentgrass.
Figure 16. Multiple deck vibratory seed separator.