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MECHANICAL SEED CLEANING AND HANDLING

Agriculture Handbook No. 354

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This handbook supersedes Agriculture Handbook No. 179, "Seed Cleaning and Handling."

Washington, D.C. Issued October 1968

For sale by the Superintendent of Documents, U.S. Government Printing Office Washington, D.C. 20402—Price 55 cents

L.C. Agr. 68-270

MECHANICAL SEED CLEANING AND HANDLING

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INTRODUCTION

Agriculture is the largest single industry in the world, and seed production is an important segment of this industry. Grass and legume seed production in the United States alone is valued at more than $250 million annually, and imports represent another $15 million. When the production of vegetable, grain, and flower seed is included, the total annual value climbs to $750 million. Seed is important not only as planting stock but also as a source of basic raw material for many manufacturing processes.

Seed, as it comes from the field, contains various contaminants like weed seeds, other crop seeds, and such inert material as stems, leaves, broken seed, and dirt. These contaminants must be removed, and the clean seed properly handled and stored to provide a high-quality planting seed that will increase farm production and supply uniform raw material for industry. The procedures used to meet present quality standards result in a loss of up to 50 percent of the good seed even though many special machines and techniques are used for seed cleaning and handling.

Attempts are being made to reduce seed losses by developing equipment and methods to improve efficiency in cleaning, treating, handling, and storing of seed. Although the research is concerned mainly with grass and small legume seeds, the techniques and equipment involved are generally applicable to all types of seed—forage, grain, vegetable, flower, tree, and industrial oil seed.

Manufacturers of seed machinery have done an outstanding job in developing processing equipment.[1] Some of the present seed-cleaning machines make extraordinary separations of small crop and weed seeds; however, the entire seed-cleaning problem is very complex, and improvements are still needed in methods and equipment to reduce the heavy seed losses.

This handbook was prepared as a guide in understanding, selecting, arranging, and operating seed processing equipment. Various types of seed cleaners and related machinery are described; principles of separation for both commercial and experimental developments are discussed; and basic concepts of seed handling, storage, and plant layout are presented.

There are many other related factors, not discussed here, which are important in any consideration of efficient seed production. Some of these are improved seed varieties, good cultural practices, effective seed harvesting techniques, accurate seed testing, and economic aspects of seed processing.

This publication is not intended to replace manufacturers' instruction manuals or the knowledge and experience of operators—rather, it is meant to supplement them.

Acknowledgment is made to Hilmer E. Carlson, Agricultural Engineering Department, Oregon State University, for the use of his diagrams and sketches.

SEED CLEANERS AND SEPARATORS

Much seed cleaning is or should be done in the field before the crop is harvested. Good cultural practices like spray programs, crop rotation, and roguing can minimize many serious weed and contaminant problems.

When a seed lot enters the processing plant for cleaning, contaminants are removed by the use of special equipment that takes advantage of differences in physical characteristics of various components in the mixture. The chief

[1] A list of manufacturers of seed processing machinery is available by writing to the Agricultural Engineering Research Division, Agricultural Research Service, Beltsville, Md.

characteristics used in making separations are size, shape, density, surface texture, terminal velocity, electrical conductivity, color, and resilience.

Many types of seed-cleaning machines are available that exploit the above physical properties of seed, either singly or in some combination. There are air-screen cleaners, specific gravity separators, pneumatic separators, velvet rolls, spirals, indent cylinders, indent disks, magnetic separators, electrostatic separators, vibrator separators, and others. Of these, the most widely used machine is the air-screen unit; it is common to all seed-cleaning plants from the small farm operation to the largest commercial installation. All the other separators can be considered secondary machines which follow the air-screen unit in the processing sequence.

The choice of machines used and their arrangement in a processing line depends primarily on the seed being cleaned, the quantity of weed seeds and other contaminants in the mixture, and the purity requirements that must be met. Seed for planting is of little value unless it reaches the farmer in a viable condition, essentially free of contaminants, and at a price he can afford. The degree to which these requirements are satisfied is related to the equipment used, its arrangement in the processing plant, and the knowledge and skill of the man operating the machine.

Air-Screen Cleaner

The air-screen cleaner is the basic machine in a seed-cleaning plant. It makes seed separations mainly on the basis of three physical properties—size, shape, and density.

There are many makes, sizes, and models of air-screen cleaners ranging from the small, one-fan, single-screen machine to the large, multiple-fan, six- or eight-screen machine with several air columns. Screens are manufactured with many sizes and shapes of openings. There are more than 200 screen types available, and with a four-screen machine, more than 30 thousand screen combinations are possible.

The typical air-screen cleaner now found in a farm seed-cleaning plant is a four-screen machine located beneath a seed hopper, as shown in figures 1 and 2. Seed flows by gravity from the hopper into a feeder that meters the seed mixture into an airstream, which removes light, chaffy material so that the remaining seed can be distributed uniformly over the top screen. The top screen scalps or removes large material, the second screen grades or sizes the seed, the third screen scalps the seed more closely, and the fourth screen performs a final grading. The finely graded seed is then passed through an airstream, which drops the plump, heavy seed, but lifts and blows light seed and chaff into the trash bin.

The arrangement described above uses two screens as top screens and two as bottom screens. Other arrangements possible with a four-screen machine are three top and one bottom, or one top and three bottom.

Screen Numbering System

The size of a round-hole screen is indicated by the diameter of its perforations. Perforations larger than 5½/64ths of an inch are measured in 64ths. Therefore, a 1-inch round-hole screen is called a No. 64, a ½-inch screen is a No. 32, and so forth. Screens smaller than 5½/64ths of an inch are measured in fractions of an inch. Therefore, the next size smaller than 5½ is 1/12th; then, in descending order, 1/13th, 1/14th, and so forth.[2]

The smallest round-hole perforation commonly used in air-screen machines is a 1/25th which has a hole diameter of 0.040 inch. However, for special cleaning requirements, round-hole screen in smaller sizes (down to 0.016 inch) can be obtained from manufacturers of perforated metal. These special screens use a different numbering system and must be mounted on frames to fit air-screen machines. Swedish and other foreign manufacturers use the metric system in designating sizes of screen openings.

Oblong-hole screens are measured in the same manner as round-hole screens except that two dimensions must be given. In large oblong-hole or slotted screens, the hole width is indicated in 64ths of an inch; for example, 11 x ¾ means an opening 11/64ths of an inch wide and ¾ths of an inch long. In slotted screens smaller than 5½/64 x ¾, width is generally indicated in fractions of an inch; for example, 1/12 x ½. There are some exceptions to this latter designation in that such sizes as 5/64 x ¾, 4⅞/64 x ¾, 3/64 x 5/16, and others, use the large-screen numbering system with hole widths indicated in 64ths of an inch. In all cases, the final number is the length of slot.

[2] A table of decimal equivalents for various designations of round holes in screens is shown in the Appendix. This table is useful in comparing hole sizes of screens with different number designations.

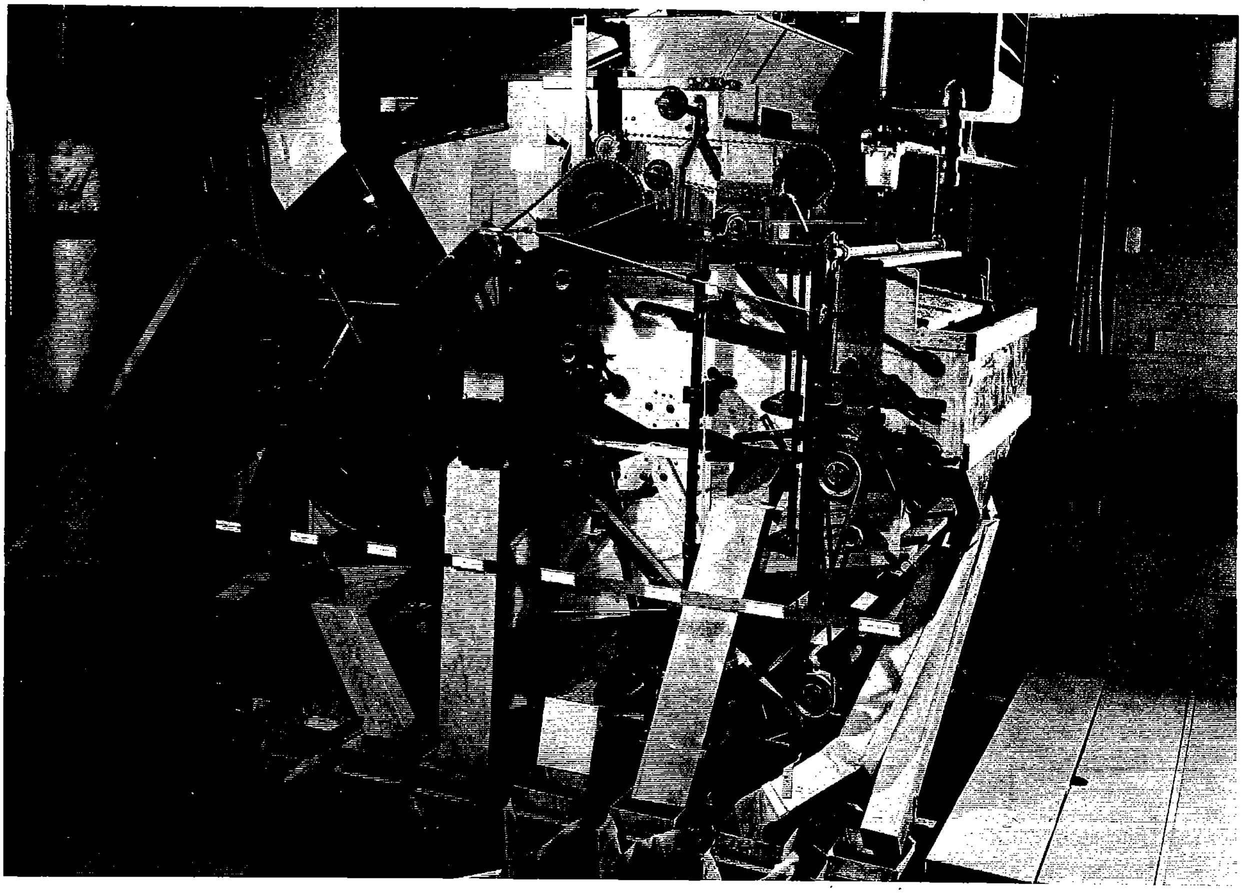


FIGURE 1.—Air-screen cleaner. S-205-6-59

Wire-mesh screens are designated according to the number of openings per inch in each direction. A 10 x 10 screen has ten openings per inch across, and ten openings per inch down the screen. The size 6 x 22 has twenty-two openings per inch across the screen, and six openings per inch down the screen. Such screens as 6 x 22 have openings which are rectangular in shape, and are the wire-mesh equivalents of oblong-perforated or slotted screens.

Triangular screens may be measured in two ways. The system most commonly used in the seed industry indicates length of each side of the triangle in 64ths of an inch. The sides of the hole in a No. 11 triangular screen are 11/64ths of an inch long. Another system used by perforators is to designate the triangular opening as the diameter of the largest circle that can be inscribed in the triangle.

Table 1 shows screens in sizes and shapes commonly stocked by manufacturers of seed-cleaning machinery.

Selecting Screens

The two basic screens for cleaning round-shaped seed are a round-hole top screen and a slotted bottom screen. The round-hole top screen should be selected so as to drop the round seed through the smallest hole possible, and retain anything larger. The seed drops through the top screen onto the slotted bottom screen, which takes advantage of seed shape and retains the round, good seed while dropping broken crop seed and many weed seed.

The basic screens for cleaning elongated seed (oats, fescues) are a slotted top screen and a slotted bottom screen. In special separations it may be necessary to pass such seed through round-hole top screens or over some screen other than a slotted bottom screen, but generally, slotted top and bottom screens are used.

The basic screens for lens-shaped seed (lentils, flax, and Korean lespedeza) are usually a slotted top screen and a round-hole bot-

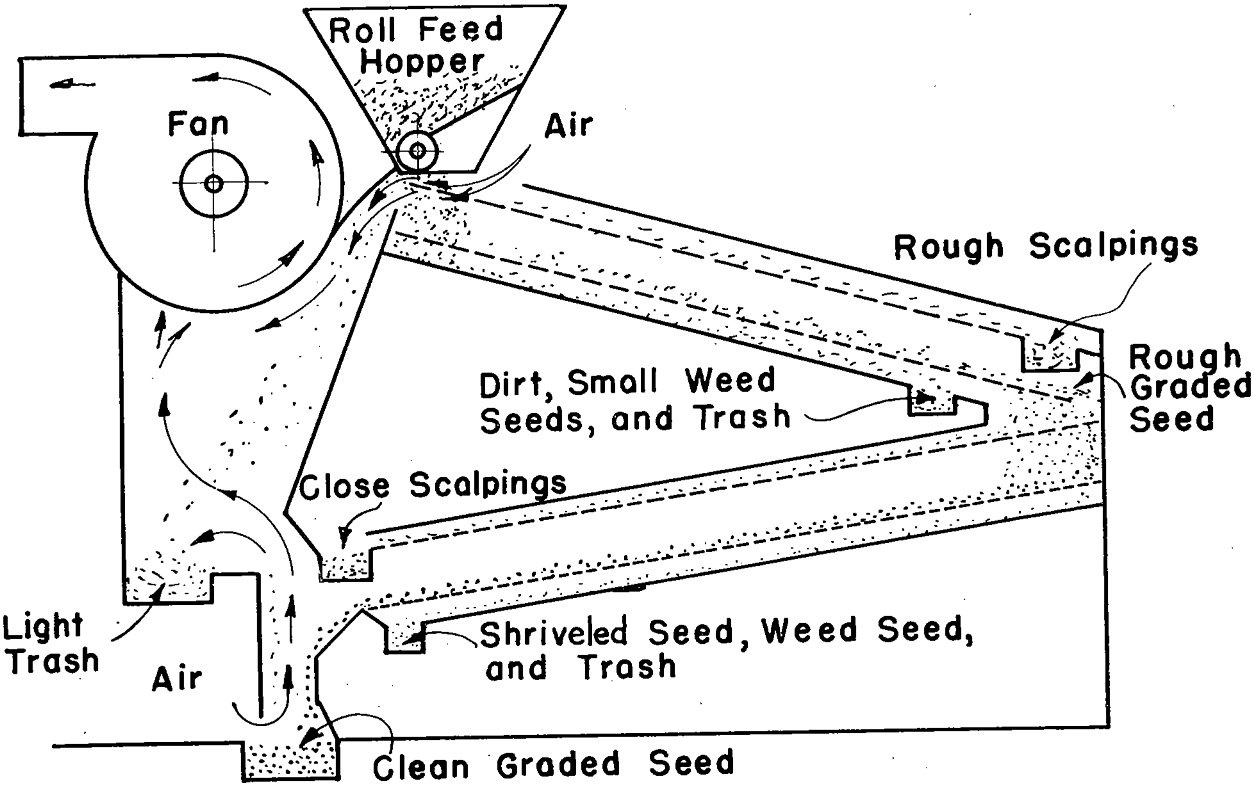


FIGURE 2.—Schematic view of air-screen cleaner.

tom screen. These shapes allow the best cleaning possible when a machine is equipped with only one top and one bottom screen. The lens-shaped seeds tend to turn on edge and drop through a slotted top screen but lie flat and travel over a round-hole bottom screen, which will pass most other crop and weed seeds.

Since most air-screen cleaners have more than two screens, the general rule is to equip the cleaner with oblong- and round-hole top screens, and oblong, and round-, square-, or triangular-hole bottom screens. With few exceptions, this system assures the most thorough seed separation.

One of the lens-shaped seeds commonly cleaned with an oblong-perforated top screen and a round-hole bottom screen is flax. This slick, shiny seed must turn on edge to drop through the oblong holes. If the top screen is a perforated-metal type, some of the seeds will slide over the screen without turning on edge, thus reducing capacities and increasing seed loss. When a wire-mesh screen with rectangular openings is used in place of the oblong-perforated screen, greater capacities and accuracy can be achieved for two reasons: The roughness of the wire surface encourages the flax to turn on edge more readily and drop through the openings, and the wire mesh presents many more openings per square inch of screen area.

Many seed shapes cannot be neatly classified as round, elongated, or lenslike. For example, timothy is shaped like a football, vetchling like a cube, and dock or sorrel like a pyramid. Corn occurs in many irregular shapes, and sudangrass falls in an intermediate classification between round and elongated. Consequently, when screen types are selected for specific seeds, the choice depends largely upon what must be removed from that mixture. When sudangrass is cleaned in a multiple-screen unit, the top screens usually will be a round-hole and an oblong, and the bottom screens also a round-hole and an oblong.

Special Separations

After seeds have been "sized" with a round-hole screen, further separation can be made with other hole shapes. One of the earliest used screens for special separations was the "dock" screen, 3/64 x 5/16, devised mainly to remove dock, mustard, ragweed, and other

TABLE 1.—*Sizes and shapes of screens commonly stocked by seed machinery manufacturers*

PERFORATED METAL SHEET									WIRE CLOTH			
Round holes			Oblong holes		Tri-angles	Oblong cross slot	Round-hole half sizes	Oblong half sizes	Square openings	Oblong openings		
Frac-tions	64ths		Fractions [1]	64ths	64ths							
Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
---	6	24	1/24 x ½	4⅞ x ¾	--	6 x ¾	5½	7½ x ¾	3 x 3	2 x 8	4 x 15	6 x 14
1/25	7	25	1/22 x ½	5 x ¾	8	7 x ¾	6½	8½ x ¾	4 x 4	2 x 9	4 x 16	6 x 15
1/24	8	26	3/64 x 5/16	5½ x ¾	9	8 x ¾	7¼	9½ x ¾	5 x 5	2 x 10	4 x 18	6 x 16
1/23	9	27	1/20 x ½	6 x ¾	10	9 x ¾	7½	10½ x ¾	7 x 7	2 x 11	4 x 19	6 x 18
1/22	10	28	1/18 x ¼	6½ x ¾	11	10 x ¾	8½	11½ x ¾	8 x 8	2 x 12	4 x 20	6 x 19
1/21	11	29	1/18 x ½	7 x ¾	12	11 x ¾	9½	12½ x ¾	9 x 9	3 x 14 sp.	4 x 22	6 x 20
1/20	12	30	1/18 x ¾	8 x ¾		12 x ¾	10½	13½ x ¾	10 x 10	3 x 16	4 x 24	6 x 21
1/19	13	31	1/16 x ¼	9 x ¾		13 x ¾	11½	14½ x ¾	12 x 12	3 x 16 sp.	4 x 24 sp.	6 x 22
1/18	14	32	1/16 x ½	10 x ¾		14 x ¾	12½		14 x 14	3 x 17 sp.	4 x 26	6 x 23
1/17	15	34	1/15 x ½	11 x ¾		15 x ¾	13½		15 x 15	3 x 20	4 x 28	6 x 24
1/16	16	36	1/14 x ¼	12 x ¾		16 x ¾	14½		16 x 16	3 x 21	4 x 30	6 x 25
1/15	17	38	1/14 x ½	13 x ¾		18 x ¾	15½		17 x 17		4 x 32	6 x 26
1/14	18	40	1/13 x ½	14 x ¾		11½ x ¾	16½		18 x 18		4 x 34	6 x 28
1/13	19	42	1/12 x ½	15 x ¾			17½		20 x 20		4 x 36	6 x 30
1/12	20	44		16 x ¾			18½		22 x 22			6 x 32
	21	48		17 x ¾			19½		24 x 24			6 x 34
	22	56		18 x ¾			20½		26 x 26			6 x 36
	23	64		19 x ¾			21½		28 x 28			6 x 38
		72		20 x ¾			22½		30 x 30			6 x 40
		80		21 x ¾					32 x 32			6 x 42
				22 x ¾					34 x 34			6 x 50
				24 x ¾–L					36 x 36			6 x 60
				32 x 1					38 x 38			
									40 x 40			
									45 x 45			
									50 x 50			
									60 x 60			

[1] 1/22 x ½ diagonal.

plump or round weed seed from thinner clover seed.

Bottom screens with triangular openings are being used for separating wild buckwheat and field bindweed from small grains, and dock and sorrel from fescue. These triangular-shaped weed seeds can be dropped throuth the openings, while longer crop seeds will "float" over them.

Triangular openings in screens do not become plugged as readily as round holes. For this reason, bottom screens with slotted or triangular holes are also used in some cases to separate round seed from elongated seed, such as mustard from oats. A 6 x 15 wire-mesh bottom screen will remove burclover from subterranean clover even though both have been screened to the same size with a round-hole screen. The subterranean clover is round and will not go through the narrow slot, while the thin burclover will.

Since seed shape and size are so important in screening operations, seed measuring has been investigated as a basis for selecting optimum shape and size of screen holes. This research is discussed in a later section.

Percentage of Open Area

In selecting screens, another point to be considered is the percentage of open area. A good screen must have openings as close together as possible without impairing the structural strength of the material. Wire-mesh screens have more openings per square inch than perforated-metal screens. For this reason, they are excellent bottom screens for small seeds, and they permit a more accurate high-capacity screening than is possible with perforated-metal screens. Comparing a perforated-metal screen to an equivalent wire-mesh screen, the perforated screen has only a fraction of the total number of openings per square inch that are available in the wire-mesh screen, and consequently would reduce capacity if used.

Another reason that wire-mesh screens serve better as bottom screens is that their surfaces are rough and seeds passing over them are caused to turn, tumble, and present all sides to the openings. As a result, if the seeds are small enough in one dimension, they have every chance to drop through. Perforated-metal screens have smooth surfaces and seeds may lie flat and "float" over the openings.

Bottom screens may take advantage of this flotation. In this case, it is desirable for the good seed to lie flat and float over the perforations rather than turn on edge and drop through the screen along with the contaminants.

Length of Slot

Slotted screens are perforated in different lengths, such as the sizes 1/14 x ½ and 1/14 x ¼. Seed processors use the half-inch length to drop hulled oats when they are cleaning seed oats. Cleaners of market grain want to hold the hulled oats but drop small weed seed. In this case, the shorter slotted hole is desirable because it will float the long seed (oats) over the screen but drop the weed seeds. Processors of Korean and Kobe lespedeza find that the 1/18 x ¼ slot is fine for Korean but a longer slot, size 1/18 x ½ or 1/18 x ¾, is needed for Kobe, which is a flatter, wider seed, and will not pass rapidly enough through the 1/18 x ¼ slot. For the same reason, a three-quarter-inch long slot is good in a bottom screen for cleaning seed wheat because it effectively drops wild oats, quackgrass, or cheat without losing any more good wheat than would be dropped with a shorter slot.

The length of slot should be carefully considered when selecting a slotted screen. For a top screen, the slot must be long enough to pass good seed freely and give adequate capacity. In a bottom screen, the slot should be long enough to give weed seed every chance to engage the perforation and drop through, yet short enough to prevent excessive loss of crop seed.

Screen Dams

Screen dams are objects fastened to a screen to make it sift more completely than normal. They are used for very close and accurate separations of small round seed. For example, dodder can be removed from Korean lespedeza with a one sixteenth round-hole bottom screen equipped with dams. Operators of flat-screen corn graders frequently use dams on all screens to insure maximum accuracy of grade. Dams may be constructed of any material, but commonly are strips of wood lath about a quarter of an inch high and 2 inches wide. When fastened over the cross braces of the screen with nails or screws, the dams are positioned crosswise to interrupt the smooth flow of seeds down the screen, causing them to stop momentarily and be thoroughly sifted. This provides ample opportunity for all seeds to contact the perforations and to drop through the screen if size and shape of the openings permit.

Dams also can be used to cause elongated seeds to upend and drop vertically through a round or slotted hole. For example, screen dams are effective in separating ryegrass and flaxseed. When this mixture is passed over a one-twelfth round-hole screen with dams, the seed flow across the screen is retarded and seeds collect behind the dams. As the ryegrass attempts to work its way over the dam, it approaches an upright position and the oscillation of the screen causes the seed to pass through the screen endwise, making the separation. Also, rattail fescue can be dropped from fine fescue using a 6 x 26 slotted wire screen fitted with dams.

When screen dams are used on round-hole-bottom screens, the accuracy of sifting is increased so that a heavier layer of seed may be carried on the screen, with a resultant increase in capacity.

Except when a screen is being used for grading, dams are generally used only on bottom screens. Ordinarily, top screens drop their good seed quickly enough, and dams on a top screen would cause some weed seeds that normally flow over the screen to stand on end and drop through with good seed.

Because of the close sizing and upending of seeds that dams encourage, there is a tendency for screen holes to plug more readily than in conventional screening. This means that more attention must be paid to keeping the screens clean.

Screen Attachments

Most air-screen cleaners are equipped with traveling brushes beneath the screens that move from side to side sweeping lodged seed from the openings. The two materials used for brush bristles are hair and nylon. It is the general opinion that nylon, although more expensive initially, will last considerably longer and do a more effective job of dislodging seed than the hair bristles. Rollers or flat wipers also may be used under screens instead of brushes.

Mechanical hammers or bumpers are sometimes used to assist brushes in dislodging seed by striking the screen ribs periodically at top center, bouncing seed free of the openings.

Clod-crushing rolls are another air-screen attachment. These usually consist of two spring-loaded, rubber-covered rolls mounted so that material passing through the first grading screen is fed between the rolls where dirt clods are crushed without damaging seed. The second, or fine-grading, screen drops the crushed dirt and retains the seed.

An attachment that can be used to improve the separating action of a top screen is a piece of oilcloth lying flat on the screen with the slick side down. The seed mixture flows between the cloth and screen, and the weight of the cloth tends to keep long pieces of straw and stems flat on the screen so that they do not stand on end and pass through the openings with good seed.

In some cases, it is a good practice to blank off the lower section of a top screen. Once a line has been determined where all the good seeds have dropped through, the screen can be blanked off from that line to its discharge edge with paper, plastic, sheet metal, or other suitable material. Then, any undesirable material that has passed over the upper section of open perforations will flow onto the blanked-off portion and have no further chance to stand on end and drop through with good product.

Adjustments

Feed rate can be adjusted by increasing and decreasing the speed of the metering roller, or by varying the opening of the metering gate located in the bottom of the feed hopper. The feed rate should be regulated to keep the final grading screen about seven-eighths full. It is better to have a small section of the screen uncovered part of the time than to flood the screen occasionally.

Airflow is usually regulated by means of baffles in the air ducts. The top air is adjusted to blow out light chaffy material and dust. The bottom air is regulated to a higher blast than the top air so that it will blow out light seed and heavier trash.

Oscillation of the screens is controlled by means of variable-speed pulleys and should be adjusted to keep the seed action "alive" over the screen. The greater the oscillation, the faster the seed movement over the screens. If this movement is too fast, the seeds hop across the screen and will not be separated. If it is too slow, the seeds have a tendency to glide across the screen with the larger material and not sift through.

The pitch can be adjusted for each screen individually in most air-screen machines. The steeper the screen, the faster will be the flow of seed across it, and the more likely a long seed is to stand on end and go through. The smaller the pitch angle, the longer the material takes to pass over the screen. This gives more time and a better chance for seed to line up with a hole and pass through the screen, as well as the best chance for a long seed to stay in the horizontal position and slide over the screen in lieu of through it.

Capacities

Capacities for air-screen machines vary considerably depending on the machine size, the crop seed being processed, and the amount and type of contaminant to be removed. Approximate rates listed by manufacturers for a four-screen machine (screen size: 42 inches wide and 44 inches long) are 75–125 bu./hr. for seeds, 100–175 bu./hr. for cereal grains, and 200–350 bu./hr. for beans.

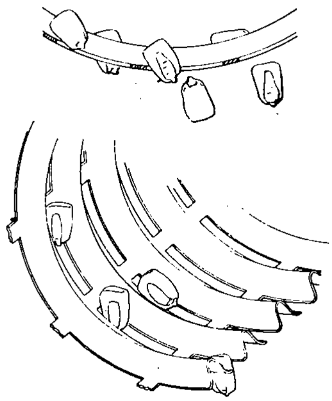
Further Cleaning

After seed is cleaned on the air-screen machine, it is inspected to determine if further separating is needed, and, if so, what special machines are required to make the specific separations.

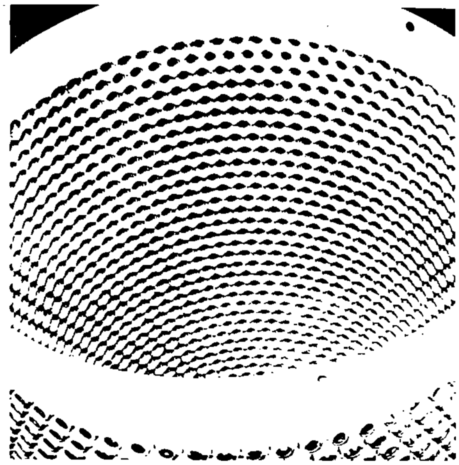
Subsequent cleaning may be done with additional units that again use size properties. Or, machines may be employed that exploit other physical properties of seed like density, surface texture, or terminal velocity. The characteristic differences in the physical makeup of the seed and its remaining contaminants will dictate the equipment to be used next. The many types of machines used to make these further separations will be discussed in following sections.

Grader

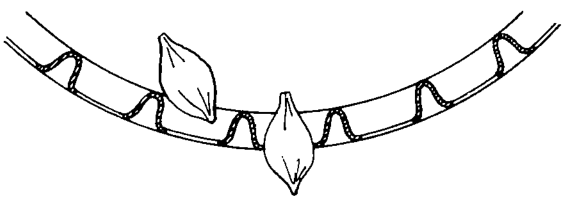
The grader is a size separator that classifies seed either by width or thickness. It employs cylindrical screens or "shells" that are mounted horizontally and have slotted or round perforations as shown in figure 3. In operation, the seed lot to be separated is fed into one end of the rotating shell where it tumbles and migrates toward the tail end. Longitudinal movement is caused by a continuous spiral channel and a slight incline of the cylinder. During the transit, seeds or particles smaller than the perforation drop through the shell while larger material is retained and discharged out the tail end. The dropped material may be directed to a vibrating conveyor, screw auger, chute, or other means of removing it from the machine



The saddle dividing the channels or grooves up-edges grain or other material to proper thickness sizing position.



View at end of cylinder showing round recessed perforations used for width sizing.



Cross-sectional view from section of cylinder with round recessed perforations which are used for width sizing. The perforation at the bottom of the recess causes the grain or other material to be up-ended and positively presented to the perforation.

FIGURE 3.—Slotted and round perforations in grader shells.

Three types of perforations (one slotted and two round) are used in the cylinder shells. The slotted perforations are available in widths from 3/64 to 24/64 inch and are located at the bottom of a corrugated groove having steeply slanted sides. The corrugation acts to tip the seeds or particles on edge so that the cross-sectional dimensions can be sensed. In this case, thickness of the particle determines whether it can drop through the slotted hole.

Round perforations are available in two styles. Large holes, from 13/64- through 26/64-inch diameter, are perforated at the bottom of a deep indentation. This construction tends to upend particles so that widths can be sensed. Large particles like oats, peanuts, and certain grass seeds can be upended readily to drop through the hole if their widths permit. Smaller holes, from 4/64- through 12/64-inch diameter are not indented. With these perforations, bars running the length of the shells introduce a periodic tumbling action which again encourages upending and width-sizing of the particles. Small round holes can do a good job of dropping bluegrass singles from doubles.

The various perforations are kept free of plugged particles by a soft, rotating rubber-blade cleaner located outside the shell at the top. The cleaner runs the full length of the shell and taps or pushes wedged particles free of the holes. A unique feature of this cleaning action is that it occurs when the perforation is inverted, and gravity therefore helps remove the plugged material. In contrast, cleaning mechanisms on conventional flat screens must work against the force of gravity in performing their function.

Various model arrangements are available containing from one to six shells per machine. Capacity will vary greatly depending on the product being processed and the percentage of the total lot that passes through the perforations. With hybrid seed corn, for example, from

25 to 80 bu./hr. can be sized per shell. The largest single use of the grader is sizing corn to fit planter plates.

Horizontal Screen Cylinder

The horizontal screen cylinder sizes products by width or by thickness and is similar to the grader in many respects. Material introduced to the rotating cylinder either passes through the perforations or is discharged from the tail end.

The cylindrical screens or "reels" contain slotted perforations, round perforations, or both. The slotted screens are made from stainless steel wire. This construction provides a great deal of open area in a given surface and encourages good capacities. The round perforations are deeply indented as in the grader shells to upend particles for width sizing. The cylinder frame is constructed so that one, two, or three different lengths of screen can be used in one machine. Also, round-hole, slotted, or both types of screen can be assembled on one reel. This means that up to four different size fractions can be produced in one pass through the same reel.

Special lifter bars in the reel act to feed particles to the screen even when the screen surface is nearly vertical. This tends to use more of the surface in a given revolution and increase capacity.

Screen cleaning is accomplished with resilient rubber rollers mounted over the top of the reels. Lodged particles are pushed back into the cylinder with gravity aiding in the process. As in the grader, the cleaning takes place when the cylinder is free of its bed of material.

The machines are available in single and multiple reel combinations, and capacities vary with the product and the separation involved. These cylinders have many uses but primarily are used to size-grade corn.

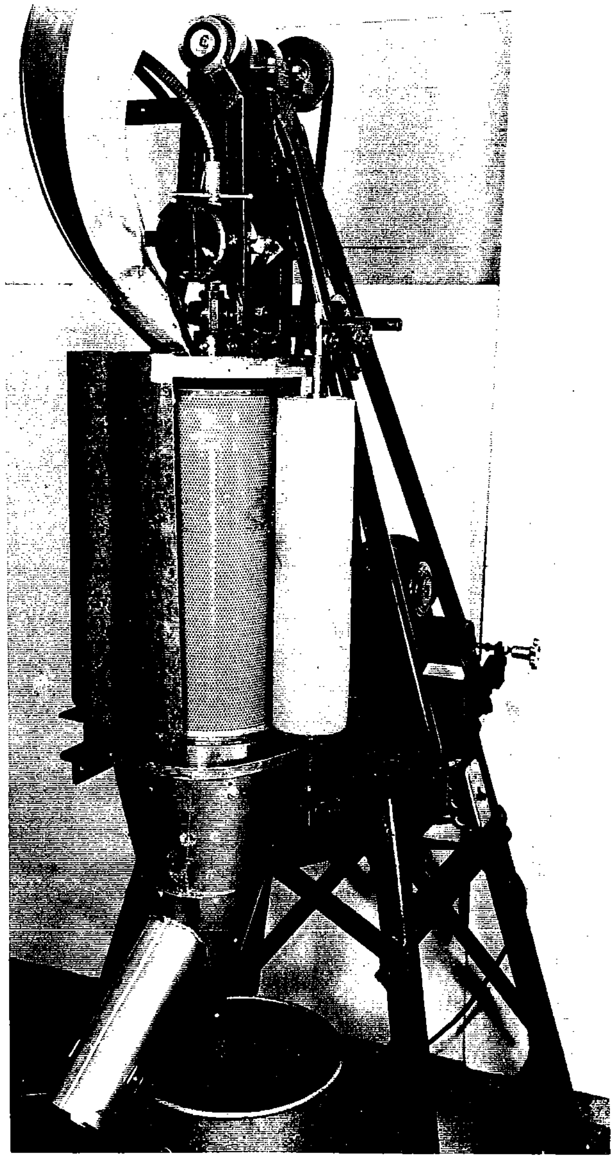


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FIGURE 4.—Vertical screen cylinder with one-half of cover removed.

Vertical Screen Cylinder

The vertical screen cylinder is an experimental development that is aimed at performing the same function as a conventional, reciprocating, flat screen but in a more efficient manner.

The unit shown in figure 4 employs a round or slotted-hole screen rolled into a cylinder of 8-inch diameter. In operation, the cylindrical screen is rotated about its vertical axis and also reciprocated vertically.

Seeds to be separated are fed into the top of the cylinder to a feed cone seen in figure 5. The cone starts seeds into a rotary motion and directs them against the rotating screen. Centrifugal force holds the seeds against the screen, and the vertical reciprocation, along with the pull of gravity, causes the seeds to move downward. Small seeds go through the screen and into a center discharge collecting shell, while large seeds slide down the inside of the screen to a separate discharge.

The vertical cylinder unit has several advantages compared to a conventional flat

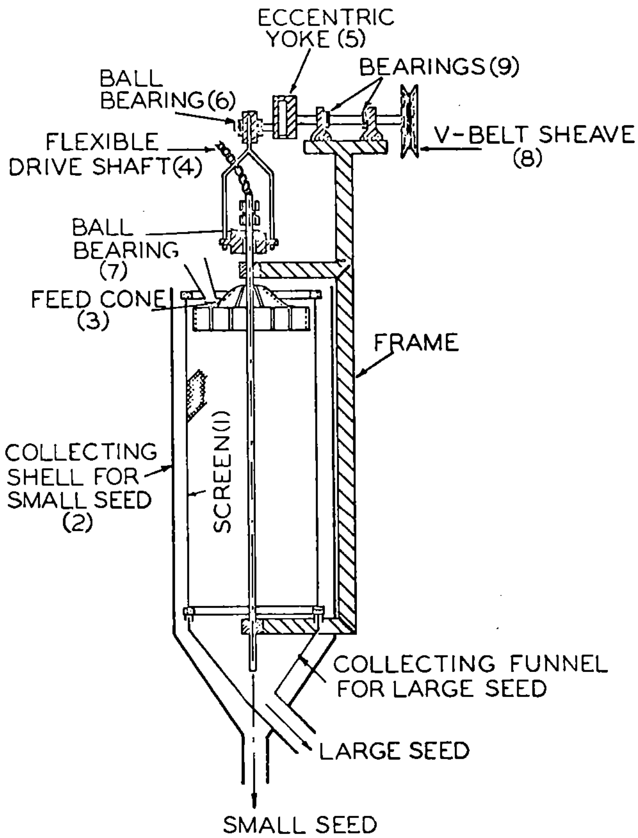

Figure 5.—Schematic diagram of vertical screen cylinder.

screen. It shows higher capacity per unit area of screen surface because centrifugal force acting on the seed is greater than the force of gravity, and this speeds up passage of seed through the screen. The seed layer is more uniformly distributed over the vertical screen than on flat screens. Screen cleaning is accomplished readily with a resilient roller which rolls against the screen.

Other desirable features are simple feeding by pouring seed into the top of the machine, small floorspace requirement, and an ability to operate satisfactorily when tilted. Tilting has relatively little effect on the separating action because centrifugal forces acting on the seeds are several times that of gravity.

Efficiency of separation is affected by screen revolutions per minute, frequency of vibration, amplitude of vibration, feed rate, and screen size. Optimum adjustments have been determined by tests with a mixture of wheat and clover. Separating efficiencies were determined by weighing the clover left in the wheat after a given run. At comparable separating efficiencies, the vertical screen showed more than twice the capacity of a flat screen.

Other tests have included the separating of rattail fescue from fine fescue, and crotalaria from corn, as well as the sizing of sunflower seed—all with good results at greater capacities than those obtained with a flat screen.

Indent Disk Separator

Seeds that have been size-graded by width and thickness can be further separated on the basis of length differences. Length separators are of two general types—the indent disk and the indent cylinder—but both use the principle of lifting short seeds from a mixture with a given pocket, or indentation, which is too shallow to accommodate long seeds.

The indent disk separator consists of a series of indented disks which revolve together on a horizontal shaft. Each disk contains numerous undercut recesses on each face. (See figs. 6 and 7.) As the disks revolve, the recessed pockets lift out the short seeds and reject the longer seeds; for example, vetch can be lifted, leaving oats, ryegrass, and other elongated seeds, and crimson clover can be lifted, leaving ryegrass and fescue seeds.

If the contaminants in a mixture are longer than the seed being cleaned, a pocket is chosen that will lift the good seed. When several sizes of short contaminants are to be removed, the disks are located so that disk pocket size increases progressively from intake to discharge end of the machine. Short seeds are removed first, with longer seeds being lifted as the seed mass moves toward the discharge point. When there is only one separation to be made, many disks of the same size and shape are incorporated in a machine, or several machines, to increase capacity. (See fig. 6.)

Seed Travel

Seed travel from intake end of the machine to discharge end is provided by vanes attached to spokes of the disks. The removable vanes operate like a screw conveyor to move the seed mass slowly through open portions of the disk. In addition to conveying, this operation brings the seed mass in contact with each disk and facilitates separation. The vanes and spokes also agitate the seed mixture, thus minimizing stratification.

The housing of the machine closely fits the rims of the revolving disks, but there is sufficient clearance to prevent the crushing of seed. This favors seed travel through the center and open portions of the disks.

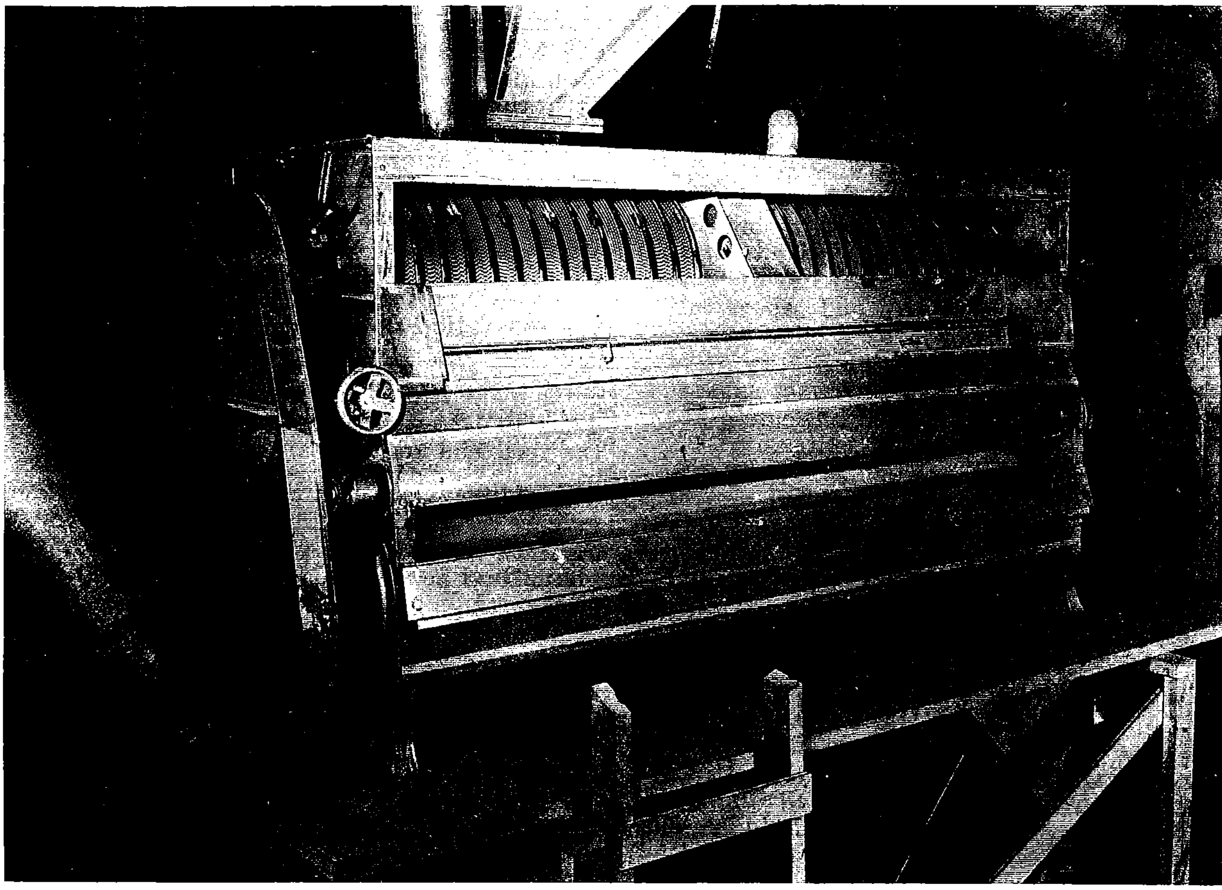

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FIGURE 6.—Indent disk separator above an indent cylinder separator.

Disk Pocket Design

The disk pocket functions like an elevator bucket. As the disk passes through the reservoir of seed at the bottom of the machine, short seed will be held in the pocket by the ability of the seed to become seated on the pocket bottom. Whether a seed is lifted or rejected depends upon its length and position of center of gravity. If the center of gravity extends beyond the pocket lip, the seed is rejected. Seed leaves the pocket in the same manner that an elevator bucket discharges its load.

Disk pockets are made in three basic shapes, and each shape is available in several sizes. In any one disk, the length or height of a pocket is essentially the same as the width, and depth is about one-half the width. The undercut part of the pocket is referred to as the bottom.

The "R" pocket.—This pocket or indent was designed to remove broken rice grains from whole grains. The lifting edge is flat, while the leading edge is round. Pocket design is such that it will reject round seeds, but will lift out cross-broken grain or elongated seeds on the flat surface.

The "V" pocket.—This pocket was designed to remove roundshaped seeds. The pocket has a round lifting edge. "V" pockets tend to reject tubular, or elongated seeds, as they have no flat surface to bear on. These seeds tip out of the pockets as the disk revolves.

Both the "V" and "R" pockets are made only in the smaller sizes, usually 2½ mm. to 6 mm. in pocket width measured on a line from the center of the disk. These disks are designed primarily for removing small materials from a mixture, such as dodder, dock, sorrel, or plantain from fescues and ryegrass. Both types

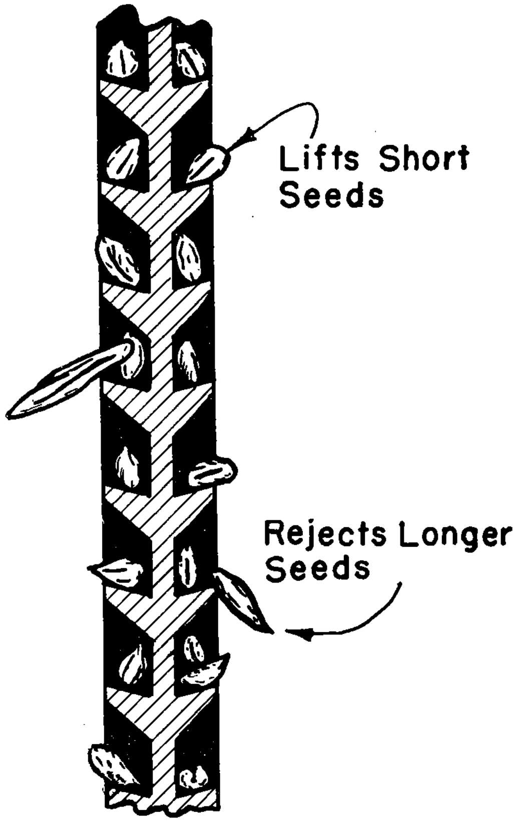

FIGURE 7.—Cross section of an indent disk separator.

of pockets are designed to give the maximum contact surface according to the shape of the material being lifted. The letters "V" and "R" are always followed by a number, which indicates the pocket size in millimeters. For example, an R5 pocket has a flat lifting edge and a radial width of 5 mm.

The square pocket.—Some disks are made with pockets designated solely by letter. They carry no numeral to indicate width, and are available in larger sizes than the "R" and "V" pockets. Normally these pockets are square-faced.

Operation

Disk rotational velocity.—The rotating speed of the disks should be held nearly constant since variations of only a few revolutions per minute affect the efficiency of disk operation. Too great a velocity prevents the material from becoming seated in the pocket bottom, or prevents the disks from discharging seed properly. Low velocity will reduce capacity.

Disk pocket selection.—When several different pocket sizes and types are used in one machine, the disks are grouped into sections, with the smaller-sized pocket disks installed near the seed intake. In this arrangement, material shorter than the crop seed can be lifted and discharged first, then the crop seed will be lifted and the long contaminants rejected. The selection of "R", "V", or other pockets, (or a combination of these) depends on the shape characteristics of the seed and the separation desired.

Reject and rerun.—Adjustments in the machine make it possible for liftings from various disks to be either discharged or returned to the feed end for recleaning.

Seed travel adjustment.—Conveyor vanes may be added or removed as desired to move the seed mass through the machine at a rate giving best separation. Capacity and efficiency of separation will be influenced by the number of short particles to be removed compared to the number of pocket recesses needed to remove them. The travel speed of the mass therefore may need to be varied. Raising the tailings gate tends to keep seed in the machine longer and gives the disks more time to lift out short particles.

Combination units.—Single rotor disk machines may be combined in various arrangements. One typical setup employs a large-pocket unit mounted over a small-pocket unit. When a seed lot is fed into the top unit, the large pockets lift the main mass of seed and reject long unwanted material. Liftings of the top unit then are delivered to the bottom machine where two or three pocket sizes may be in use. Each pocket size will lift a different length fraction, and depending upon the composition of the seed lot, pocket size and disk arrangement can be chosen to either lift the clean seed or discharge it as tailings.

Indent Cylinder Separator

Indent cylinders use centrifugal force and length differences to lift material from a seed mass, making a length-sizing separation; for example, sloughgrass can be lifted, rejecting meadow foxtail.

The indent-cylinder separator, shown as the bottom unit in figure 6, consists of a rotating, horizontal cylinder and a movable, horizontal separating trough. The inside surface of the cylinder has small, closely spaced, semispherical indentations. In operation, the seed mass to be separated lies on the bottom of the cylinder. As the cylinder rotates on its axis, the short seeds in the mass are lifted from the mixture by the numerous indents. At some point before reaching the top of the rotation, the seeds drop from the indents and are received by an adjustable trough or vibrating tray. (See fig. 8.)

Indent Pocket Design

Shapes.—Various shapes of indents have been tested. The shapes of bottoms and sides, the slope angle of the sides, and the indent depth in relation to width provide a wide range of separation characteristics. For example, an indent with cone-shaped sides was best for the removal of seeds which would not roll readily. A cylinder having spherical-shaped indents drawn slightly shallower than their diameter was better for removal of round seeds, such as crimson clover or soybeans. Indents with straight, vertical sides showed good lifting ability, but they became plugged more readily than indents with tapered or curved sides.

In the conventional indent cylinder, a compromise in pocket design was reached where side slope, depth, width, and shape provided the best results for the most seeds normally encountered. The indent is hemispherical and its size is described by a number which indicates its diameter, expressed in 64ths of an inch. For example, a No. 4 indent cylinder has pockets 4/64ths of an inch in diameter. Indent sizes available range from No. 2 to No. 32. This numbering scheme does not indicate depth, and depths vary somewhat in the same size indent made by different companies.

Selecting the indent.—Good selection involves the use of the smallest size indent that will satisfactorily lift all material to be removed. The combination of centrifugal force and indent size lifts short particles and carries them the highest out of the main seed mass. Next to fall from the indent are intermediate-size seeds. The longest seeds fall free of the indent only a short distance above the seed mass, or are not lifted at all.

Some materials are too long to lift and may roll along the bottom of the cylinder causing a stratification of the seed mass. To prevent this stratification, screw conveyors or similar devices inside the separator agitate the seed. This also tends to level the seed mass in the machine and prevent buildup at the feed end. Too much buildup would let material enter the separating trough without having been lifted by the indents.

At the feed end of the cylinder there are many undersize particles in the seed mass. These quickly find their way into indent pockets and are lifted. As these sizes are depleted and the mass works toward the center of the cylinder, the intermediate-size material is removed. At the tail end of the machine, the final and closest length-sizing is accomplished. There usually is a retarder at the tail end to act as a dam and maintain a satisfactory depth of material in the cylinder. If the cylinder is "starved" at this point, the indents

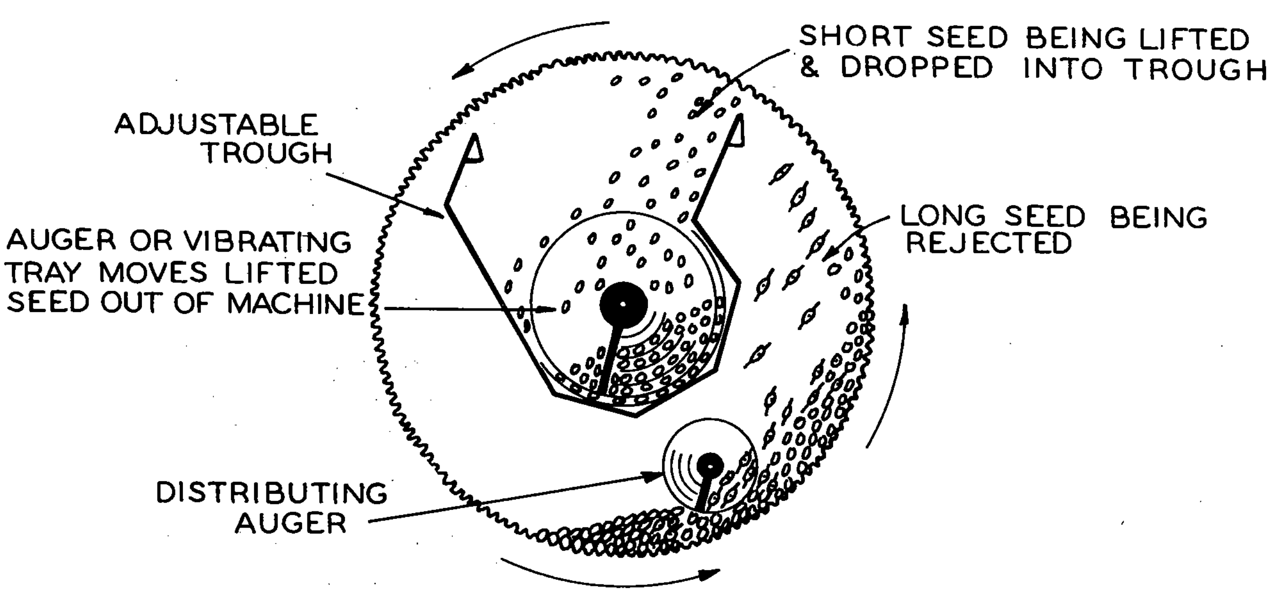

FIGURE 8.—Cross section of an indent cylinder separator.

will lift longer particles than desired. Material flows through the cylinder from feed to tail end by gravity or by an open conveyor running in the mass of material.

Operation

The indent cylinder generally shows its greatest efficiency when lifting dense material. For this reason, the unit finds much use with small grains and legumes. Although not as extensive, its use with grass seed is increasing.

Unlike the disk separator, seedcoat texture, density, and moisture content of the seed do affect separation in an indent cylinder. Friction of the seed slipping out of the indent affects the distance it will travel in the pocket before being dropped. Hence, a rough or wet seed will be lifted and carried from the seed mass more readily than a slick, dry one. The following two adjustments, together with the variations in physical properties of seed, provide a wide range of separation response in this machine.

Speed of cylinder.—A seed is held in the indent recess by centrifugal force sufficient to lift it from the seed mass and to retain it until some determined point of the travel arc is reached. Adjustment for cylinder speed is therefore provided on this machine. Speed should not be increased beyond the amount required to carry the seed to a point directly over the cylinder axis. Speeds in excess of this amount will not allow the seed to drop from the indent. On the other hand, speed must be great enough to lift seed from the mass. Between these two extremes, maximum separation efficiency can be obtained.

Adjustment of separating trough.—The edge of the separating trough can be set at any position giving best separation. Trough position for any given seed mixture will be dictated by the speed of the cylinder, indent size and shape, and level of the seed mass. Combination of these variables gives considerable flexibility in operation.

Methods of Use

Single unit.—Where only one length separation is needed, a single unit is used in the processing plant.

Multiple units.—For more than one length separation, a useful multiple-cylinder unit can be arranged wherein the cylinders are grouped vertically, with the top cylinder having a medium-size indent. Liftings of the top cylinder are sent to a lower cylinder fitted with a small indent. Tailings of the top cylinder are sent to another lower cylinder fitted with a large-size indent. The top cylinder acts as a "splitter," and the final separations of each fraction are made in the two bottom cylinders.

Combination.—The indent cylinder also can be employed as one component of a single assembly offering several mediums of seed processing. For example, equipment is manufactured which provides for scalping, aspiration, disk separation, and cylinder separation all in one machine.

Special Indent Cylinder

Microscopic measurements of seeds lifted by commercial indents have shown that in many cases there is enough length difference to salvage a high percentage of the crop seeds removed with the contaminants. Special experimental cylinders designed according to seed measurements were found effective in making these separations.

Seed Measuring

Specific seed types and their contaminants were measured microscopically to determine length, width, and thickness for each component. This was done with the equipment shown in figure 9, using a scale in the microscope eyepiece to read dimensions to the nearest thousandths of an inch.

An analysis of plotted measurement data provided the following information: (1) The differences, if any, in the ranges of length, width, and thickness dimensions of crop seed and contaminant; (2) the optimum diameter and depth of an indent to exploit length difference; (3) the optimum type and size of screen hole to exploit width or thickness difference; and (4) a basis for predicting yield and purity of final "clean" product.

Seed measurements have indicated consistently that alfalfa and pigweed, for example, are very similar in width and thickness, but that most alfalfa seeds are longer than pigweed. Likewise, measurements of bentgrass and its frequent contaminants show that the bentgrass is significantly longer.

Special Indent Design

Capitalizing on existing length differences, indents were designed from seed measurements to remove short contaminants from bentgrass, pigweed from alfalfa, and many other weed seeds from crop seeds. For bentgrass mixtures, a straight-side indent 0.032 inch in diameter

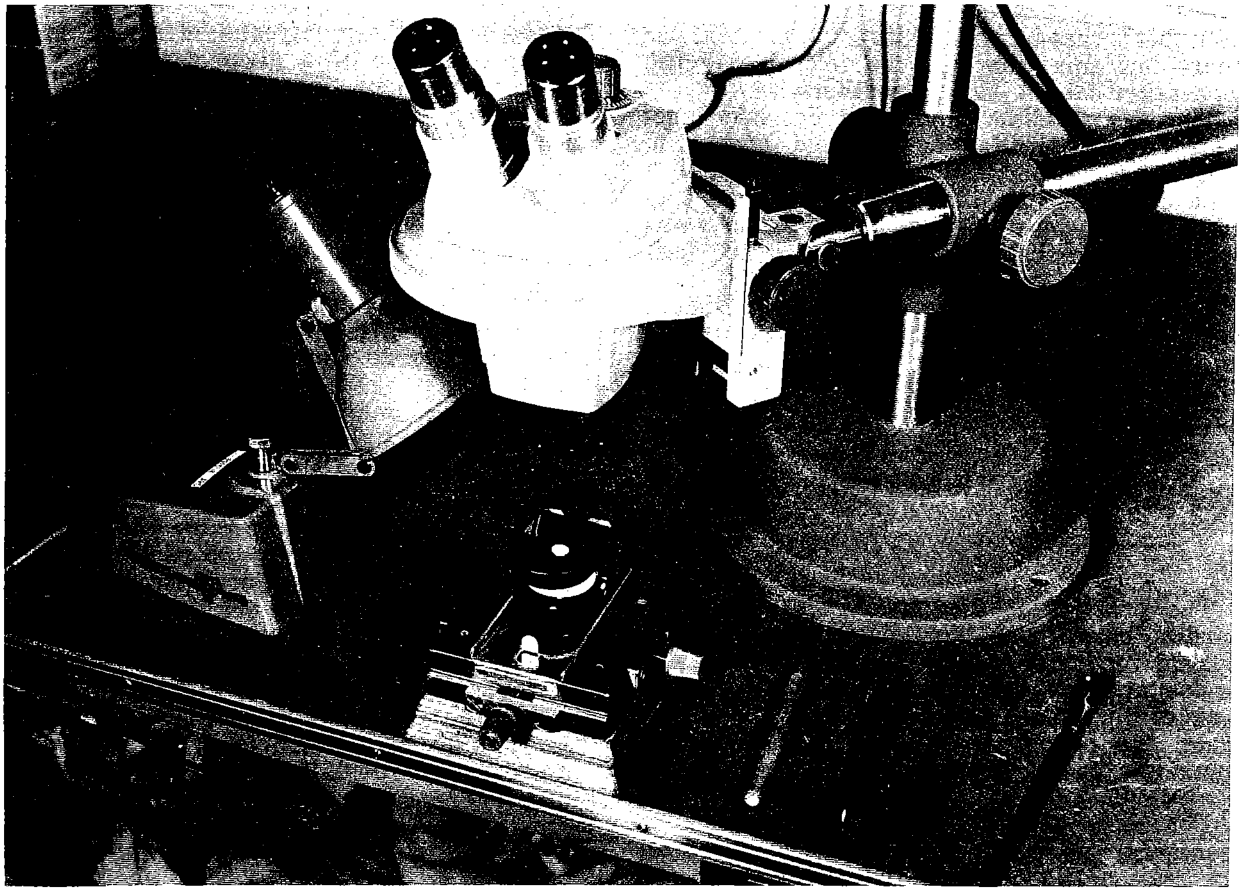

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FIGURE 9.—Equipment for measuring seed microscopically.

and 0.012 inch in depth was constructed and used successfully to remove such contaminants as Western yellowcress, red sandspurry, toad rush, path rush, mouse-ear, big mouse-ear, shepherds-purse, and small dirt clods.

To remove pigweed from alfalfa, a straight-side indent was designed and tested that has a hole depth approximately one-half that of the No. 4 commercial indent generally used. Although it made a good separation, this indent was abandoned because short alfalfa seeds lodged crosswise in the holes. To overcome the lodging, a shallow hemispherical indent was produced (0.065 inch in diameter and 0.025 inch in depth) that performed satisfactorily.

Processor Trials

Farm and commercial seed processors have had special indent cylinders constructed for cleaning bentgrass, alfalfa, and other seeds. In processing bentgrass, the straight-side indent has shown favorable performance—contaminant removal is good, crop shrinkage is small, and indent plugging is negligible. In-plant operation has shown that care must be taken not to flood the "bentgrass" cylinder since this deprives some contaminant of the chance to encounter an indent and be lifted out.

Another important factor in processing small seeds like bentgrass is cylinder speed. Tests have shown that slow speeds must be used to permit small seeds to nest in the indents. Best results were obtained with a peripheral speed of 30 feet per minute which is equivalent to 5 revolutions per minute in a cylinder of 23-inch diameter. At these low speeds, centrifugal force has little to do with the lifting of a seed; instead, the relationship of seed length to indent size is the controlling factor.

To minimize plugging, a brush can be mounted at top-dead-center which will help free lodged seeds. Capacities are relatively low with bentgrass—from 30 to 100 pounds per hour—but this rate may be tolerable if the separation cannot be made otherwise.

The straight-side indent has not been successful with alfalfa in full-scale operation.

Even though pigweed removal was good with little crop loss, the indent plugging was prohibitive. However, good performance was obtained with the special, shallow, hemispherical indent.

Several manufacturers of commercial indent separators will now construct special cylinders on request with a greater choice in depth and diameter of indents.

Screen Selection According to Seed Measurement

The practice of seed measuring, described earlier, has proven very helpful in selecting screens for a size separation. When seed measurements from representative samples of crop and contaminant are tallied on a common scale, the comparison shows immediately if there is a usable difference in width or thickness dimensions.

For example, the range of width measurements for the contaminant may be lower on the scale or higher than the width range for the crop. This indicates three things: (1) Width differences can be used to separate crop and contaminant; (2) a round-hole screen should be used because a round hole senses width and separates particles on this basis; and (3) the ideal hole diameter of the screen can be picked from the scale at a value between the two width ranges.

Another approach is indicated if the range of thickness measurements for the contaminant should fall in a different region of the scale than thickness measurements for the crop. A slotted-hole screen (perforated or wire mesh) should be used here because a slot senses thickness and separates on this basis. Again, a scale value that falls between the thickness ranges will determine the optimum hole size. In this case, the important hole dimension is the minimum opening in the slots.

Frequently, the ranges of width or thickness measurements for crop and contaminant will overlap, particularly if the seed lot has been through a preliminary sizing operation. When there is some overlap, the plotted data may indicate a particular hole size that can make a partial separation or a complete separation but with some crop loss. From representative samples, the measurement data provide a basis for predicting the purity and lot shrinkage resulting from use of a given screen.

Depending upon the actual distribution of seed measurements in overlapping ranges, it may be possible to exploit width differences with one screen (round-hole) and thickness differences with another screen (slotted-hole). This possibility, as well as the hole size to use, will be indicated by the plotted data.

The seed measuring technique described here can be used as an aid in determining proper screens or indents for any of the seed separators discussed so far—all of which are size sensitive.

Specific Gravity Separator

The specific gravity separator classifies material according to density or specific gravity. This unit was originally developed by the mineral industry to separate ore from clay or dirt and to grade ore in mining districts. The gravity separator, as it is commonly called, has been adapted by the seed industry for the grading of seed and the separating of crop seed and contaminants. (See fig. 10.)

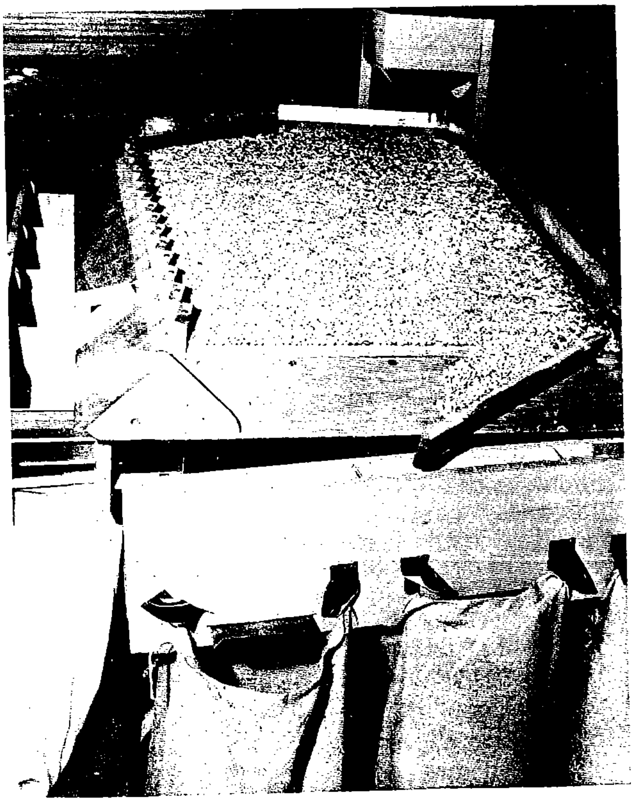

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FIGURE 10.—Specific gravity separator.

There are three basic rules that apply to gravity separation:

1. Particles of the same size but different ties can be separated.
2. Different-size particles of the same density can be separated.
3. A mixture of particles of different sizes and densities cannot be separated.

Component parts of the gravity separator are an airblast fan, an air-equalizing chamber, a perforated deck, a variable-speed eccentric, deck rocker arms, a feeding or metering device, a deck end-raise adjustment, and a deck side-tilt adjustment. The end-raise adjustment varies the inclination of the discharge edge. The side-tilt adjusts the deck so that the back is higher than the front. One end of the deck is the discharge edge and the sides are the banking rails.

A mixture to be separated is metered at a uniform rate to the back of the deck. The slant of the deck and its oscillating motion move the seed over the deck. Air forced up through the porous deck from the equalizing chamber forms thousands of small jets which cause the material to stratify into layers of different densities in much the same manner as water stratifies ground cork and sand. Cork floats on the surface of water, and sand will form a layer on the bottom. In the air-stratified material, the light material floats and the heavy material is in contact with the deck, as shown in figure 11. The oscillating motion of the deck "walks" the heavy material uphill nearly parallel to the discharge edge, and the air "floats" the light material downhill. As the material travels from the feed point on the deck to the discharge edge, a gradation of material takes place ranging from light material on the lower side of the deck to heavy material on the upper side. By means of movable splitters, the discharge can be divided into any number of density fractions.

To illustrate the machine's capability, consider a seed lot made up of crimson clover, wild geranium, dirt clods, and rocks. When this mixture is passed over a properly adjusted gravity separator, the geranium seed and immature clover seed will be discharged at the low side of the deck, the rock and heavy dirt clods at the upper side, and the good crimson clover seed in the middle.

The Deck

The deck can be called the "heart" of the gravity machine, and deck covering plays an important role. Separation efficiency is dependent on air distribution through the deck, and on inclination and movement of the deck.

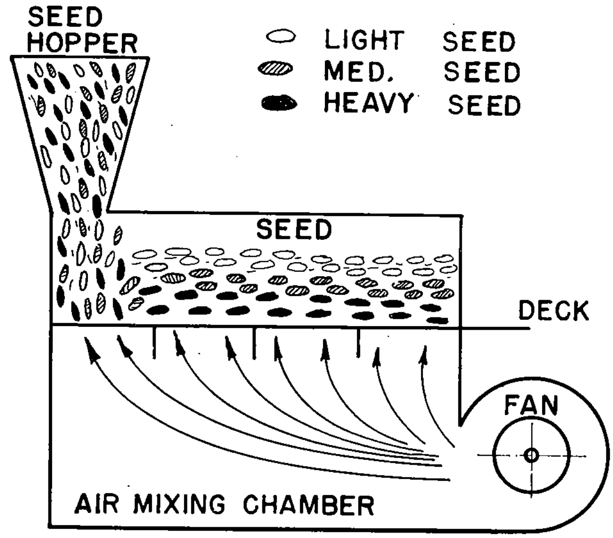


FIGURE 11.—Cross section of specific gravity separator.

About three or four types of deck coverings are needed to handle a range of seed crops varying in size from small grasses to beans. Coverings that have veen used satisfactorily are linen, other cloth of various weaves, small-hole perforated metal, plastic, and wire mesh.

The main job of the deck covering is to help stratify seed material above the deck, yet adequately restrict airflow to build up static pressure within the air chamber and insure uniform air distribution. A closely woven covering gives best results for small seed, while a coarser weave is required for large seed. It is imperative that the deck covering be made from material that will withstand abrasion and is free of lint, which would collect dust particles and clog openings, that would prevent uniform air distribution.

Adjustments

Feed rate adjustment.—The rate of material entering the gravity deck is important and greatly affects operation efficiency. Optimum rates vary according to the difference in density or specific gravity of the mixture components. The greater the difference, the more rapid will be the travel of light material to the low side of the deck and the subsequent moving of heavy material to the high rail. Greater feed rates are possible with this type of mixture. Conversely, when separating a mixture with small differences in specific gravity, seed travel toward the sides is not as pronounced, and feed rate must be reduced.

Insufficient feed rate causes seed to travel across the deck in a thin bed, and portions of the deck may be "starved." For satisfactory separations, the deck surface should be covered at all times. An excessive feed rate will flood the deck, prevent proper stratification of the material, and cause good seeds to be discharged with the middlings or rejects.

Air adjustment.—The airstream through the porous deck prevents light seed from touching the deck while it "floats" to the low side. The air is regulated to permit heavy seed to contact the oscillating deck. The sideways motion of the deck imparts an uphill direction to the heavy seed.

A common error in adjustment is an oversupply of air through the deck. If this is the case, the intense airstream acts as a mixing agent rather than a separating means, and formation of horizontal layers or strata does not take place. The basic principle of successful gravity operation consists of stratifying the particles into layers of different densities through the use of air, and separating the layers by a combination of eccentric motion and inclination of the deck. These actions take place in two zones on the deck—the stratifying area, and the separating area.

The size of the stratifying area at the rear of the deck depends on existing differences in specific gravity of the seed particles. The greater the difference in specific gravity, the smaller will be the area required for stratification. Seed particle motion in the stratifying area can be considered essentially vertical, and results in a stratified seed mass, with light material "floating" on top and heavy material partially suspended just above the deck surface.

The remaining portion of the deck is the separating area. Here, motion of the seed particles is confined generally to certain layers, the direction of motion being essentially horizontal. The lifting action of the airstream still must be maintained at a degree sufficient to retain the formerly established stratification. However, as the seed particles proceed on their journey to the front or discharge edge of the machine, the stratification becomes less pronounced. Movement of the lighter particles to the low side of the deck and heavier particles to the high side begins to appear. The separation becomes complete when the vertical stratification has dissipated and given way to a horizontal gradation of material as it flows off the deck.

Excessive air rate tends to shift the seed material on the deck to the low rail and produce uncovered areas at the upper rail. Insufficient air rate shifts the seed material to the high rail with uncovered areas appearing at the lower rail. Satisfactory operation requires uniform coverage of the deck at all times.

Side-tilt adjustment of the deck.—The side-tilt adjustment (back to front) depends upon the area required for stratifying. The greater the difference in specific gravity of the seed components, the smaller will be the required stratification area, and the steeper may be the side tilt of the deck. Conversely, a flatter tilt is required for seed mixtures having more similar specific gravities. Capacity of the gravity machine is directly related to the side tilt; therefore, the most efficient operation involves the maximum side-tilt setting that still gives the mixture enough time on the deck to become separated.

End-raise adjustment of the deck.—Increasing the end-raise inclination of the discharge edge causes more material to flow toward the low side of the discharge edge, and flattening the raise moves material to the high side. The usual slope of the discharge edge is 2° - 6° from the horizontal, although greater slopes may be required for some seed lots.

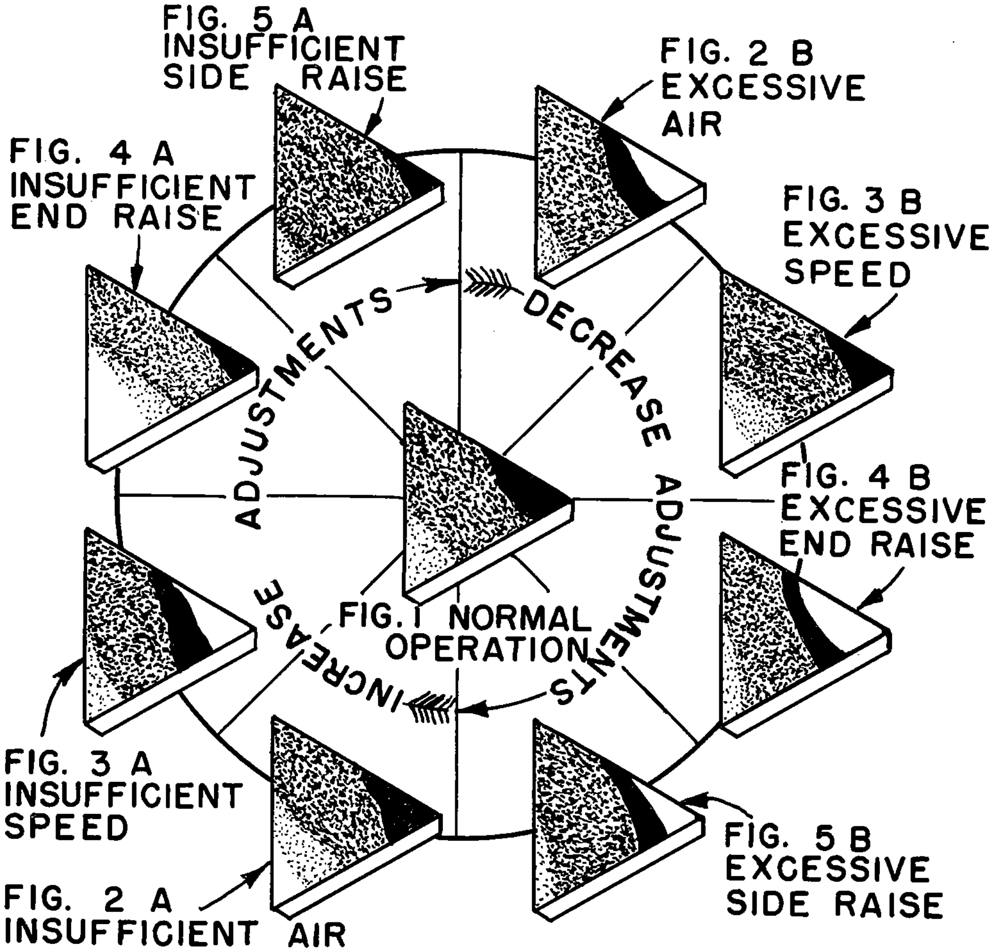
Eccentric thrust adjustment.—Heavier materials of the seed mixture are forced to travel uphill due to motion induced by the eccentrics. This uphill travel is caused by the inclination of the toggles supporting the deck, which are activated by the eccentric thrust. The deck is given a horizontal motion as well as an upward and downward motion, which moves seed in the direction of the deck travel. The deck surface then drops from the seedbed and again contacts it on the next forward stroke. Heavy seed particles "hop" across the surface of the deck at a rate governed by the various machine adjustments. The faster the motion, the faster the movement of material across the deck to the upper side. Slowing the motion tends to shift seed toward the low side of the deck.

All five of these machine adjustments are of critical importance and are closely interrelated. They must be matched properly to obtain efficient operation of a gravity separator. Figure 12 illustrates typical deck patterns for normal operation and for unbalanced conditions resulting from faulty adjustments.

Air Separator

Many different types of air separators are manufactured for seed processing. Some are called aspirators and others, pneumatic separators, but all use the movement of air to divide materials according to their terminal velocities.

GRAVITY ADJUSTMENT CHECK CHART



A. START THE SEPARATION AND WAIT FOR THE MATERIAL TO DEFINE A CONSTANT PATTERN OF DISTRIBUTION.

B. COMPARE EACH PATTERN OF MATERIAL DISTRIBUTION WITH FIG. I FOR IDEAL OR OPTIMUM ADJUSTMENTS.

C. CORRECT ERRORS OF ADJUSTMENT IN THE FOLLOWING ORDER.

1. AIR ADJUSTMENT FIG. 2 A OR 2 B
2. ECCENTRIC SPEED FIG. 3A OR 3 B
3. END RAISE SLOPE FIG. 4A OR 4 B
4. SIDE RAISE SLOPE FIG. 5A OR 5 B

FIGURE 12.—Check chart for adjustment of specific gravity separator.

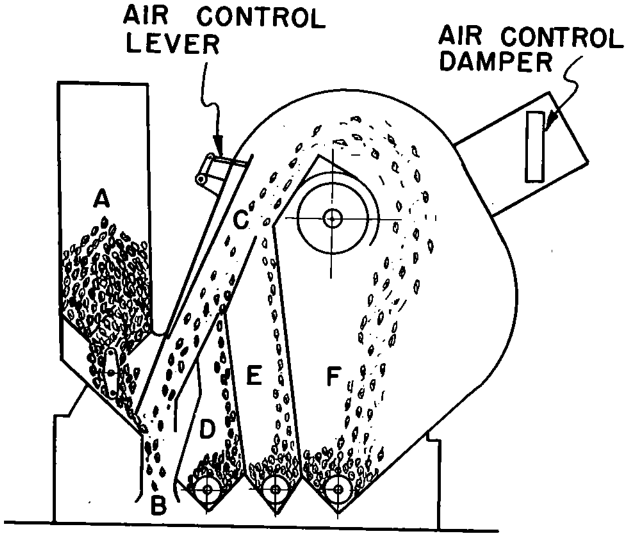


FIGURE 14.—Cross section of fractionating aspirator: A, Feed hopper; B, air column through which heavy seeds fall against the airflow; C, column into which lighter seeds and chaff are lifted; D, column which receives the heavier liftings; E, column which catches salvage grass seed, broken seed, or light and unusable seed; F, column into which extremely light waste materials are delivered.

can be regulated by the air-control damper in the fan discharge pipe and by a variable-speed electric motor driving the fan. This separating unit can provide four fractions in a continuous operation.

Figure 15 is a cross section view of a pneumatic separator. When seed enters the feed chute, the light seed, splits, broken seed, chaff, and straw are lifted by the airflow up through the column and are deflected by an inverted cone to a discharge pan. Heavy seed falls against the airflow until it is diverted by an inclined screen to the heavy seed outlet. In principle, this separator is much like the blowers used extensively by seed analysts in seed-testing laboratories. An essential difference, however, is the continuous feed-discharge feature of the pneumatic separator as contrasted to the batch operation of the seed-testing blowers.

With adequate control of airflow and feed rate, many precise separations can be made with air separators. Examples are removing rattail fescue and quackgrass from meadow foxtail, empty tree seed from full seed, sunflower hulls from the meats, broken and immature sorghum seed from good sorghum seed, halfbeans from whole beans, and cone parts and trash from various flower seeds.

Velvet Roll Separator

The velvet roll separator is a special seed-cleaning machine that divides material by differences in surface texture and shape. It consists primarily of pairs of velvet-covered rollers placed side by side in contact with one another, and set at an angle. The rolls, when viewed from the top, rotate outwardly in opposite directions, and have an adjustable shield above them.

Figures 16 and 17 show, respectively, a velvet roll separator and the basic principle of operation. A seed mixture to be separated is fed onto the rolls at the upper end so that seed travels down the incline formed by the rolls. Rough-coated seeds, sharp-pointed seeds, and broken seeds catch in the velvet and are thrown against the shield, which deflects them back to the roll. They bounce back and forth in this manner until they are worked over the roll and out of the mixture. Smooth-coated seeds spin and work their way down the incline and are discharged from the lower end of the rollers. The separation is a graduated one with rougher seed being thrown out first; then progressively smoother material is thrown out as seeds approach the discharge or lower end of the rollers.

The velvet roll machine, like other seed-cleaning equipment, needs balanced adjustments to give best performance. The speed of the rolls, angle of incline, clearance between shield and rolls, and rate of feed are all adjusted according to the particular seed mixture requirements. The clearance between rollers and shield should be great enough so that seed can turn freely without touching both shield and roller at the same time, but small enough so that rough-surfaced seeds will be thrown repeatedly against the shield as the seed comes in contact with the roller. If the clearance is too great, many rough seeds will fall back into the smooth-seed stream. When the clearance is too little, smooth seed will be pressed against the roller and rolled out with the rough-surfaced seed.

The rate of feed is important on a velvet roll machine. If too great, many seeds will not come in contact with the rollers, and therefore will not have the chance to be separated. The rate of feed and angle of incline of the rollers can be increased as the differences in surface texture of the seeds in a mixture increase. The speed of the rolls is another important factor, and should be adjusted as required to make the separation. The faster the roll speed, the greater the "throwout." If too much good seed is being thrown out, the roll speed should be decreased. When too much

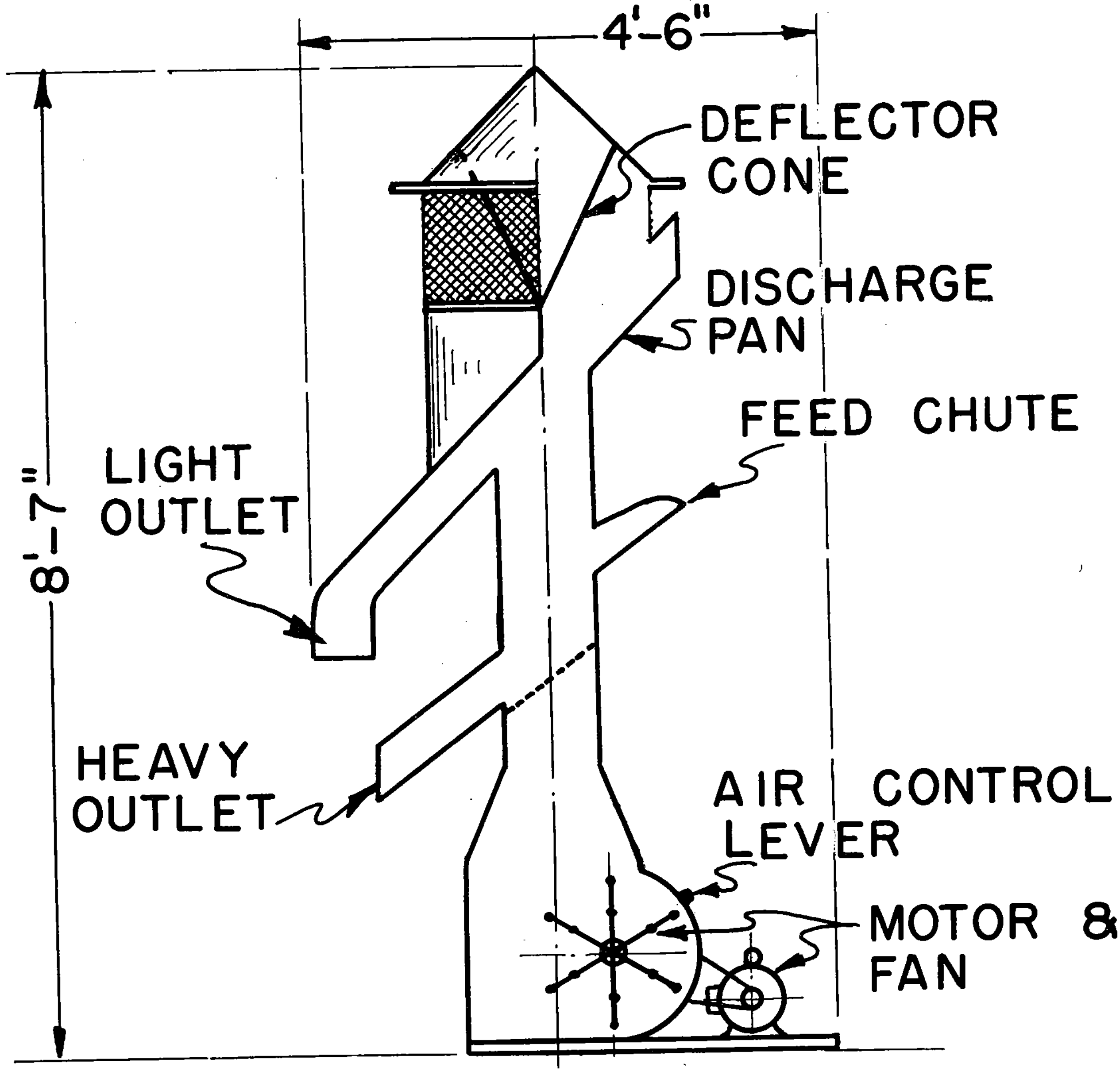


FIGURE 15.—Cross section of pneumatic separator.

rough seed is discharged with the clean seed, the roll speed should be increased.

Since the effects of machine adjustments are sometimes difficult to see, the following practice is recommended in adjusting the velvet roll separator. Make only one change at a time; operate the machine 5 minutes after each change, and then observe the results. If rough-coated seed is found in the smooth-seed discharge, the rolls are running too slow, or the machine is being fed too heavily. If too much smooth seed is being thrown out with the rough seed, the rolls are running too fast.

The velvet roll machine is not complicated, and once set in operation, can run continuously with little attention. It is used to finish many seed separations where capacity requirements are not too high. The name "dodder roll" is sometimes assigned to this unit as it is used to remove rough-coated dodder weed seed from smooth legume seed. Other possible separations are dirt clods from beans, dock from clovers,

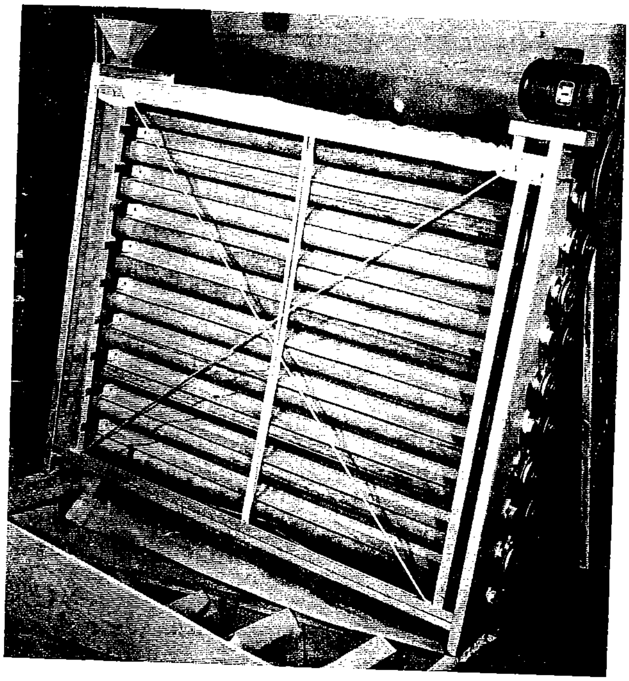


FIGURE 16.—Velvet roll separator.

cocklebur from sunflower seed, unhulled from hulled lespedeza, and many rough weed seeds from smooth crop seeds.

Spiral Separator

The spiral separator classifies seed according to shape and ability to roll or slide. It is a simple machine that has no moving parts and requires very little floorspace. After it is placed under a feed hopper and the feed rate regulated, the spiral will operate steadily with little or no care, and with no power cost. It is light and relatively easy to move into or out of the processing line as needed. It may readily be taken to the seed location rather than moving the seed lot to it. Some separations can be made with this unit that are not possible with air-screen machines, length separators, and other seed cleaners.

Basically, this separator consists of one or more sheet-metal flights wound on a central tube in the form of a spiral. The unit resembles an open screw conveyor standing in a vertical position. (See fig. 18.)

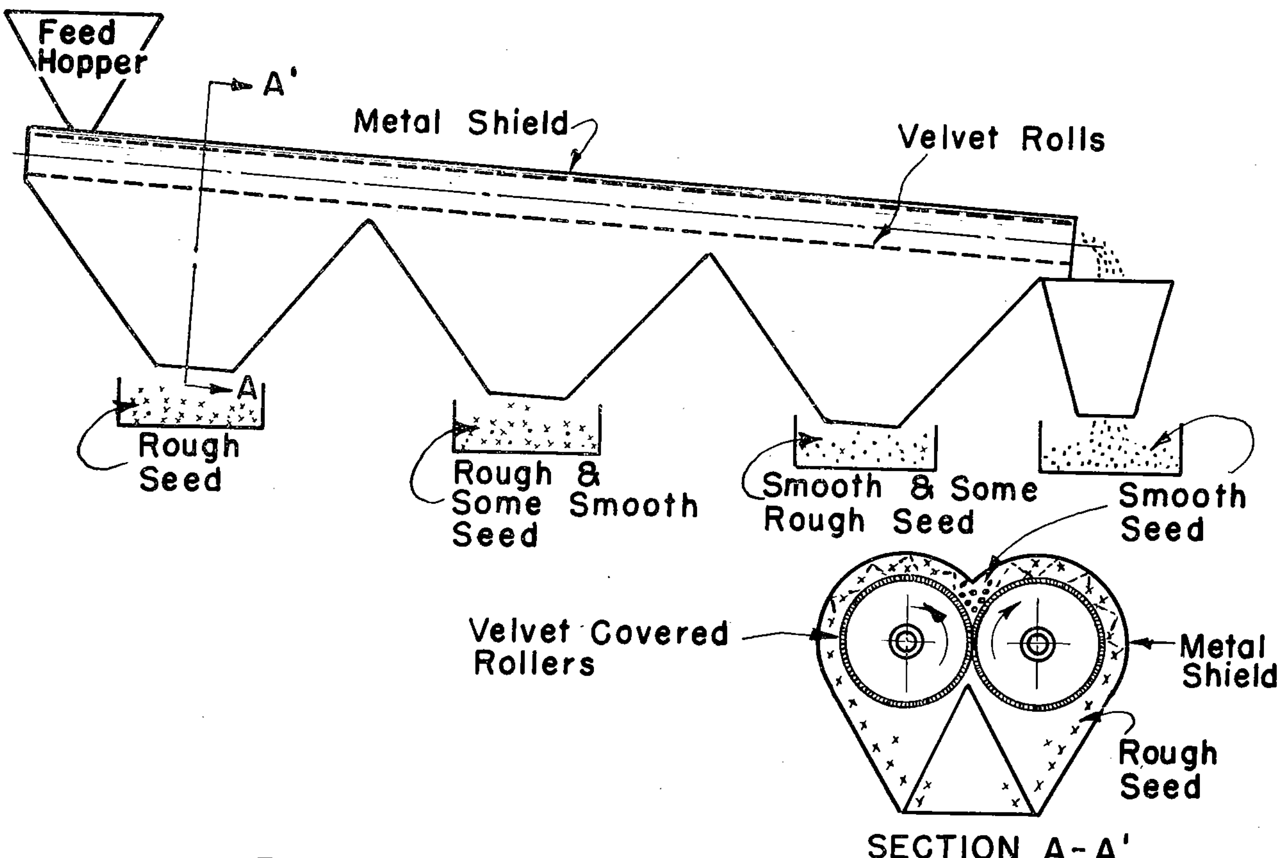


FIGURE 17.—Side view and cross section of velvet roll separator.

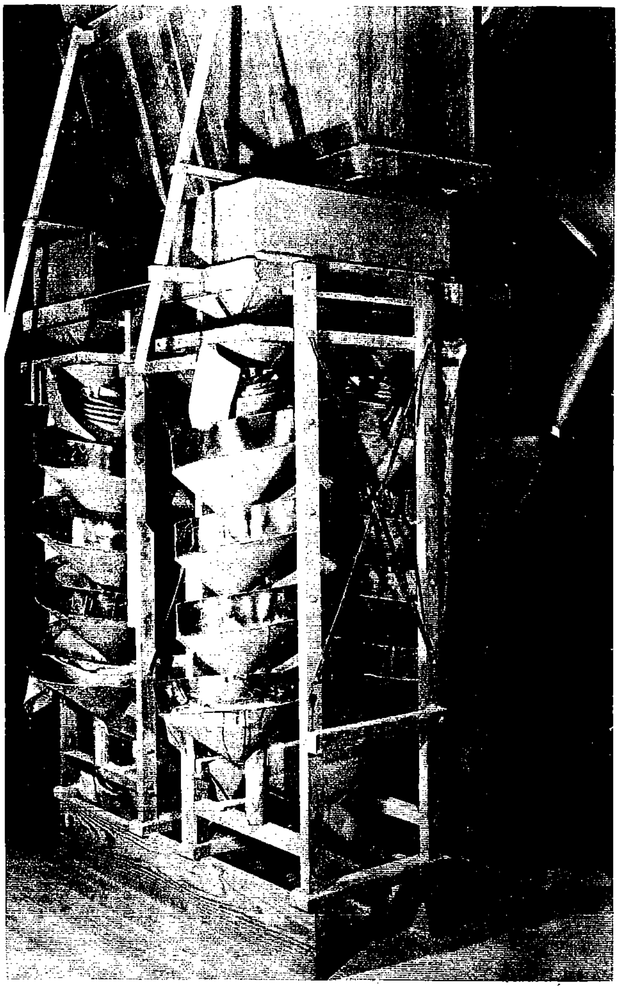


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FIGURE 18.—Spiral separator.

In operation, a seed mixture is introduced at the top of the inner spiral. Round seeds roll down the inclined flight while irregularly shaped seeds tend to slide. The faster the seed travels down the flight, the larger the arc of travel becomes because of centrifugal force. The round seeds, having greater velocity, make a wider circle than the irregularly shaped seeds, and the original mixture can then be divided into fractions by splitters at the discharge end of the flight.

Spiral separators sometimes have multiple flights arranged in order of increasing size, with each flight having a separate discharge chute. Seeds that roll well because of their roundness travel downward in a spiral path of increasing diameter. These seeds will flow over the edge of one flight to another until they reach one of sufficient diameter to coincide with the seed-travel path. Such a separator, with flights of several widths, will produce gradations of a seed mixture ranging from flat seeds at the small-diameter, inner flight to smooth, round seeds on the outer flight.

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

The chief disadvantages of the spiral are lack of flexibility in adjustment, and a relatively low capacity, which ranges from 200 to 700 pounds an hour, depending upon the seed being separated.

Inclined Draper Separator

Like the spiral, the inclined draper also separates seeds on the basis of their ability to roll or slide. The rolling or sliding properties are governed by the shape and texture of the seeds, and by the frictional characteristics of the draper surface they are contacting.

A seed mixture to be separated is metered from a hopper to the center of an inclined draper belt traveling in an uphill direction, as shown in figure 19. Round or smooth seeds, like vetch, will roll and slide down the draper faster than the draper is traveling up the incline. In contrast, flat, rough, or elongated seeds, like oats, will be carried to the top of the

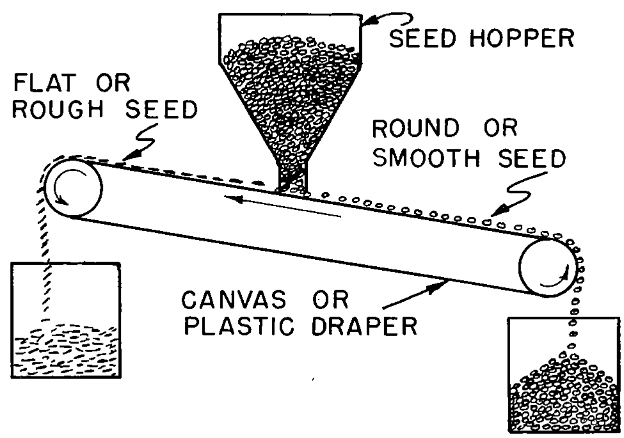

FIGURE 19.—Cross section of inclined draper seed separator.

incline, thereby making the separation. The seeds dropping off the draper at its lower end are gathered in one chute, and the seeds reaching the upper end are dropped into a second chute.

To gain capacity in commercial operation, multiple draper belts can be used in a single machine. (See fig. 20.) The rate of feed to the draper may be varied. The rate should be slow enough to allow each seed to act individually and not be hindered from rolling or sliding by those that are stationary. Also, a seed should not be forced to move by those that are traveling.

The angle of incline may be varied according to the rolling or sliding characteristics of the seed mixture. The speed of the draper may be varied to simulate a shorter or longer length of incline, and belts with different degrees of roughness may be used as the draper. A relatively rough canvas belt may be employed when rolling tendencies are predominant in seed of the lower fraction, while a smooth belt is more useful if a sliding action is wanted for the lower fraction.

In many cases, a smooth belt can do all that a canvas belt does, and in addition, can provide a means of making a more precise separation. This is particularly true with small seeds of different shape or texture, like timothy and dogfennel. Even though there is a shape difference in these seeds, the protruding fibers in a canvas belt will prevent small seeds from rolling or sliding. A smoother surface can detect the differences in shape or texture of these small seeds and let one roll or slide downhill, thereby making a separation.

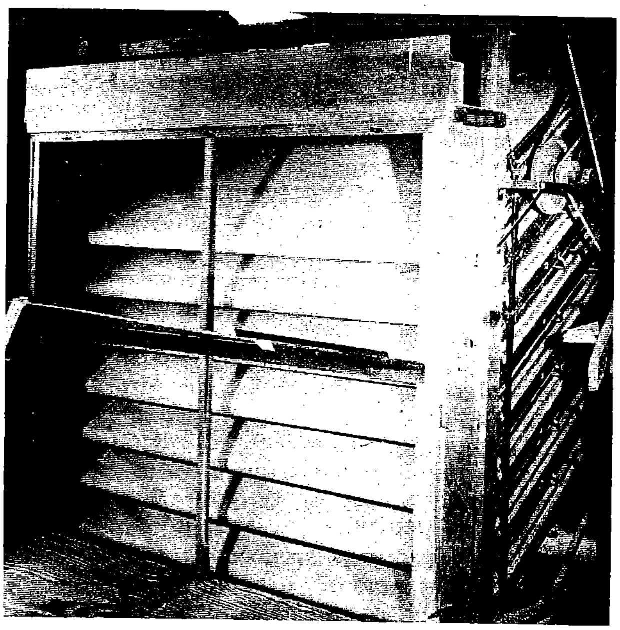

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FIGURE 20.—Commercial inclined draper equipped with multiple draper belts.

In adjusting the machine to perform a given separation, start with a very low rate of feed, a slow draper speed, and a flat draper slope. Increase the angle of slope until none of the rolling or sliding fraction of the mixture is being carried to the top. Increase the draper speed until none of the flat or elongated seed is falling off the lower end. Increase the rate of feed until it becomes obvious that quantity is interfering with individual seed action and changing previously set conditions; then reduce the feed rate a small amount.

Typical separations made by the inclined draper are buckhorn plantain from red clover, oats from vetch, grass seed from crimson clover, and other flat, rough, or elongated seeds from round, smooth seeds. This machine is also used extensively for removing trash and weed seed from garden beet seed.

Horizontal Disk Separator

The horizontal disk separator (fig. 21) is a special machine that divides seeds by their relative abilites to roll or slide over a horizontal surface when acted on by varying amounts of centrifugal force. Physical factors affecting this separation are shape, weight, and surface texture of the seeds. The unit is used primarily to salvage rejected seeds from other cleaning equipment. It can separate mixtures where one seed type rolls or slides more readily than another.

The separating action of the horizontal disk is similar to that of the spiral and can be more selective. The disk machine has an adjustable speed control which varies the centrifugal force acting on the seeds and therefore changes the proportions of the mixture retained on the disk or rejected.

The disks are mounted at regular space intervals, one above another, on a hollow vertical shaft. The seed mixture is fed from a hopper into the hollow shaft which meters seed to each disk through variable orifices. A plastic fence with two adjustable outlets confines seed in the center of the disk, discharging two single seed rows, spaced 180° apart, to the outer portion of the disk, as shown in figure 22. Centrifugal force causes round or smooth seeds to roll or slide off into either of two discharge areas, while irregularly-shaped seeds remain on the disk until they are raked off at

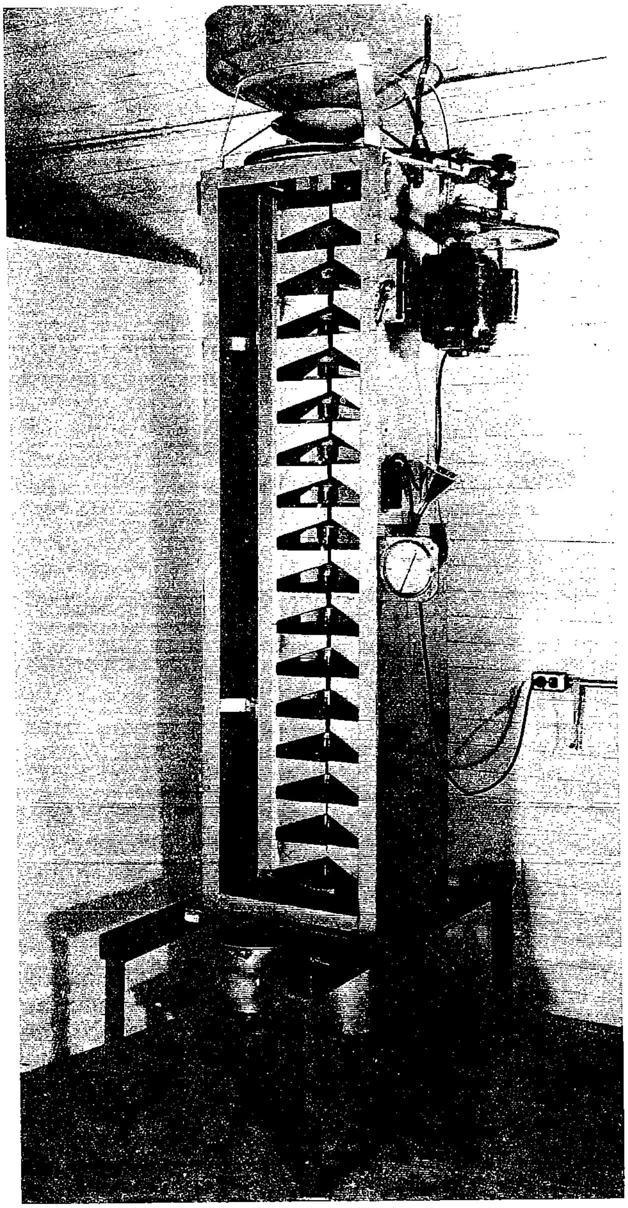

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FIGURE 21.—Horizontal disk seed separator.

two points. The outer region of each disk is banked like a highway curve to offset, partially, the increased rolling tendency due to increased centrifugal force that is present as a seed moves away from the center of the disk rotation.

The 16-disk machine pictured in figure 21 has a capacity ranging from 300 to 500 pounds per hour, depending upon the seed being cleaned.

Magnetic Separator

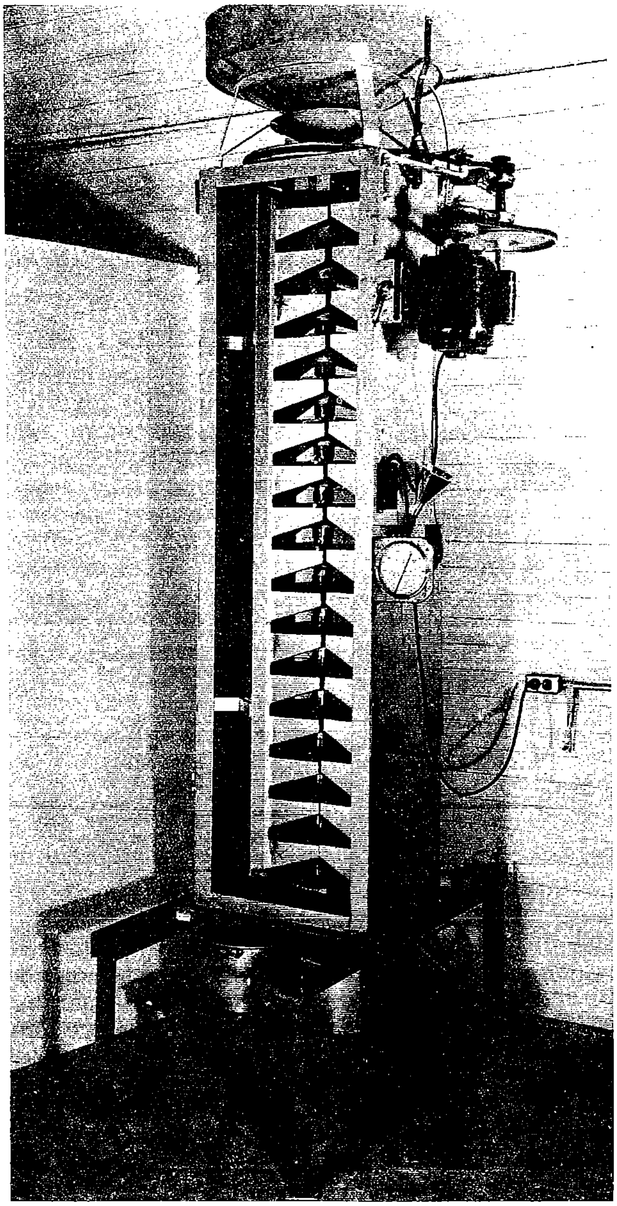
The magnetic separator takes advantage of differences in seedcoat characteristics. Generally, the crop seed will have a smooth coat, like legumes, while the seed or material to be removed will have a rough coat or sticky surface that can pick up and retain a fine iron powder when pretreated with water or a combination of water and oil.

Several different makes of magnetic separators are used in the seed industry representing American, German, and English developments. Some employ permanent magnets and others use electromagnets in their operation. All are considered finishing machines and are becoming increasingly popular as seed standards grow more exacting.

The operating principle of a single-drum magnetic separator is shown in figure 23. The seed mixture is fed into a screw conveyor that tumbles and mixes the seed with a proportioned water spray and a finely ground iron powder. The powder will adhere to rough seedcoats, cracks in a seedcoat, dirt clods, chaff, or seeds with a sticky residue on the surface. The mixture is then discharged from the mixing screw onto the revolving drum, which has a high-intensity magnetic field. The rough-textured or sticky seeds, which are now coated with iron powder, are attracted to the magnetic drum, but smooth good seeds (free of iron powder) flow off the drum in a regular manner, thereby making the separation. If a permanent magnet is used to provide the magnetic field, the seeds adhering to the drum fall by gravity when they reach an unmagnetized area on the bottom or back side of the drum. With electromagnetic drums, a rotating brush at the back of the drum surface removes the iron-coated seeds and inert material as well as free iron powder.

The efficiency of the magnetic cleaning process depends largely upon the components of the seed lot, the water and iron powder used, and the mixing or treating operation. The greater the difference in surface characteristics of the components to be separated, the more effective the separation will be. Best use is made of existing differences when proper amounts of water and powder are thoroughly mixed with the seed lot.

The water and powder dosages will vary according to the amount of contaminant to be removed, roughness and water-absorbing character of the contaminant, and the surface texture of the desirable crop seed. Too little water or powder prevents proper coating of the contaminant. Too much water can cause clus-



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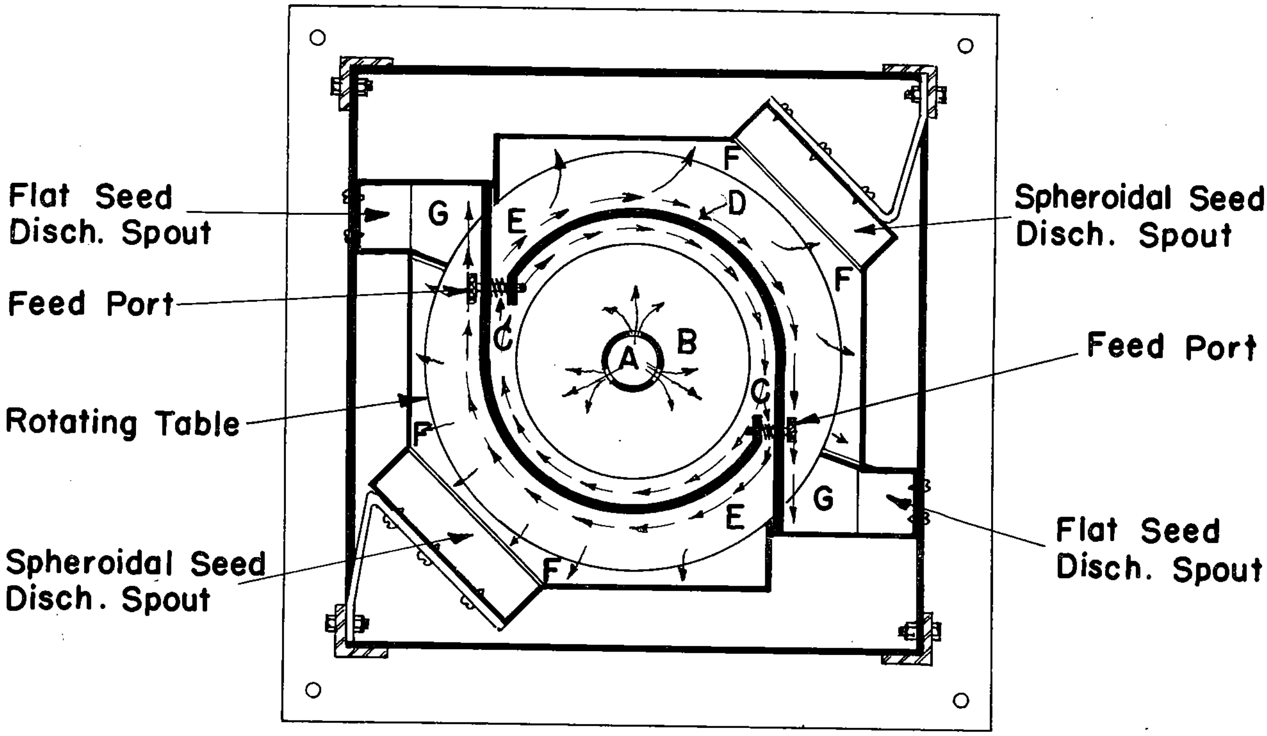

FIGURE 22.—Cross section of horizontal disk separator: A, Hollow vertical shaft which meters seed to the disks; B, inner portion of disk; C, adjustable outlets; D, plastic fence; E, outer area of disk; F, discharge for round seed; G, rakeoffs for flat seed.

tering of seeds, discoloration, excessive crop loss, and poor pickup of powder. Enough powder should be used to insure that the amount needed is available. Greater amounts are wasteful if not reclaimed but not particularly harmful. Seeds with hard, smooth coats (like sericea lespedeza) tend to take up less powder than seeds with rougher coats (like sweetclover).

Various iron powders are available for use in magnetic separation. They all contain a high percentage of pure iron, but they differ in particle size and shape, apparent density, and presence of other elements. Generally, separation efficiency is best with powders of fine particle size. Practice varies in the salvage and reuse of iron powder. There is some evidence that the powder changes with use and becomes less effective; even so, some cleaning plants reuse the same powder or blend salvaged powder with new stock and achieve good performance in their magnetic operations. Other plants use the powder only once.

After the proper amounts of water and powder have been established, it is extremely important to mix them well with the seed lot. Successful magnetic cleaning requires that all of the contaminant, but none of the desirable seed, be coated with powder. Properly operated screw conveyors, augers, and batch units can do an effective job of mixing.

Magnetic separators are effectively used in cleaning clover, alfalfa, lespedeza, trefoil, and other seeds to remove dodder, buckhorn plantain, wild geranium, sorrel, dock, inert matter, and other contaminants. It is claimed that separation of some mixtures is improved by adding a soluble oil to the moistening water. Hulled johnsongrass, for example, reportedly can be removed more effectively from sudangrass by this treatment because the oil helps the iron powder cling to the johnsongrass seed. A light scarification of this seed mixture also helps the johnsongrass to hold powder.

In addition to removing impurities, magnetic separators can be effective in raising germination of clean seed lots. The cracked, broken seeds and some of the immature, misshapen seeds of a clean lot will pick up iron powder and be removed, leaving good, whole seed.

Both the permanent magnet and the electromagnet have performed well as energizing units. The machines using permanent magnets

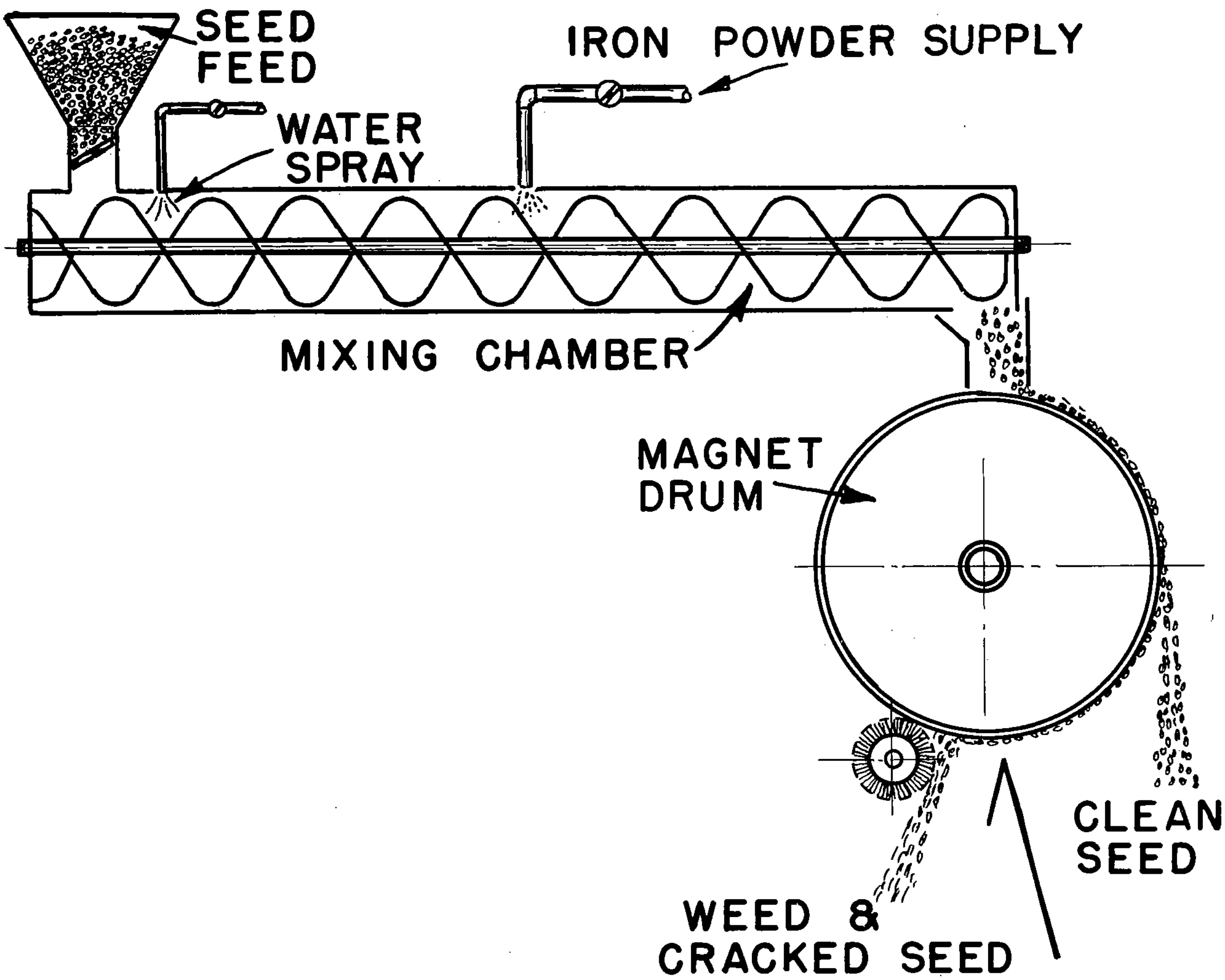

FIGURE 23.—Cross section of a single drum, magnetic separator.

usually cost less than those with electromagnets. On the other hand, the magnetic field can be varied in electromagnetic machines, and this offers the possibility of greater precision in separating certain lots. Regardless of magnet type, most machines use two or more energized drums in series. The clean fraction from the first drum passes over the next drum so that any iron-coated seeds missed by one drum will contact the next and be removed. Multiple drums permit capacities to be increased without sacrificing purity. Capacities of magnetic separators range from 200 to 2,000 pounds per hour, depending on machine size and the seed lot being cleaned.

Bumper Mill

The bumper mill was originally developed to remove weed seeds from timothy. It makes separations by exploiting differences in shape, surface texture, and—to a lesser degree—weight of seeds.

The unit consists of two sets of identical superimposed decks suspended in a rigid frame and connected by a linkage. (See fig. 24.) 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

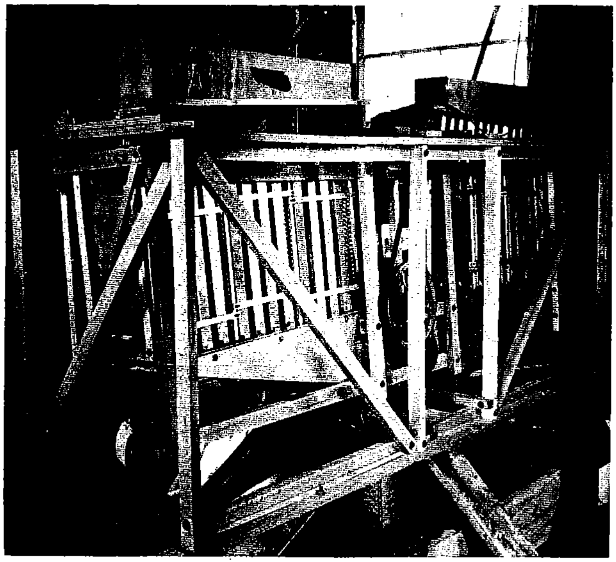

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FIGURE 24.—Bumper mill.

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- × 9-inch smooth metal plates, and a feeder is positioned to supply seed continuously to each plate.

As the rocking deck battery bumps the rubber cushion, all seeds are given an uphill motion. The plump timothy seed has a tendency to roll downhill between each bumping cycle, and will travel a shorter distance uphill than the 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.

When this machine is properly adjusted in deck angle, feed rate, stroke length, and stroke frequency, it can separate alsike clover, Canada thistle, sorrel, ryegrass, quackgrass, buckhorn, and other contaminants from timothy and similar rounded seed.

Vibrator Separator

The vibrator separator is designed to separate seeds by their differences in shape and surface texture. This is an experimental development that has progressed through several stages—it has been constructed as a single-deck laboratory model, as a 30-deck pilot plant prototype, and as a 500-deck full-scale machine.

The vibrator separator is similar to the bumper mill and the gravity separator in that all three machines perform their separations on inclined reciprocating decks. However, the vibrator separator is different from the gravity separator since it uses a solid-textured deck and does not employ air stratification of a seed mass in its operation. Another important difference is that the stroke of the vibrator separator is much faster and shorter than that of the other two machines.

Basically, the vibrator separator consists of an inclined textured deck which is activated by an electromagnetic vibrator whose stroke is adjustable. (See fig. 25.) The whole assembly can be tilted sideways and forward to provide a wide range of deck slopes.

Multiple decks may be mounted in a rigid frame so that one or two vibrators will power the whole assembly. The decks can be of varying textures, as needed, ranging from smooth metal or plastic laminates to rough sandpaper depending upon the seed components being separated. However, a fine-textured sandpaper deck works satisfactorily for most separations and is used on the multideck machines. The vibration can be regulated by a rheostat controller in the electrical circuit which governs the length of stroke.

In operation, a seed mixture is introduced near the center of the upper edge of the inclined deck. The action and direction of vibration causes all seeds to try to climb the incline, but flat, rough, or hairy seeds climb more readily than the rounded or smooth seeds. On each stroke the round, smooth seeds will travel a shorter distance up the incline and may roll or slide to the low side of the deck. The forward deck tilt 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.

With a suitable deck surface, inclination, and vibration, the unit can make many separations which are difficult or impossible with conventional seed cleaners. It will remove silverhair and rough bluegrass from bentgrass, mustard and pigweed from alfalfa, barnyardgrass and dodder from carrot, morning-glory from sorghum and soybeans, vernalgrass from ryegrass, stems from flax, watergrass from onionseed, clods and leaves from various flower seeds, and many other contaminants from desirable seed.

The single-deck unit has been successfully adapted for mechanized purity analyses in seed-testing laboratories where it is used primarily to concentrate quackgrass and Canada thistle in test lots of tall fescue, orchardgrass,

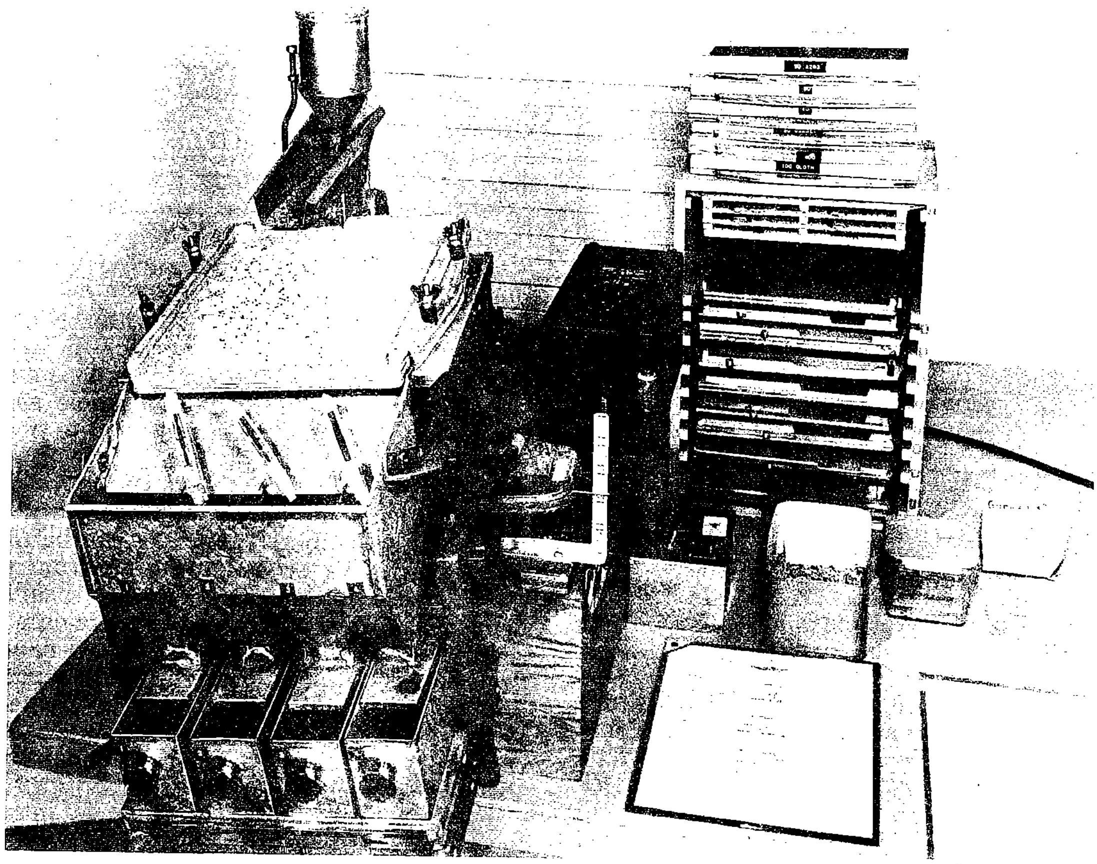

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FIGURE 25.—Vibrator separator (single-deck).

fine fescue, and ryegrass. The machine also can be used to make many other complete or partial separations that may aid the seed analyst, plant breeder, weed researcher, or seedsman who need to process a small quantity of high-value seed.

A 30-deck model was built to test the feasibility of multideck construction in larger-scale operation. It performed well in salvaging good ladino clover from clover-pigweed screenings and in removing silverhair from bentgrass. A seed processor has built and operated a 500-deck unit (shown in fig. 26) based on the same design. The decks are about 4 x 10 inches and are covered with a fine-grade sandpaper (80 grit). The complete assembly is energized with two matched electromagnetic vibrators. Capacity ranges around 200 pounds per hour in salvaging certified ladino clover from screenings.

Electrostatic Separator

Electrostatic seed cleaners take advantage of differences in electrical characteristics of seed to make many separations that cannot be made with conventional seed-cleaning equipment. The degree of separation possible depends upon the relative abilities of seeds in a mixture to conduct electricity or to hold a surface charge.

Electrostatic separations have been practiced extensively in the mineral industry for many years. To a lesser degree, various agricultural foodstuffs also have been cleaned electrostatically. Examples are removing leaf and stem material from raisins, watercress seed from rice, chaff from flour, and contaminants from coffee. Recently, this principle of separation has been applied to seed mixtures, and several makes of electrostatic separators are receiving limited use by the seed industry.

It has long been known that substances can be "electrified" or charged with static electricity. For example, a comb which has been passed through hair will attract lightweight objects like bits of paper. This attraction occurs because the electric charge on the comb is now different from that on the paper. Basically, the same principle is used in elec-

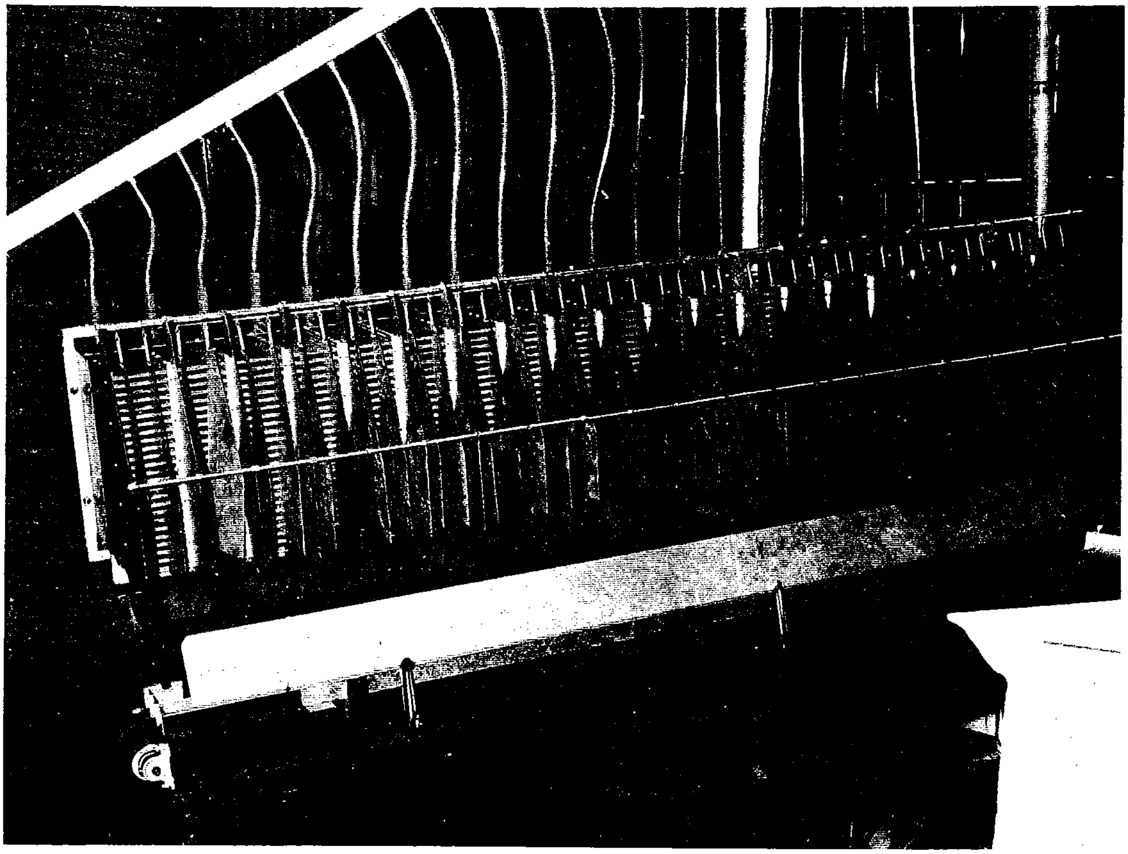

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FIGURE 26.—Vibrator separator (500 deck).

trostatic cleaning where seeds are separated according to how well they retain or lose an electric charge.

The usual arrangement of an electrostatic seed separator consists of a feed hopper, a conveyor belt or cylinder, a high-voltage power unit and electrode, and adjustable dividers and containers. (See fig. 27.) In operation, seeds are metered from the hopper to the belt or cylinder and conveyed into an electric field surrounding the electrode where they become charged. A given seed will tend to hold or lose charge according to its electrical conductivity. Depending on field characteristics, some seeds are repelled by the electrode and attracted by the moving belt. With another field arrangement, the opposite is true and seeds are attracted by the electrode. These attractions or repulsions cause deflections in the paths taken by seeds as they leave the belt or cylinder. Dividers in the drop paths then can be positioned to collect any desired fraction of the distribution.

Field characteristics are dependent on the high-voltage electrode. One position of the electrode will provide a discharging or "pinning" field. Seeds passing through this field are sprayed with electrons and become negatively charged by conduction. The better conductors of the seed mixture will lose this charge and fall in a normal discharge pattern from the belt. Seeds that are relatively poor conductors will adhere to the belt until their charge is neutralized.

A different electrode position can produce a static or "lifting" field. When seeds pass through this field, they receive a positive charge by induction. With seeds that are good conductors, the positive and negative charges already present tend to migrate on the seed surface. 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 attrac-

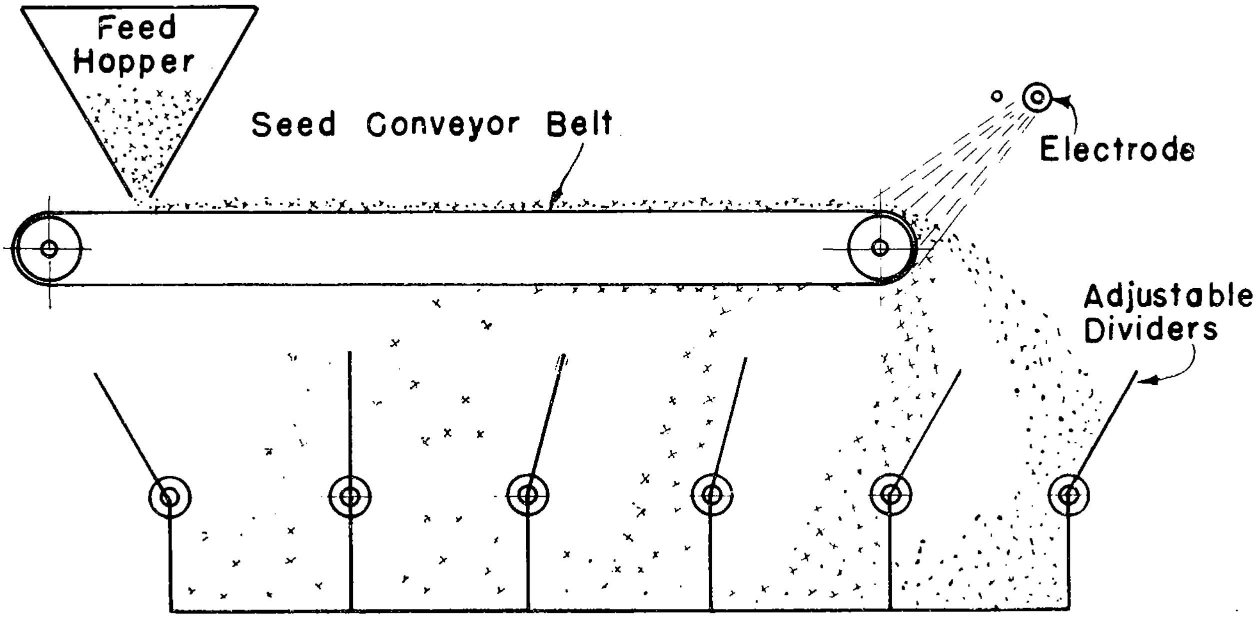

FIGURE 27.—Schematic drawing of an electrostatic seed separator.

tion then exists between the seed and 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.

The best combination of field characteristics, voltage setting, and divider positions for a given separation depend upon the seed mixture and surrounding atmospheric conditions and are best determined by trial and error.

An experimental unit developed for electrostatic separation is shown in figure 28. Main objectives of research conducted with this unit have been to learn what seed mixtures can be separated, the effects of seed moisture content on separating efficiency, and the influence of high-voltage exposure on the germination of seed.

Moisture content was found to play an important role in separation, stemming from the fact that a seed's ability to conduct electricity is influenced by seed moisture. Changes of 2 to 3 percent in moisture were great enough to impair separation. However, variations in seed moisture can be compensated for, to some degree, by changes in machine settings.

Another factor influencing separation efficiency is uniformity of voltage. Uncontrolled voltage variations in the supply line are magnified in the power unit and appear as wide fluctuations at the electrode. Since these fluctuations will distort the seed trajectories, it is important to employ a constant-voltage transformer or other means of regulating the voltage supply.

High-voltage exposure was studied by subjecting Chewings fescue, ryegrass, and subterranean clover to voltages ranging from 10,000 to 45,000 volts in increments of 5,000 volts. In another test, the following seed types were exposed 50 or more times to voltages up to 25,000 volts: ladino clover, red clover, Dutch white clover, alfalfa, common ryegrass, perennial ryegrass, creeping red fescue, and alta fescue. All exposed lots and untreated control samples were germinated in an official seed testing laboratory, and no significant differences were found in germination.

Many seed mixtures have been separated electrostatically in the research program. Some of these are curly dock from red clover, bachelors-button and chervil from common and perennial ryegrass, sheep sorrel from alsike clover, wild radish from crimson clover, red clover from lotus, watergrass and trash from onion, morning-glory from asparagus, trash from bluegrass, whitetop from alfalfa, pigweed from snapdragon, and hulled bermudagrass from white clover.

Acceptance of electrostatic separation in the seed industry has been varied, due in part to operation in uncontrolled climatic conditions. However, research studies indicate that separating efficiency can be improved when

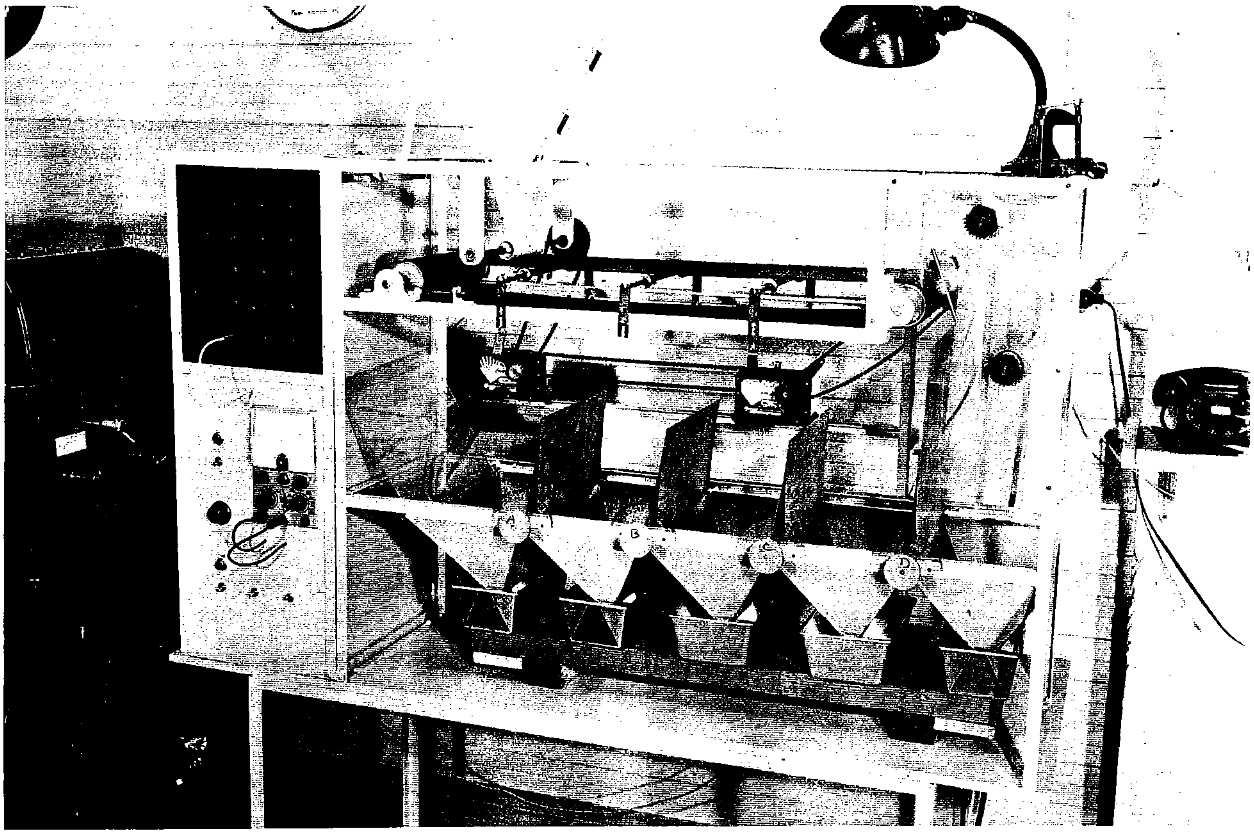

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FIGURE 28.—Electrostatic seed separator developed cooperatively at Oregon State University.

seed moisture and voltage supply are regulated. This means that best results will be obtained when the electrostatic separator is operated in a controlled atmosphere and with a constant voltage supply.

Color Separator

The color separator is an electronic machine that sorts materials according to color or light-dark characteristics. Some of the agricultural products now being color separated are lemons, peanuts, walnuts, coffee beans, peas, garden beans, rice, and raisins.

Several manufacturers produce color separators which vary somewhat in mechanical operation, but are similar in basic concept. (See fig. 29.) The objects to be sorted are passed through a brightly illuminated viewing area where light reflected from the object is compared with light reflected from a standard background surface previously chosen as acceptable. When the light reflection is different, a signal is generated, amplified, and used to eject the off-color object from the mixture, leaving a product of fairly uniform color and shade.

The objects may be conveyed into the viewing area on the ends of suction ferrules, or they may enter by gravity flow. In one type of gravity flow, the objects fall from the periphery of a cone; in another, they are discharged single-file from a horizontal belt so that their trajectory passes through the view area. In all cases, the objects are scanned individually by one or more photocells, any of which can trigger the reject command and remove the unwanted object mechanically or pneumatically.

In a sense, the color separator functions like a human inspector. The photocell is the eye, the electronic circuits are nerves, the amplifier is the brain, and the air ejector is the hand. However, the similarity ends there because the color separator can sense differences not detected by the eye; it can view an object from four sides simultaneously; and it can be set

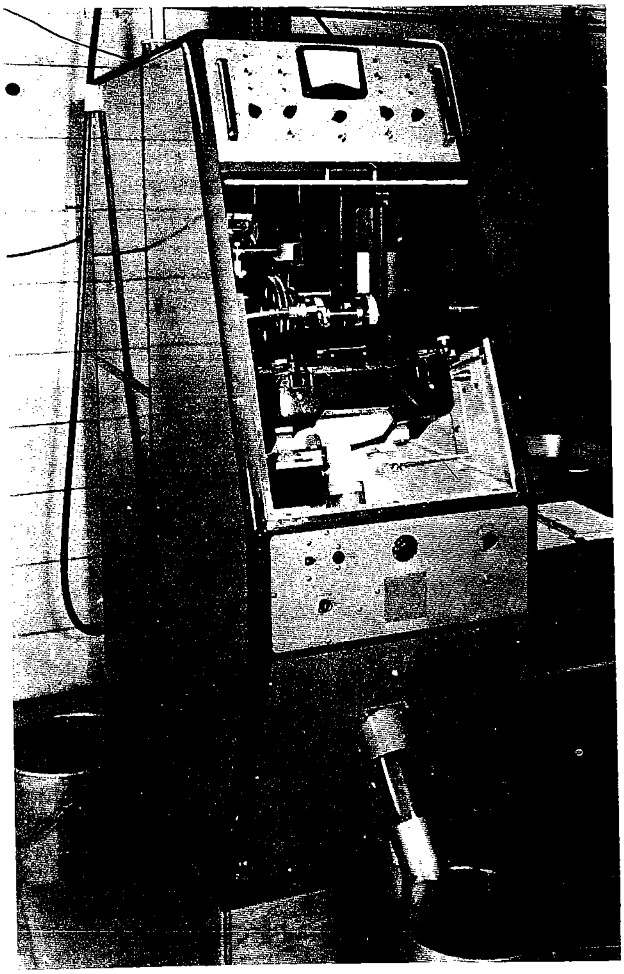

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FIGURE 29.—Color separator.

to produce an end product whose color or shade is essentially constant over any given time period.

Both light-dark separation and true color separation can be accomplished in the same pass through some machines. For example, a machine may be equipped with four viewing stations where each contains a photocell that is light-dark sensitive. In addition, two of the stations may have color-sensitive photocells. This means that six separate optical circuits are at work comparing the light reflectivity of the object with that of the standard background. The separator circuits can be adjusted to reject objects lighter than the background, objects darker than the background, or both. Also, the amplifier can be set so that two different color separations are made at the same time as the light-dark separations. Such versatility lets this type of unit perform some very difficult separations, like the sorting of peas that are discolored in varying degrees and hues from frost damage, weevil attack, bleach, or mold.

Most of the color separations being practiced in seed processing are with relatively large seeds ranging in size from rice to lima beans. Recently, however, special interest has been paid to smaller seeds like sesame, onion, beet, mustard, tomato, and flower seeds. Although small seeds can be separated, capacities usually are low—for example, about 40 pounds per hour with mustard seed. In contrast, peas and corn can be processed at rates up to 500 pounds per hour.

Present techniques in color separation evaluate every seed singly. Although this practice tends to limit capacities, it offers the advantage of extremely accurate and consistent results.

Resilience Separator

The resilience separator is an experimental development designed to separate seeds on the basis of difference in resilience or bounce properties. In its simplest form this machine consists of a feeding device that drops seeds onto an inclined hard surface, and several pans located to catch seeds from different trajectories as they bounce after impact.

One test model consists of a long inclined plane interrupted with several bounce plates. As a seed mixture slides down the plane and impacts on the plates, seeds that bounce farthest from the plane are trapped and others continue down the plane to another plate. In this way, one seed gets several chances to bounce out of the mixture during one continuous pass. Relatively poor bouncers tend to miss each trapping point and are discharged into a collector at the bottom of the plane. A full-size unit of this design was constructed by a seed processor and used to remove ryegrass from orchardgrass.

Another test unit employs glass plates inclined at 45° and arranged generally one above another with alternating slopes. (See fig. 30.) As a seed mixture impacts on the top plate, resilient seeds bounce far enough to clear the second plate while poor bouncers travel only to the plate or perhaps not that far. Seeds that go over or under the second plate are caught separately in "good bounce" or "poor bounce" fractions, respectively, and seeds impacting on the second plate are provided another chance to bounce and be classified. The cycle can be repeated as many times as desired in one pass through the separator by adding plates.

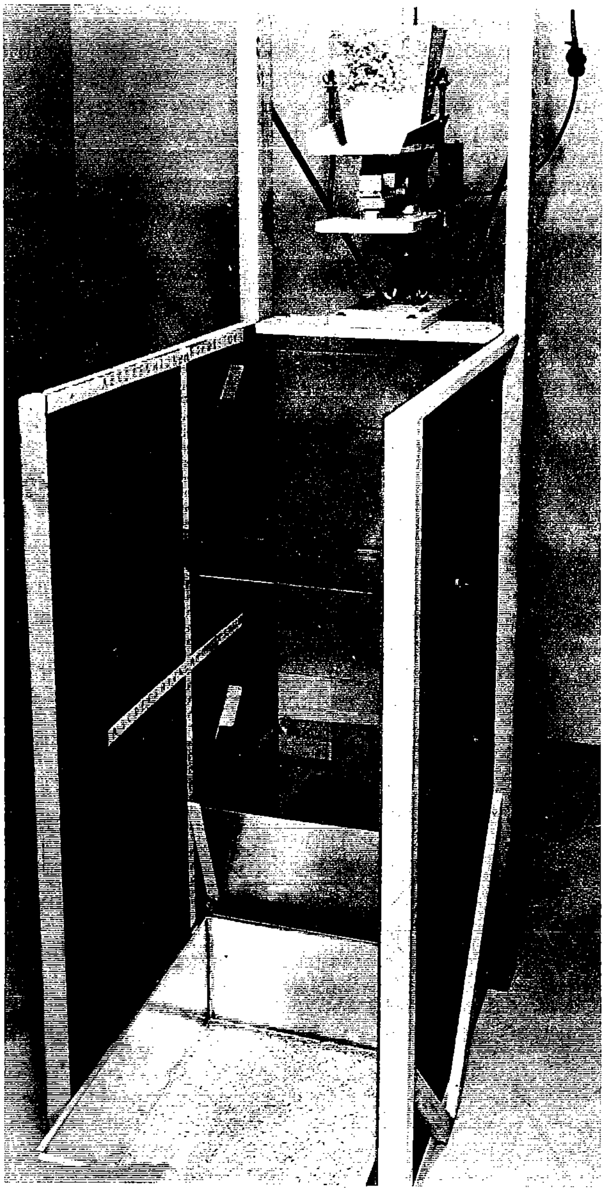

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FIGURE 30.—Resilience separator with glass bounce plates.

The glass plates of the unit shown in figure 30 are equipped with pins and supported by pegboard panels to make for easy adjustments. With this arrangement, individual plates can be added, removed, rotated, and moved horizontally or vertically as needed.

Limited tests with the multiple-plate model have shown encouraging results in removing white clover from bluegrass, ryegrass from orchardgrass, asparagus from beet seed, and dirt clods from ladino clover.

Other Separators

In addition to the conventional and experimental separators already described, there are other separators and related equipment used in seed processing which are peculiar to certain crops or find limited use for some reason. Scalpers, debearders, hammermills, and huller-scarifiers fall in this category and are discussed in a later section. Other examples are the stoner, reverse roll, diverging rolls, inside velvet roll, cocklebur roll, buckhorn machine, and polishers.

Stoner

The stoner is a type of specific gravity machine, but it produces only two fractions on a sloping deck—heavies at the high end and lights at the low end. It will remove rocks from beans, sand from clover, or other heavy components from light ones. Generally, the stoner can show greater capacities than the gravity machine but cannot make as fine a separation.

Reverse Roll

The reverse roll is used mainly to remove dirt clods or other rough material from beans. Rubber wipers contact a rough-surfaced roll and travel around it in a direction opposite to the roll rotation. When a mixture is fed to the machine, the wipers take beans to their direction while the roll takes dirt and rough material with it.

Diverging Rolls

The diverging rolls are somewhat like the velvet roll machine except that the fabric-covered rolls diverge and form a space that gradually widens toward the discharge end. Dirt clods, rocks, and other rough material can be removed from beans, and the variable space serves to size the crop, dropping out small beans first.

Inside Velvet Roll

The inside velvet roll also is used mainly to remove rough material from beans. This machine is similar to an indent cylinder with fabric lining the inner surface. Rough material tends to cling to the fabric and be lifted away from the smooth beans.

Cocklebur Roll

The cocklebur roll is an experimental device developed to remove thorny seeds from smooth ones, like cocklebur from sunflower seed. The unit employs a conveyor belt and a pressure roll covered with polyurethane foam. When a mixture is conveyed under the rotating roll, thorny seeds will adhere to the foam covering and be raised from the belt where a doffing roll can remove them.

Buckhorn Machine

The buckhorn machine is used primarily to prepare buckhorn plantain seed so it can be removed from legume seed such as alfalfa and the clovers. Often, these seeds are so similar in size, density, and surface texture that they cannot be separated readily. However, the buckhorn seed has a mucilaginous coating that becomes sticky when dampened and will pick up fine sawdust forming a larger seed unit with lower density and rougher texture. Sawdust does not adhere to the smooth legume seed. After small amounts of water and sawdust are mixed with a seed lot, as shown in figure 31, the coated buckhorn seeds can be removed with screens or the specific gravity machine.

Polishers

Various types of polishers may be used to clean and brighten the surface of beans, peas, and grains. Some units agitate the products with a compound like sawdust or bran in either a wet or dry process to accomplish the cleaning. Other polishers use a revolving brush to scour the grain against a rubber or screen surface.

SEED CONDITIONING AND TREATING

Many seed lots are conditioned or precleaned before they enter the usual seed processing sequence. This frequently is necessary to permit safe storing, efficient drying, ready handling, or proper cleaning. The major machines used for conditioning or precleaning are scalpers, debearders, hammermills, and huller-scarifiers.

Scalper

Scalping is a rough cleaning operation, usually performed at high capacity, that screens off foreign material larger than the crop seed. The scalped material typically contains stems, green leaves, weed seeds, insects, and trash, and it may represent half or more of the total lot. Removing this large bulk of waste early will reduce later handling and storing requirements, as well as improve cleaning efficiencies. Also, the removal of trash and high-moisture green material will lower drying costs and permit safer storage.

There are many types and sizes of scalpers available. One is a reel of perforated metal screen which turns on a central shaft and is inclined slightly from the horizontal. Material fed into the higher end tumbles inside the reel until the crop seeds drop through the perforations. Large trash stays in the reel and is discharged separately. Another type of scalper

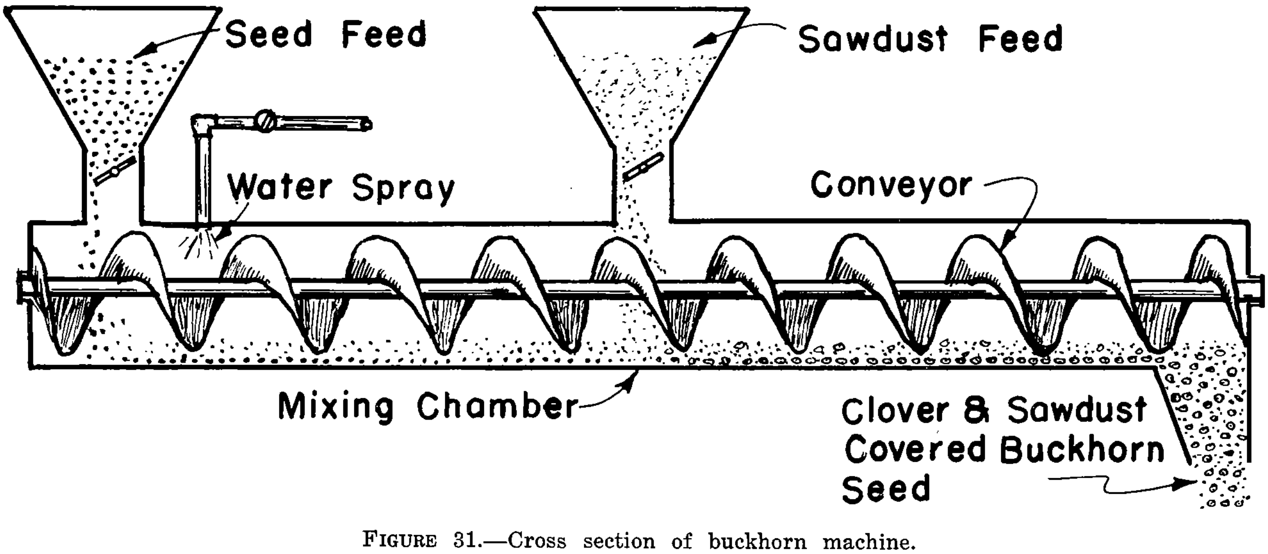


FIGURE 31.—Cross section of buckhorn machine.

makes the same kind of separation with a single, flat, perforated screen which is mechanically shaken.

Some seedsmen prefer a more complete precleaner than the basic scalpers just described. Such units are available with several flat screens or reels and may include air separation features. One model is essentially a simple air-screen separator that lifts light chaff and dust with a controlled air current, scalps large trash over a large-hole screen, and drops small contaminants through a small-hole screen. Another style using a screen reel and air separation is the scalping aspirator illustrated in figure 13.

For greatest benefits from a scalper, it should be the first equipment used when seed comes in from the field. Consequently, scalpers may be installed to advantage ahead of the main receiving elevator in cleaning plants, dryers, or storage facilities.

Debearder

Many seed lots can be cleaned directly after scalping, but others may require further conditioning. In some cases, a lot may contain unthreshed seed in the form of pods, heads, clusters, or doubles. Also, some seeds like barley have awns or beards. To minimize seed loss, these unthreshed units must be broken down to single seeds, and awns should be removed for proper separation. Debearding machines are commonly used to perform these functions and, in effect, to complete the threshing process.

The debearder consists of a horizontal beater assembly that rotates inside a steel drum. The beater is made up of a shaft with projecting arms which are pitched to move the seed mass through the drum. Stationary posts, adjustable for clearance with the arms, protrude inward from the drum and prevent the mass from rotating with the beater. In operation, this machine causes a vigorous rubbing of seeds, pods, heads, and doubles against the arms, posts, and each other. The time that seeds remain in the unit is varied by regulating a weighted discharge gate. The severity of action is controlled by the exposure time, beater speed, and clearance between beater arms and posts.

The debearder is used extensively to remove awns and hairs from certain grains, native grasses, and other seeds. Seeds with appendages like these are difficult to handle, clean, and plant because they tend to interlock and cause undesirable clustering. A properly adjusted debearder can greatly improve flow properties of such difficult-to-handle seed. Some of the jobs performed by this machine are debearding barley, clipping seed oats, threshing whitecaps in wheat, defringing carrot seed, decorticating sugar beet seed, subdividing fescue doubles, and removing fuzz from bluegrass.

Other equipment sometimes used to remove awns and appendages includes farm hammermills and, to a lesser extent, threshers operating at high speed, and tumbling pebble mills. Since all of these units, as well as debearders, rely on rubbing and abrasion to accomplish their purpose, they should be operated carefully to prevent seed damage.

Hammermill

The hammermill employs many fingerlike hammers rotating inside a section of perforated metal cylinder. Seeds processed in the mill are subjected to a vigorous beating, or rolling action between the hammers and perforated screen which removes appendages and forces the seeds through the screen holes.

Results with the hammermill depend on hammer speed, size of screen openings, feed rate, and crop condition. The screen should have an opening slightly larger than the deawned seed. If too large a screen is chosen, there will be an excess quantity of inert matter and a high percentages of awns not removed from the seed. If the screen is too small, the seed will show excess damage and the capacity will be decreased. The feed should be regulated so that the mill is approximately full at all times. If the mill is operated only partly full, there will be more seed damage and a higher percentage of awns not removed.

A good speed for the hammermill is about 50 percent of that used in a normal grinding operation; however, this can vary slightly according to individual cases. If the speed of the hammers is too fast, the seed will be mutilated, cracked, or groated. If the speed is too low, awns will not be removed effectively. Seeds of the following species have been successfully treated in a hammermill operation: bluegrass, bluebunch wheatgrass, blue wildrye, Canada wildrye, Siberian wildrye, tall oatgrass, bulbous barley, squirreltail, alfileria, and virginsbower.

Canada wildrye has also been de-awned in a threshing operation by speeding up the cylinder, setting concaves to a minimum clearance, and reducing the airblast. However, moisture content at time of threshing is quite influential in this process.

Some seeds like black grama have fine, flexible awns that do not break off in hammermills or debearders, but which lend themselves to differential burning. The seeds are dropped through a flame where an instant flashing of the hairlike awns takes place. The flame exposure must be short to avoid damaging the seed by excessive heat.

Seeds of some native grasses of the Great Plains receive little intermediate processing between harvest and planing. Arizona cottontop, for example, is harvested by heading and then is fine-chopped in a hammermill or similar unit. Special equipment then plants the seed material without removal of the fuzz or additional cleaning. Other grasses like tanglehead and cane bluestem are handled the same way.

A green-forage harvester is used in Texas wintergrass to harvest and chop the seed material in one operation for later planting. With grasses such as big cenchrus and Argentine wintergrass, both of which require precleaning to remove spines and awns, the forage harvester is used for the harvest and does part of the job otherwise performed by the hammermill.

Some seeds with cottonlike stylets, such as Texas bluegrass, defy conditioning with debearders or hammermills and cannot be planted readily with regular grass drills. An experimental solution to this problem is pelleting. All plant material, including seeds, stems, and leaves, is mixed with a binder like cornstarch, silvicon, or krilium and extruded through a quarter-inch hole in a die. Cornstarch-binder pellets can be planted with a corn planter or cotton planter. Pellets made with silvicon (from Douglas-fir tree bark) form a coarse granule which can be planted with a conventional grain drill or range seeder.

Huller-Scarifier

After scalping and sometimes debearding, many kinds of seeds can be cleaned without further conditioning. However, certain legumes and grasses may require hulling, scarifying, or both. Hulling is the removal of an outer coat or husk to improve the seed's cleaning characteristics or its planting qualities. With the husk removed, the seed is more readily handled in both cleaning and planting equipment, and, in some cases, the husks are impermeable to water and thus prevent germination. In scarification, the seedcoat itself is scratched or ruptured. Scarifying is practiced with "hard" seeds which otherwise will not absorb water and germinate promptly.

Hullers and scarifiers usually abrade the seeds between two rubber-faced surfaces or impel seeds against roughened surfaces like sandpaper or carborundum stone. The severity of abrasion or impact must be controlled accurately to prevent seed damage. Seeds of high moisture content are harder to hull or scarify than seeds with less moisture, and clean seed scarifies more uniformly and with less damage than dirty seed.

Some kinds of seed lose viability quickly after being hulled or scarified, so these processes should be delayed for such seed until shortly before planting time. Other seeds that maintain viability well after being hulled and scarified can be processed soon after harvest and stored safely until the following season.

Hulling and scarifying may be performed separately or jointly, depending on the presence of unhulled seed, hard seed, or both. Some seeds that may require hulling are bermudagrass, bahiagrass, buffalograss, lespedeza (Korean, Kobe, common, and bicolor). Some seeds that may require scarification are alfalfa, subclover, white clover, suckling clover, hairy indigo, crotalaria, and wild winter peas. Some seeds that may require both hulling and scarification are sweetclover, sourclover, sericea lespedeza, crownvetch, and black medic.

Treater

The scientist, the farmer, and the seedsman are all becoming more aware of the necessity for treating seed. The use of seed treaters to protect seed from soil- and plant-borne fungi and from insects in the warehouse and the soil has been known to double the field stand in infested areas. The increased production resulting from the use of treated seed is stimulating the use of treating machines in processing plants.

Seed treaters may be divided into three categories: dry-powder applicators, slurry applicators, and liquid applicators. The dry-powder applicators were the first type used. They do a thorough job of coating the seed, but many of these units have been replaced by slurry or liquid types because of the harmful effects of breathing chemical dust, and the difficulty of controlling chemical dosage in the dry-powder units.

The introduction of wettable powders and the development of the slurry treater came next. This was considered a major step forward in seed treating, since it made possible the metering of chemicals needed to treat a given seed quantity, while at the same time confining the chemical to the seed. The slurry is a versatile treater that will handle many different commodities. However, it is not suitable for applying low dosages of the more potent chemicals. This failing led to the development of the liquid applicator.

The liquid applicator has several advantages. With it, as little as half an ounce of mercury will treat a bushel of seed without the necessity of adding water, and the treatment can be performed in temperatures as low as −20° F. The seed does not have to be completely covered to give the desire protection. Unfortunately, this technique cannot be used with vegetable or other food-crop seeds. These are still treated by the slurry method.

There are two types of liquid treaters in general use. In one type, a seed mass is tumbled in a rotating drum, and liquid is applied in small drops by a number of fingerlike tubes. The drum is set on an incline so that the seed travels from inlet to discharge as the drum rotates. The other liquid treater consists of a chemical pump and tank, an electrical motor, seed feed control, seed-weighing pan, chemical measuring cups, a seed-dispersion cone, and a rotary disk. (See fig. 32.) In this unit, seed is fed to the top of the machine where it is accurately measured in the weighing pan while the chemical is measured in metering cups. The exact proportions of seed and chemical are then dumped simultaneously. The seed falls on a dispersion cone, which spreads it to form a hollow cylinder, the wall thickness of which is equivalent to one layer of seed. The chemical falls on a high-speed revolving disk that breaks up the liquid into a fine, penetrating mist, which sprays the seed from the interior of the cylinder as the seed falls from the dispersion cone into a sacking bin.

This spray treater is satisfactory for applying very small amounts of chemical to seed, and can be easily and quickly adapted for treating a wide range of sizes and types of seed.

A further development in seed treating is a machine that employs principles of both the liquid and slurry treaters. This combination unit was developed for corn but has many other applications.

SEED HANDLING AND STORING

Effective seed handling and storing are important in the economy of seed processing. Seed lots are handled many times in receiving, drying, cleaning, and bagging, and they may be stored before, during, or after cleaning. If care is not exercised in these operations, processing efficiency will be reduced by seed damage, contamination, and handling costs.

Handling

Generally speaking, methods of handling seed in the processing plant can be classified in two major divisions—mechanical and pneumatic. Mechanical systems include various types of conveyors, elevators, vibrators, and bulk-handling schemes, while pneumatic systems employ air flow and may operate above or below atmospheric pressure.

Mechanical Methods

Belt conveyor.—The belt conveyor is an endless moving belt that can transport material horizontally and at an incline. The belt may be supported by idler rolls, or it may slide in the bottom of an open trough. Little or no seed damage takes place in this type of conveyor, but contamination or intermixing of bulk seed lots is possible when the belt travels in a trough. In contrast, trough-forming belts supported by inclined rollers are self-cleaning and find extensive use in corn and grain handling.

Bucket elevator.—The bucket elevator consists of buckets attached to an endless chain or belt which runs along a vertical or steeply inclined path. The system may be enclosed in a single housing called a "leg," or separate housings for the lift leg and return leg. The buckets load themselves as they pass through a seed hopper or "boot" at the bottom of the run, and, depending upon elevator type, the load is discharged by centrifugal force or gravity as the buckets round the top section of the assembly.

The centrifugal-discharge elevator is commonly operated at high speeds to obtain high capacities, and the resultant discharge velocity may cause excessive damage to injury-sensitive seed. Slow-speed units are better for easily damaged or slow-flowing materials. Another limitation of bucket elevators is that they are difficult to clean. Small seeds tend to lodge in hard-to-clean areas throughout the elevator and remain there to contaminate subsequent lots.

A different type of bucket elevator that is becoming popular in seed handling is a slow-

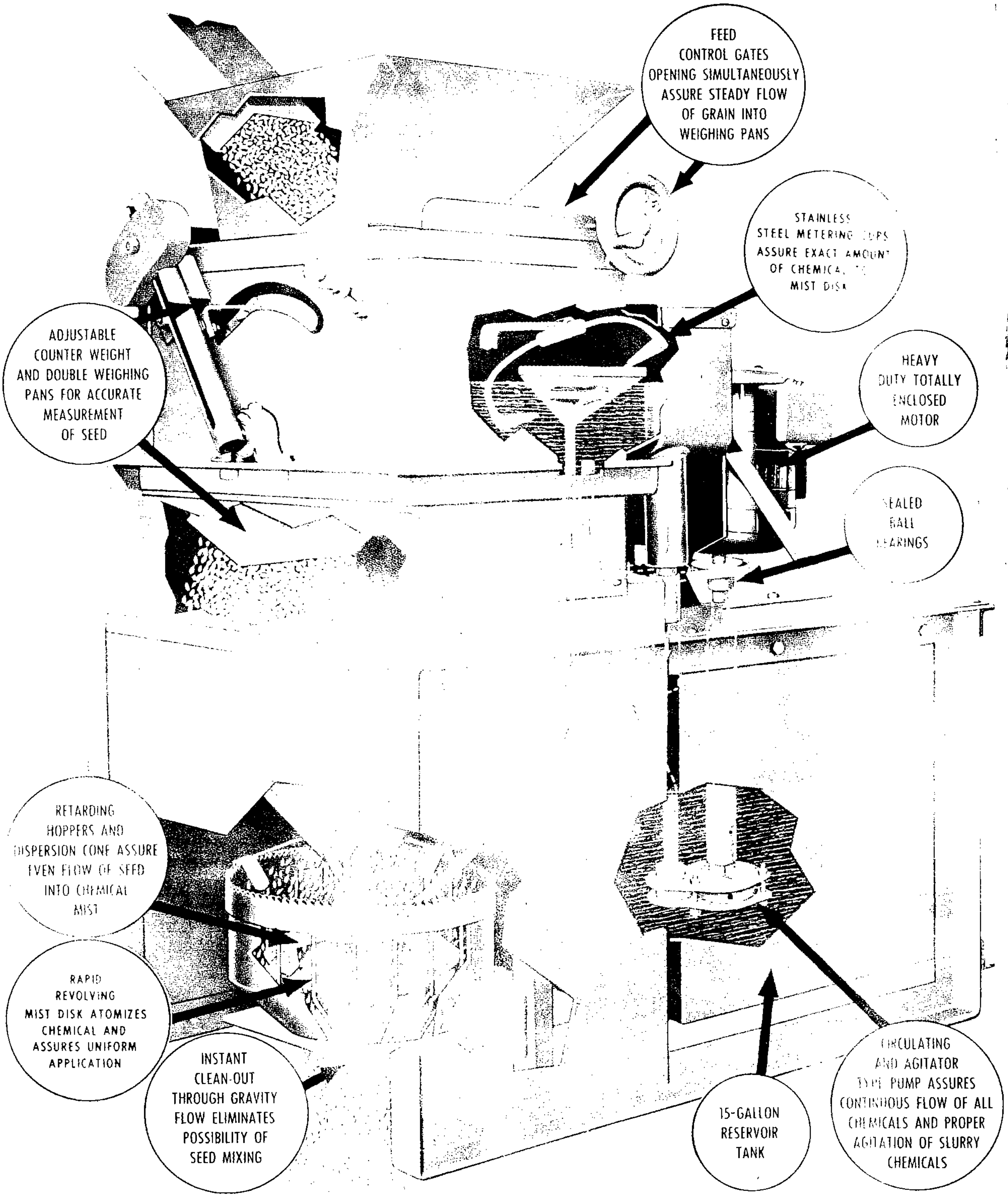


FIGURE 32.—Liquid seed treater.

speed, high-capacity, multisection conveyor that operates without a filler boot or enclosed housing. The bucket assembly can be supplied in as many compartments as desired, and in a three-compartment unit, for example, three different seed types can be lifted separately in adjacent compartments of buckets. Individual, timed rotary feeders load the compartments of each bucket section at the bottom of the elevator.

The buckets gradually turn upside down as they follow a horizontal path at the top of the conveyor and gently discharge the seed load by gravity. Because of the open-type construction, any seed dislodged from a bucket will fall in catch pans or on the floor free of the system. Since there is neither high-speed discharge to cause damage, nor boot or housing to act as a source of contamination, this elevator is well adapted to handling certified, registered, and other pure seeds.

Screw conveyor.—The screw conveyor usually consists of a long-pitch helix mounted in a U-shaped trough, with or without a cover. As the element rotates, seed fed to it is moved forward to the discharge end of the trough. Since this conveyor agitates or tumbles the product handled, it does considerable mixing. It can also function as a feeding or metering device.

Screw conveyors may operate in horizontal, vertical, or inclined paths, but capacity drops as inclination increases. A cylindrical housing surrounding the helix is commonly used when elevating at a steep incline.

This conveyor is simple but seed damage can result from the sliding, squeezing, tumbling movement provided by the screw action. Also, the unit is not self-cleaning. If the seeds being handled are smaller than the clearance between helix and housing, some may remain in the system and contaminate subsequent lots.

Vibrating conveyor.—The vibrating conveyor transports material by "bouncing" it along a tray that has a reciprocating stroke produced by electromagnetic, mechanical, pneumatic, or hydraulic action. Depending on the type of action, flow rates may be changed by varying the length or frequency of stroke. Little or no seed damage occurs in this conveyor, and it tends to be self-cleaning. One limitation, however, is that seed transport is restricted to horizontal or near-horizontal paths. Vibrating conveyors are frequently used as feeding or metering devices because they are easily adjusted for a wide range of flow rates. With proper attention, they also offer a convenient means of controlling feed rates at desired levels.

In electromagnetic units, the conveying tray is pulled sharply downward and backward by magnetic attraction and then returned upward and forward to its original position by springs. This action is modified in some designs so that electromagnets, supplemented by spring, alternately attract and repel the tray to impart the reciprocating motion. Flow rates are changed by adjusting a rheostat which regulates the power input to the electromagnet. Although frequency remains fixed at 3,600 or 7,200 cycles per minute, the stroke length of the tray is changed and this alters the conveying rate.

In experimental tests of different vibrating feeders, those powered electromagnetically showed smooth changes in flow rate as rheostat setting was varied. There was a tendency for flow rate to drift considerable over an extended period of time at a fixed rheostat setting, particularly when handling grass seed and if air temperatures fluctuated around the vibrator. However, when checked periodically and readjusted if needed, electromagnetic feeders can provide a convenient, dependable method of regulating feed rates.

Vibrating conveyors may achieve their motion mechanically in several different ways. In the positive-drive unit, the vibrations are produced by an eccentric mounted on a shaft so that its throw causes movement of an attached trough mounted in a special suspension. The trough action is similar to that of the conventional strawwalker in a combine. The geared-weight method uses two unbalanced pulleys mounted in a housing and geared together to revolve toward each other. When the two centers of gravity move in parallel in the same direction, an impulse is communicated to the housing and to an attached conveying trough. Since the impulse will be neutralized when the centers of gravity move in opposite directions, a straight-line vibration may be obtained.

Another mechanical action used to produce vibration is that of an unbalanced rotating mass. Offcenter weights are added either to the shaft of an electric motor or to a pulley driven by a motor. The vibration generated by this unbalanced condition is transmitted to an attached trough which is supported so that its movement is essentially forward and backward in repeated cylces. Feed rates can be regulated with the use of resilient material forced against the trough or suspension to dampen the vibration as desired.

Vibrating conveyors also can be powered pneumatically or hydraulically. One type of pneumatic drive uses high-pressure air and suitable valving to actuate a reciprocating piston and produce vibration which is transmitted to a trough. In another design, compressed air forces a steel ball around a closed circular race at high speed to generate the vibration. With both arrangements, feed rates can be controlled to some extent by regulating pressure of the supply air and thereby frequency of vibration. In a test of the two systems, the steel ball unit showed much better control. Hydraulic and pneumatic drives are basically similar except that the working medium of one is liquid and the other, gas. In the hydraulic system, a pump produces a flow of liquid through piping and pressure control valves to a cylinder where straight-line motion is generated. With appropriate high-speed valve action, this motion is made reciprocating and is transmitted to a conveying trough.

Aside from its use in conveyors and feeders, vibration also can be employed to improve the flow characteristics and handling of some seeds. Unit vibrators are mounted on bins, hoppers, or chutes to improve the flow of material that tends to "bridge" or cling to the sides.

Bulk-handling schemes.—In some cases, seed lots are handled by bulk or unit-load methods. The seed may be transported from field to processing plant in sacks, unit boxes, or as a bulk load in the truck bed. At the plant, the seed is either processed directly or stored in sacks, boxes, or bulk. Sacks can be handled singly by special elevators and conveyers, or in loads stacked on pallets and moved by forklift trucks. Boxes, also, are handled by lift truck, or sometimes with a box elevator which can grasp a large box, elevate it to a point where the load is dumped, and return the box to floor level. Advantages of the box method are reduced labor requirements, less chance of seed contamination, and ease of maintaining seed-lot identity.

In bulk storage, loose seed is delivered to bins by various forms of elevators, conveyors, and pneumatic systems. Scoop attachments fitted on forklift trucks are also used for handling bulk seed in open-end bins.

Pneumatic Methods

Pneumatic systems transport material by air and have the advantages of good cleanout characteristics, flexible horizontal and vertical operation, and mechanical simplicity. In order to transport material in conventional pneumatic conveyors, certain minimum air velocities are required, as shown in the tabulation below. Once this condition is achieved, a rule-of-thumb method for supplying air-volume requirements is to provide 40 cubic feet per minute under average atmospheric conditions for each pound of material to be moved per minute. Limitations of these conveyors are (1) possible damage to the seed because of high velocities, and (2) greater power requirements than in mechanical handling methods.

Air velocities needed for typical pneumatic conveying of materials at 70° F. and 70 percent relative humidity

Approximate duct velocity in lineal feet per minute	*Material to be conveyed*
2,500	Dry dust and light fluffy seed (bluegrass, meadow foxtail)
3,000	Ryegrass, fescue, and similar grass seed
3,500 to 4,000	Alfalfa, crimson clover
4,000 to 5,000	Heavy oats and cottonseed
5,000 to 6,000	Wheat, corn

Vacuum system.—The vacuum system operates below atmospheric pressure and usually includes a conveying pipe, a suction fan, a cyclone or settling chamber to drop seed from the air stream, and an airlock to discharge seed from the cyclone while retaining the vacuum. This system finds considerable use in unloading trucks, freight cars, and ships. Other successful applications are in short runs where seed is conveyed and removed from the system before it reaches a velocity that may be damaging. The vacuum system is particularly effective if material is to be collected from several points and conveyed to a single discharge.

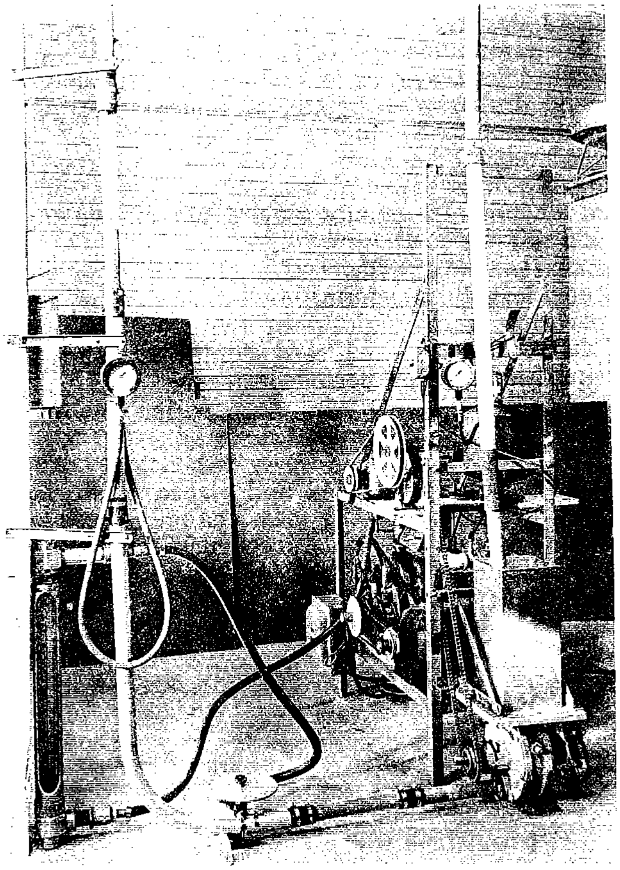
Low-pressure system.—Low-pressure systems operate above atmospheric pressure in a range of approximately 10 to 15 inches of water (about one-half pound per square inch), and require a fan, conveying line, cyclone, and a means of introducing seed into the airstream. Generally speaking, conveyors of this type employ centrifugal fans and conveying lines ranging from 6 to 24 inches in diameter. Depending upon actual system pressures, seed can be introduced by injector or auger feeders, or if a better air seal is needed, by using a rotary airlock (also called a star feeder or bucket wheel). The low-pressure and vacuum systems are the most common types of pneumatic conveyors used in seed processing.

Medium-pressure system.—Systems operating at pressures from about 15 to 50 inches of water are classified as medium-pressure conveyors. The greater pressure requirements usually result from longer runs, more elbows, or greater conveying rates. Special centrifugal fans act as the air source, and common conveying pipe sizes are 4 to 8 inches in diameter. Rotary airlock units are needed to supply seed to the airstream for this type of conveyor.

High-pressure system.—These systems operate at pressures of about 2 to 15 pounds per square inch with relatively low air volumes, and generally use small conveying pipe, about 1 to 4 inches in diameter. Positive-displacement air sources are employed in the form of rotary blowers or reciprocating piston pumps. Seed introduction to the high-pressure airstream is accomplished satisfactorily up to about 10 p.s.i with rotary airlocks, but operation at higher pressures requires special locks or air-sealing mechanisms.

Several characteristics of high-pressure systems in seed conveying are flexibility of small-size pipe runs, high solid-air ratios, and relatively low seed velocity—therefore, low seed damage. Also, with low air volumes, there is little or no dust problem, and cyclones or collectors generally may not be needed.

An experimental pneumatic conveyor of the high-pressure type has been developed that employs principles of "fluidized" flow. (See fig. 33.) Seed movement through the system takes place in the form of aerated slugs that show a high degree of mobility or fluidity. Tests were conducted with a 56-foot run of 1⅝-inch diameter tubing that included a 30-foot vertical lift and four elbows. Performance results with freeflowing seed like crimson clover showed that seed velocities were low, seed damage was negligible, and cleanout was good. Conveying rates could be varied from 600 to 1,800 pounds per hour while retaining a low seed velocity and a high solid-to-air ratio. Greater capacities—up to 6,000 pounds per hour—were achieved in the 1⅝-inch line but, necessarily, at higher seed velocities. Operating levels for this conveyor can be regulated according to the capacities required and the damage susceptibility of the seed being handled.



S-226-3-60

FIGURE 33.—Fluidized conveyor.

Storing

Almost all seed lots must be stored some time during their processing. They may be stored as brought in from the field, after a preliminary scalping operation, between later cleaning sequences, after cleaning, or after bagging. Bulk storage in the form of boxes and bins is used extensively during cleaning, and cleaned seed may be stored in bags, cartons, or bulk.

Regardless of storage method, certain requirements must be met for proper storing of seed. (1) The seed should be dry so that it will not heat or lose viability; (2) temperature and humidity of the storage atmosphere should be kept relatively low to minimize seed deterioration, especially in long-term storage; (3) seed should be handled in storage operations without producing mechanical damage; (4) physical arrangement of the storage facility should be conducive to efficient handling; and (5) good housekeeping practices should be observed.

Drying

Seeds must be stored dry if they are to retain their ability to germinate when planted. High moisture content tends to shorten seed life by increasing respiration rate, encouraging mold growth and insect attack, and increasing the danger of injury during fumigation.

sample and test for purity, germination, and other quality factors. These fractions should be as representative as possible of the entire lot. Sampling methods vary considerably, and research is being done to compare different methods.

One of the oldest sampling methods is to take small handfuls of seed from many different bags or sources and mix them together. A device that also finds much use is the "trier" —a slotted tube that can be inserted in a bag or bin to extract a small quantity of seed from many points along the tube length. Mechanized samplers are also available. Some withdraw samples periodically from a dropping seed stream while others sample the stream continuously but at a very low rate.

Sampling, like blending, is a complex and important process. The economic value of a seed lot is determined, to a large extent, by the purity and germination analyses of the sample tested. Careful sampling helps insure that the sample tested represents the original lot as nearly as possible.

Bagging

Processed seeds may be handled either in bags or in the bulk. Most farm seed cleaners use burlap bags. In some plants, the seeds are discharged directly from the final cleaning machine into the bag. Other plants may elevate the seeds to bins or tanks where they are stored and sacked off periodically.

When seed is being bagged, a small platform scale is commonly used to weigh the filled bags which are then sewn closed by hand or portable machines. Identifying tags may be stitched to the bags by the sewing machine, or they may be attached by wire.

Some bagging procedures are mechanized. One type of semiautomatic bagger is located under the bin and will receive seed, weigh it, and fill the bag. An inlet valve is automatically closed when the seed in the bag reaches a predetermined weight. The operator removes the filled bag and guides it into a combination conveyor and bag closer, after which he places an empty sack on the bagger while the unit is weighing out the next batch of seed.

A recent bagging development is an automatic unit that receives seed from an overhead bin, weighs it, fills the bag, checks the weight, and, by electronic feedback, adjusts the scales to discharge the correct weight of seed. This system will handle burlap, paper, cotton, or plastic bags ranging in size from 5 to 100 pounds capacity and at rates of 20 or more bags per minute. In some cases, the information usually found on tags is automatically printed directly on paper bags. This eliminates the need for tags while still providing such required information as lot number, variety, purity analysis, germination percent, and date.

Packaging

Seed is packaged for the retail trade in many forms of containers. It appears in cardboard boxes, vacuum-sealed cans, and bags made of plastic, paper, cotton, or burlap.

Probably the most popular packaging system is the semiautomatic type. Seed to be packaged flows by gravity from an overhead tank into scales that weigh and discharge at adjustable time intervals. In a typical operation, a box is removed from a pile, glue is applied to the flaps of one end, and the box is placed in position to receive the seed. At the end of the time interval, the seed is automatically discharged into the box, after which the operator removes the filled box and applies glue to flaps of the other end. The box is then fed into a special conveyor that applies pressure to the glued flaps. The weights of filled boxes are checked periodically as a control measure. In the final step, individual boxes are placed in cartons for shipping.

Fully automatic packaging systems perform the same operation described above, but at accelerated rates. The only manual operations are supplying collapsed boxes to the magazine that feeds the packaging machine, and placing filled boxes in the shipping cartons.

PLANT LAYOUT

In laying out a seed processing plant, many factors should be considered such as the kinds of seed to be cleaned and the contaminating crop, weed, and inert matter; the volume of seed to be processed; the type of separators to be used; the method of handling (bulk or sacks, and, if sacks, whether they will be moved by hand, roller conveyor, or forklift trucks); the conveyor system to be used (pneumatic or mechanical); and the location of receiving, storing, and shipping facilities.

The plant should be laid out so that seed is received, cleaned, and shipped without mixing or damaging the lots and with a minimum of time, equipment, and personnel. The seed separators, conveying system, and storage bins should be arranged so the seed flow can be continuous from the receiving bin to the shipping point, yet flexible enough to bypass a machine or return part of the seed for recleaning, if necessary. Accumulating tanks should be considered for use above the separators so that a machine can be stopped briefly, if needed, without stopping the entire processing line. Separators should be located so they are accessible for inspection, cleanout, and adjustment. It is desirable to allow room for future expansion of the plant as well as possible rearrangement of equipment to accommodate new machines in the processing line. Provision also should be made for dust elimination and an adequate waste-handling system to dispose of discard material from the various cleaners.

To conserve floorspace and minimize the handling of materials, seed processing machines are sometimes placed one above another, or arranged in series so that the discharge of one unit flows into another unit. Debearders are often found above air-screen cleaners, and indent disk separators are frequently mounted above indent cylinder machines.

Where a plant operation must be flexible enough to permit processing of various grass seed, legume seed, grain, corn, or other products, floorspace can be saved by mounting the processing equipment on rollers or mobile frames. Then, depending upon given cleaning requirements, the necessary machines can be rolled or moved by forklift truck into the processing line, or into storage until needed.

Types of Layouts

There are about as many different plant layouts as there are seed processing plants. However, most plants can be classified into four general types of building arrangement. These are the grain elevator, converted barn, single story, and single story with half balcony types of structures. Figure 35 illustrates these arrangements.

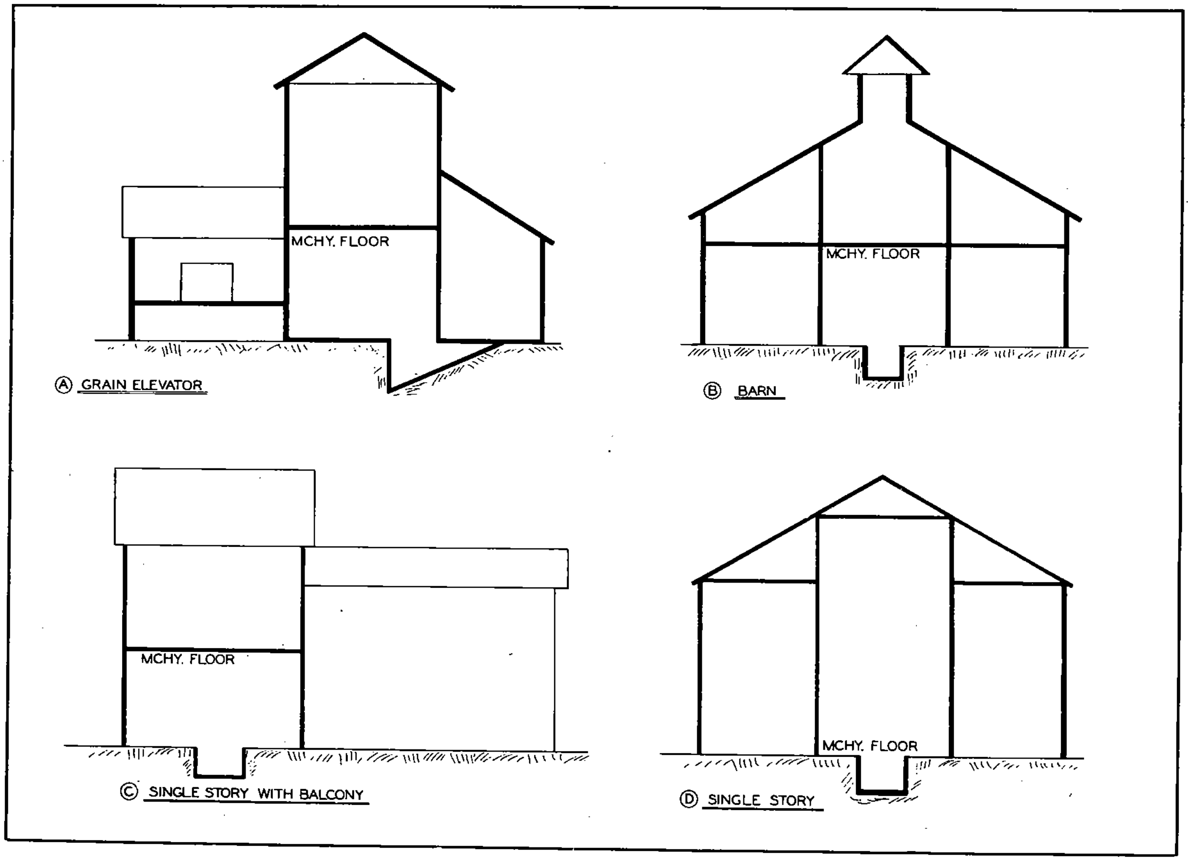


FIGURE 35.—Types of building arrangements used for seed processing plants.

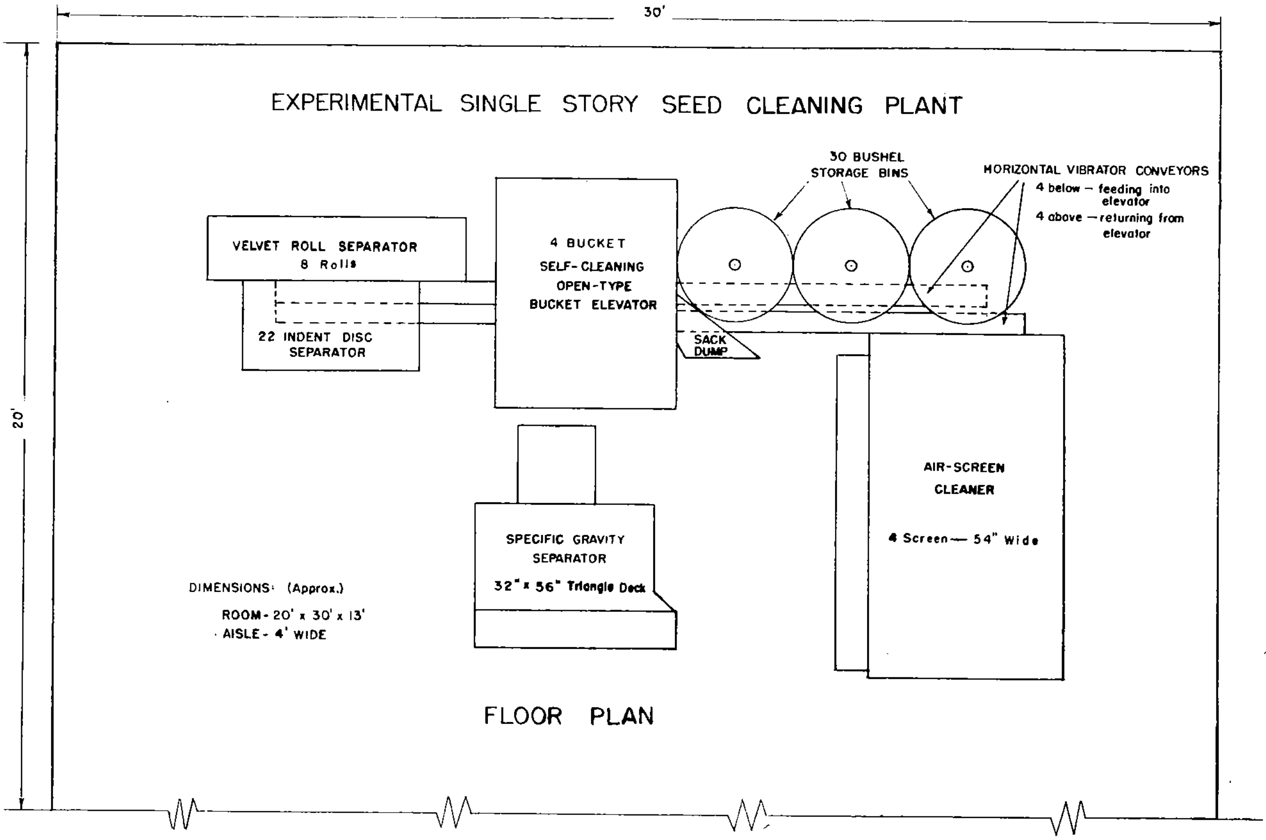


FIGURE 38.—Floor plan of the experimental single-story seed-cleaning plant at Corvallis, Oreg.

ing increasingly popular and are being added to existing plants. Types of dust elimination systems vary considerably. Probably the simplest is a fan that draws air from the sack dump and discharges it outside. More extensive is a multifan system with many air inlets that take air from strategic points throughout the plant. The inlets are located in such places as the top of a bin, the sack dump, the debearder housing, or at other machines where dusty conditions prevail. The dust fans can discharge into cyclones or a dust room for concentration of the airborne material.

The cost of a dust elimination system will vary with the installation, but, in general, will be cheaper and more satisfactory if installed with the initial processing machinery instead of being added after the plant is in operation. If the system is planned early enough, the pipe can be run in a floor tunnel or in a wall or attic where it will be out of sight and not occupy space in the processing area. Once the system is installed, it requires little attention other than periodic maintenance. A single fan can be used satisfactorily to collect dust from many points, provided a balanced system is designed that will maintain an air movement in each branch that is above the conveying velocity of the particles concerned. Air velocities around 2,000 feet per minute will convey dust; whereas air velocities needed to convey most seeds range from about 3,000 to 5,000 feet per minute.

Waste Disposal

Waste disposal is an important feature of plant layout that is often overlooked in planning. The waste material from a seed processing plant is composed of leaves, stems, weed seeds, dirt, and other contaminants that have been separated from the crop seed. Waste can be a problem of considerable magnitude if proper means are not provided to handle it. With light, chaffy grass seeds such as bluegrass, the weight and volume of the waste will often exceed that of the crop seeds.

The most common methods of waste disposal are burning the material or trucking it to a dump pile located on the banks of a gully or stream. Burning the waste tends to contaminate the atmosphere, and dumping over banks also is unsatisfactory. One disadvantage of this dumping location is that during periods of high water the weed seeds float downstream and contaminate other banks and flooded fields. There is an ever increasing effort to clean up both our air and streams, and this increases the importance of proper waste disposal from seed plants. In large operations where the volume of material is sufficient to interest feed processors, seed waste sometimes is purchased and blended with other ingredients to be made into pellets for animal feed.

If a waste disposal system is properly planned, material from various processing machines and floor "sweeps" can be spouted directly into a waste conveyor and delivered automatically to an incinerator for complete burning or to a loading hopper for trucking to an approved disposal area.

Dust elimination and waste disposal can be incorporated into a single system that collects dust and waste products from throughout the plant and conveys them to a collection chamber.

Flow Diagrams

The particular combination of machines forming a seed processing line will be determined by the seed crops handled and their contaminants. Figure 39 illustrates general sequences of operation in processing several different crop seeds including legumes, grains, bluegrass, and corn. The flow diagram for bluegrass can be used also to process other grass seeds by omitting those machines not required. For example, the machines usually used in processing ryegrass and fine fescue are the air-screen cleaner and the length separator. Depending on the contaminants, the gravity separator may or may not be used.

A typical machinery arrangement for a single-story farm seed-cleaning plant handling grass seed is shown in figure 40.

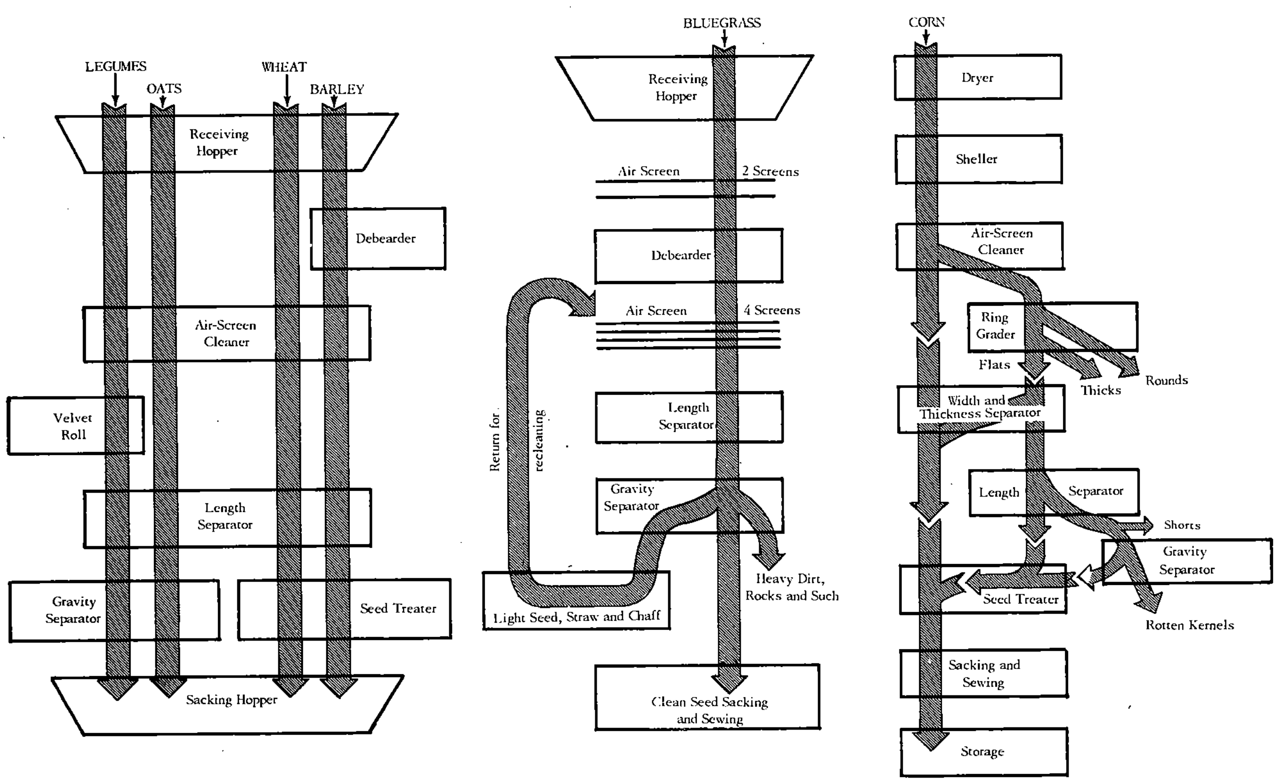


FIGURE 39.—Flow diagrams for processing seed.

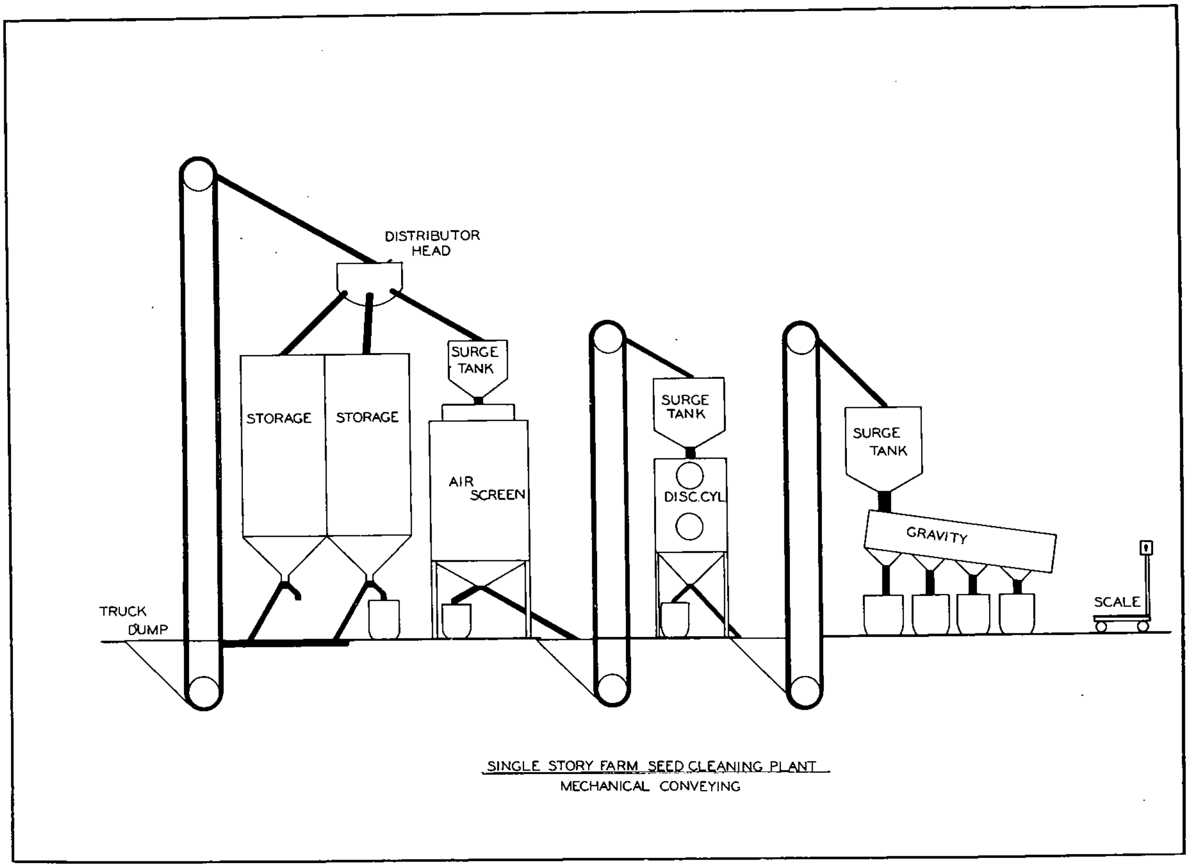


FIGURE 40.—Single-story farm seed-cleaning plant for grasses.

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APPENDIX

Decimal Equivalents of Screen Hole Designations

[Figures shown under "Decimal Equivalents" are equivalents of figures in other columns and are not arranged as a uniform linear scale. Millimeter screens are available in 0.05 mm. graduations from 0.40 mm. to 25.40 mm. (1 inch)]

Decimal equivalents	Screen hole designation: Fractions	64ths	Millimeters
1.0000	1	64	25.40
.9844	----	63	----
.9688	----	62	----
.9531	----	61	----
.9375	----	60	----
.9219	----	59	----
.9063	----	58	----
.8906	----	57	----
.8750	----	56	----
.8594	----	55	----
.8438	----	54	----
.8281	----	53	----
.8125	----	52	----
.7969	----	51	----
.7874	----	----	20.00
.7813	----	50	----
.7656	----	49	----
.7500	----	48	----
.7480	----	----	19.00
.7344	----	47	----
.7188	----	46	----
.7087	----	----	18.00
.7031	----	45	----
.6875	----	44	----
.6719	----	43	----
.6693	----	----	17.00
.6563	----	42	----
.6406	----	41	----
.6299	----	----	16.00
.6250	----	40	----
.6094	----	39	----
.5938	----	38	----
.5906	----	----	15.00
.5781	----	37	----
.5625	----	36	----
.5512	----	----	14.00
.5469	----	35	----
.5313	----	34	----
.5156	----	33	----
.5118	----	----	13.00
.5000	½	32	----
.4844	----	31	----
.4724	----	----	12.00
.4688	----	30	----
.4531	----	29	----
.4375	----	28	----
.4331	----	----	11.00
.4219	----	27	----
.4063	----	26	----
.3937	----	----	10.00
.3906	----	25	----
.3750	----	24	----
.3672	----	23½	----
.3594	----	23	----
.3543	----	----	9.00
.3516	----	22½	----
.3438	----	22	----
.3333	⅓	----	----
.3281	----	21	----
.3203	----	20½	----
.3150	----	----	8.00
.3125	----	20	----
.3047	----	19½	----
.2969	----	19	----
.2891	----	18½	----
.2852	----	18¼	----
.2813	----	18	----
.2756	----	----	7.00
.2734	----	17¼	----
.2656	----	17	----
.2578	----	16½	----
.2500	¼	16	----
.2422	----	15½	----
.2362	----	----	6.00
.2344	----	15	----
.2266	----	14½	----
.2188	----	14	----
.2165	----	----	5.50
.2109	----	13½	----
.2031	----	13	----
.2000	⅕	----	----
.1969	----	----	5.00
.1953	----	12½	----
.1875	----	12	----
.1797	----	11½	----
.1772	----	----	4.50
.1719	----	11	----
.1667	⅙	----	----
.1641	----	10½	----
.1575	----	----	4.00
.1563	----	10	----
.1496	----	----	3.80
.1484	----	9½	----
.1429	1/7	----	----
.1417	----	----	3.60
.1406	----	9	----
.1339	----	----	3.40
.1328	----	8½	----
.1260	----	----	3.20
.1250	⅛	8	----

Decimal equivalents	Screen hole designation Fractions	64ths	Millimeters
.1181	----	----	3.00
.1172	----	7½	----
.1142	----	----	2.90
.1133	----	7¼	----
.1110	1/9	----	----
.1102	----	----	2.80
.1094	----	7	----
.1063	----	----	2.70
.1055	----	6¾	----
.1024	----	----	2.60
.1016	----	6½	----
.1000	1/10	----	----
.0984	----	----	2.50
.0977	----	6¼	----
.0945	----	----	2.40
.0937	----	6	----
.0909	1/11	----	----
.0906	----	----	2.30
.0898	----	5¾	----
.0866	----	----	2.20
.0859	----	5½	----
.0833	1/12	----	----
.0827	----	----	2.10
.0820	----	5¼	----
.0787	----	----	2.00
.0781	----	5	----
.0769	1/13	----	----
.0768	----	----	1.95
.0762	----	4⅞	----
.0748	----	----	1.90
.0742	----	4¾	----
.0728	----	----	1.85
.0714	1/14	----	----
.0709	----	----	1.80
.0703	----	4½	----
.0689	----	----	1.75
.0669	----	----	1.70
.0667	1/15	----	----
.0664	----	4¼	----
.0650	----	----	1.65
.0630	----	----	1.60
.0625	1/16	4	----
.0610	----	----	1.55
.0591	----	----	1.50
.0588	1/17	----	----

Decimal equivalents	Screen hole designation Fractions	64ths	Millimeters
.0586	----	3¾	----
.0571	----	----	1.45
.0556	1/18	----	----
.0551	----	----	1.40
.0547	----	3½	----
.0531	----	----	1.35
.0526	1/19	----	----
.0512	----	----	1.30
.0508	----	3¼	----
.0500	1/20	----	----
.0492	----	----	1.25
.0476	1/21	----	----
.0472	----	----	1.20
.0469	----	3	----
.0455	1/22	----	----
.0453	----	----	1.15
.0435	1/23	----	----
.0433	----	----	1.10
.0430	----	2¾	----
.0417	1/24	----	----
.0413	----	----	1.05
.0400	1/25	----	----
.0394	----	----	1.00
.0390	----	2½	----
.0374	----	----	.95
.0354	----	----	.90
.0352	----	2¼	----
.0335	----	----	.85
.0315	----	----	.80
.0313	1/32	2	----
.0295	----	----	.75
.0276	----	----	.70
.0273	----	1¾	----
.0256	----	----	.65
.0236	----	----	.60
.0234	----	1½	----
.0217	----	----	.55
.0197	----	----	.50
.0195	----	1¼	----
.0177	----	----	.45
.0157	----	----	.40
.0156	----	1	----
.0117	----	¾	----
.0078	----	½	----

Glossary

(Names of seeds referred to in this publication)

Common	*Botanical*
Alfalfa	*Medicago sativa*
Alfileria	*Erodium cicutarium*
Alsike clover	*Trifolium hybridum*
Alta fescue	*Festuca arundinacea*
American sloughgrass	*Beckmannia syzigachne*
Argentine wintergrass	*Stipa* spp.
Arizona cottontop	*Trichachne californica*
Asparagus	*Asparagus officinalis*
Bachelors-button	*Centaurea cyanus*
Bahiagrass	*Paspalum notatum*
Barley	*Hordeum* spp.
Barnyardgrass	*Echinochloa crusgalli*
Beans	*Phaseolus* spp.
Beet (garden)	*Beta vulgaris*
Bentgrass	*Agrostis* spp.
Bermudagrass	*Cynodon dactylon*
Bicolor lespedeza	*Lespedeza bicolor*
Big mouse-ear	*Cerastium vulgatum*
Black bindweed (wind buckwheat)	*Polygonum convolvulus*
Black grama	*Bouteloua eriopoda*
Black medic	*Medicago lupulina*
Bluebunch wheatgrass	*Agropyron spicatum*
Bluegrass	*Poa*
Buckhorn plantain	*Plantago lanceolata*
Buffalograss	*Buchloe dactyloides*
Bulbous barley	*Hordeum bulbosum*
Burclover	*Medicago hispida*
Canada thistle	*Cirsium arvense*
Canada wildrye	*Elymus canadensis*
Cane bluestem	*Andropogon* spp.
Cenchrus (sandbur)	*Cenchrus pauciflorus*
Carrot	*Daucus carota*
Cheat	*Bromus* spp.
Chervil	*Chaerophyllum* spp.
Chewings fescue	*Festuca rubra* var. *commutata*
Clover	*Trifolium* spp.
Cocklebur	*Xanthium pennsylvanicum*
Common lespedeza	*Lespedeza striata*
Corn	*Zea mays*
Crimson clover	*Trifolium incarnatum*
Crotalaria	*Crotalaria* spp.
Crownvetch	*Coronilla varia*
Dock	*Rumex* spp.
Dodder	*Cuscuta* spp.
Dogfennel	*Anthemis cotula*
Dutch white clover	*Trifolium repens*
Fescue	*Festuca* spp.
Field bindweed	*Convolvulus arvensis*
Flax	*Linum usitatissimum*
Hairy indigo	*Indigofera hirsuta*
Johnsongrass	*Sorghum halepense*
Kobe lespedeza	*Lespedeza striata* 'Kobe'
Korean lespedeza	*Lespedeza stipulaces*
Ladino clover	*Trifolium repens*
Lentils	*Lens culinaris (Ervum lens)*
Lima beans	*Phaseolus lunatus*
Meadow foxtail	*Alopecurus pratensis*
Morning-glory (common)	*Ipomoea purpurea*
Mouse-ear (chickweed)	*Stellaria media*
Mustard	*Brassica* spp.

Common	*Botanical*
Oats	*Avena* spp.
Onion	*Allium cepa*
Orchardgrass	*Dactylis glomerata*
Path rush	*Juncus tennis*
Peas	*Pisum sativum*
Perennial ryegrass	*Lolium perenne*
Pigweed	*Amaranthus graecizans*
Plantain	*Plantago* spp.
Quackgrass	*Agropyron repens*
Ragweed	*Ambrosia* spp.
Rape	*Brassica* spp.
Rattail fescue	*Festuca myuros*
Red clover	*Trifolium pratense*
Red fescue	*Festuca rubra*
Red sandspurry	*Spergularia rubra*
Rice	*Oryza sativa*
Rough bluegrass	*Poa trivialis*
Ryegrass	*Lolium* spp.
Sericea lespedeza	*Lespedeza cuneata*
Sesame	*Sesamum indicum (S. orientale)*
Sheep sorrel	*Rumex acetosella*
Shepherds-purse	*Capsella bursa-pastoris*
Siberian wildrye	*Elymus sibiricus*
Silverhair	*Aira caryophyllea*
Snapdragon	*Anterrhinum* spp.
Sorghum	*Sorghum vutgare*
Sorrel	*Rumex* spp.
Sourclover	*Melilotus indica*
Soybeans	*Glycine max*
Squirreltail	*Sitanion hystrix*
Subclover	*Trifolium subterraneum*
Suckling clover	*Trifolium dubium*
Subterranean clover	*Trifolium subterraneum*
Sudangrass	*Sorghum sudanense*
Sugar beet	*Beta vulgaris* var. *saccharifera*
Sunflower	*Helianthus annuus*
Sweetclover	*Melilotus alba*
Tall oatgrass	*Arrhenatherum elatius*
Tanglehead	*Heteropogon contortus*
Texas bluegrass	*Poa arachnifera*
Texas wintergrass	*Stipa leucotricha*
Timothy	*Phleum pratense*
Toad rush	*Juncus bufonius*
Tomato	*Lycopersicon esculentum*
Terfoil	*Lotus*
Vernalgrass	*Anthoxanthum aristatum*
Vetch	*Vicia* spp.
Vetchling	*Lathyrus*
Virgins-bower	*Clematis ligusticifolia*
Watercress	*Rorippa nasturtium-aquaticum (Nasturtium officinale)*
Watergrass	*Echinochloa crusgalli*
Western yellowcress	*Rorippa sylvestris*
Wheat	*Triticum* spp.
White clover	*Trifolium repens*
Whitetop	*Cardaria*
Wild geranium (cranesbill)	*Geranium* spp.
Wild radish	*Raphanus raphanistrum*
Wild winter peas	*Lathapus hirsutus*

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