

PRINCIPLES OF GRAVITY SEPARATION *Jim Thomas*

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All gravity separators utilize the same principles to effect a separation. Once these principles are understood, it is usually a simple step to adjust a gravity separator to produce optimum separation. The term "Gravity Separator" is a contraction of the proper name "Specific Gravity Separator" which means, a separator of particles differing in their specific gravities.

About 250 B.C., Archimedes discovered the law of specific gravity which is ALL BODIES FLOATING IN OR SUBMERGED IN A LIQUID ARE BUOYED UP BY A FORCE EXACTLY EQUAL TO THE WEIGHT OF THE LIQUID THEY DISPLACE. The specific gravity of a particle is the ratio of its density to some standard substance, the standard usually employed being water with a unit of 1. Particles having a specific gravity of less than 1 will float and particles with a specific gravity greater than 1 will sink.

Gravity separators use air as a standard rather than water. Since air is lighter than water, the relative difference between particles of differing weights is widened. For this reason, the gravity separator is a very sensitive machine and when operated correctly can produce a very precise separation.

THE PROCESS OF STRATIFICATION

Air is used as the separating standard through the process of stratification. Stratification occurs by forcing air through the particle mixture so that the particles rise or fall by their relative weight to the air. Figure 1 in the following illustration represents a cross section of the gravity separator directly over a fan. A particle mixture has been introduced on top of the screen deck with the fans off. In Figure 2, the fan has been turned on and adjusted so that the heaviest particles rest on the surface of the deck and the lightest particles are completely free of the surface of the deck. Proper regulation of the air flow at this time is critical or the result is a situation seen in Figure 3 where all particles are lifted free of the separating surface by excess air.

The more difficult the separation, the greater is the area that is required to obtain proper stratification. For example, the stratification area is large when separating frosted beans from saleable beans because there is relatively little difference in weight. However, the stratification area is small when removing rocks from beans because there is a large difference in weight. Higher capacities likewise require greater areas for stratification.

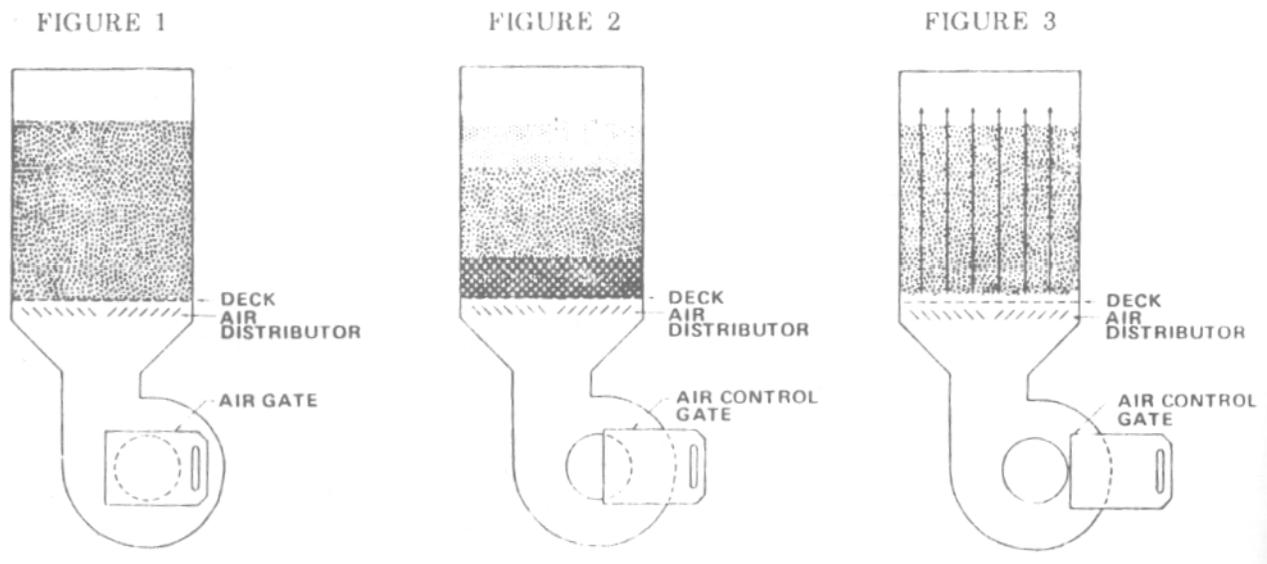
Once the material becomes stratified, the vibrating action of the deck begins pushing the heavier layers in contact with the deck toward its high side. At the same time, the lighter layers which are at the top of the bed and do not touch the vibrating deck, float downhill toward the low side of the deck. As the material flows downhill from the feed end to the discharge end of the deck, the vibrating action gradually converts the layers of vertical stratification to a horizontal separation. By the time the material reaches the discharge end of the deck, the separation is complete. Heavier materials should be concentrated at the high side of the deck, light materials should be at the low side of the deck and intermediate materials will be in between.

It should be noted that the drawing, Figure 4, represents an ideal situation. While ideal situations are nice in theory, they rarely occur in actual practice. Usually the stratification area will not be clearly defined and must be assumed to occupy an area of from 2 to 6 square feet around the feeder. Also, the separation process will begin immediately after the material becomes even partially stratified. Therefore, it is important to stratify the material as quickly as possible or light material may be carried to the high side of the deck before the stratification process occurs. The best way to accomplish this is to use more air at the feed end than at the discharge end.

In many separations, the distinction between heavy good particles and lighter poor particles is not visible to the unaided eye. In this case, periodic testing for weight per test volume at various points along the discharge is necessary to determine if the correct separation is being made.

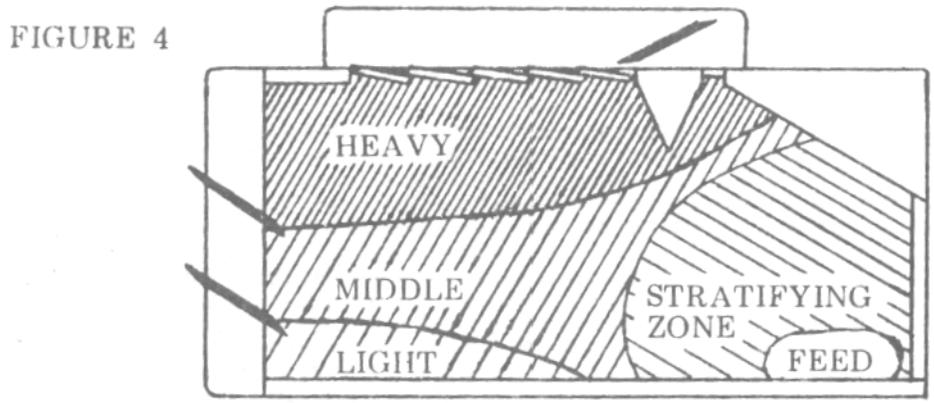
The discharge from the gravity separator is a continuously graded product ranging from the heaviest particle to the lightest particle. In practice however, this continuous grade is broken down into three products

- (1) a heavy or acceptable product;
- (2) a light or reject product; and
- (3) a small middling product which has not fully separated. In processing where rocks or other heavy trash is present a fourth product is sometimes divided consisting of rocks and some good product for further processing.



THE THEORY IN PRACTICE

Figure 4 represents a top view of the ideal situation in the operation of a gravity table.



The seed mixture, similar to Figure 1, falls from the feeder onto the deck. The area immediately around the feeder is called the STRATIFYING AREA. In this area, the vibration of the deck and the lifting action of the air combine to stratify the material into layers, with heavier layers on the bottom and lighter layers on the top as shown by Figure 2. Separation cannot occur until the material becomes stratified.

The size of the stratification area will depend on the difficulty of separation and on the capacity at which you are processing. At no time should it exceed one-third of the deck surface.

WHAT A GRAVITY SEPARATOR CAN AND CANNOT DO

We have stressed the need for earlier processing on products to be introduced onto the gravity separator. Earlier processing can eliminate problems with attempting to make separations that cannot be accomplished. There are three rules developed by Oliver W. Steele which state what can be separated on a Gravity Separator.



**RULE 1.** PARTICLES OF THE SAME SIZE BUT DIFFERING SLIGHTLY IN SPECIFIC GRAVITIES CAN BE SEPARATED.

A common example of this would be the separation of similar size seeds the lighter of which has been hollowed out by insect damage or lack of development.



**RULE 2.** PARTICLES OF THE SAME SPECIFIC GRAVITIES BUT DIFFERING IN SIZE, WILL BE GRADED ACCORDING TO THE SIZE OF THE PARTICLES

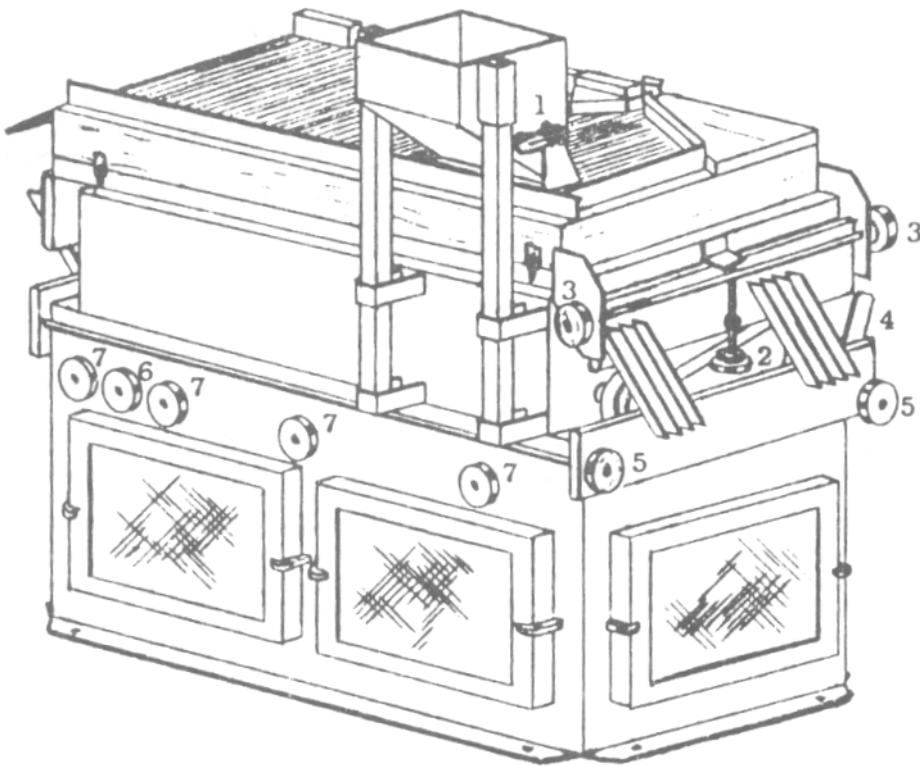
A common example of this would be the elimination of shriveled corn kernels from whole corn kernels of the same weight.



**RULE 3.** PARTICLES DIFFERING IN SPECIFIC GRAVITIES AND ALSO DIFFERING IN SIZE CANNOT BE EFFICIENTLY SEPARATED ON A GRAVITY.

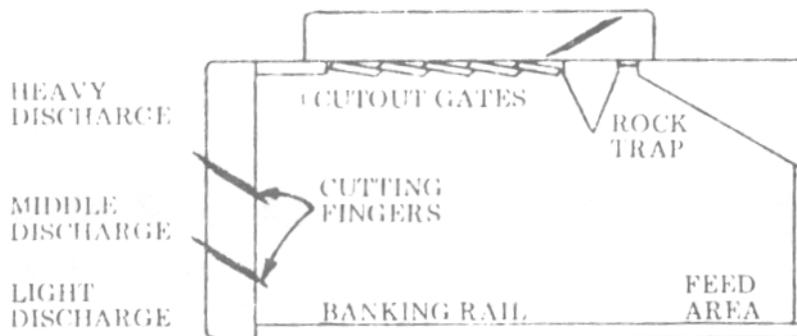
An example of this would be the separation of moon flower vine seed from soybeans where the particles are the same size and the same weight as well. In cases such as this, other processing machinery must be looked to.

## CONTROLS OF THE OLIVER GRAVITY



LEFT HAND MODEL

- |                                |                            |
|--------------------------------|----------------------------|
| 1. Feed rate control           | 5. Side Tilt clamping knob |
| 2. End Raise Control           | 6. "More speed" Control    |
| 3. Clamping knob, end raise    | 7. "More air" control      |
| 4. Side tilt adjustment handle |                            |



## CONTROLS OF THE GRAVITY SEPARATOR

Before starting to operate the machine it is necessary to have a thorough understanding of the controls and their location on your Gravity Separator. Proper regulation of the controls is the key to successful gravity separation and proper use of these controls should be understood prior to attempting an actual separation.

THE DECK. The most important part of the Gravity Separator is the deck because it is the main separating surface. It consists of a carefully constructed wooden frame to counteract vibration problems with a screen or cloth overcover which is the surface on which the separation takes place.

On the open end of the deck are mounted two cutting fingers which are adjustable to channel different fractions of the finished product according to their value. On the heavy side of the deck towards the feed end is the rock trap which is used to bleed a heavy trash product from the machine to avoid contamination of good heavy product. These features will be discussed further in these instructions but knowledge of their location is important as well as understanding the controls that affect the five variable adjustments on the gravity separator.

THE FIVE ADJUSTMENTS. All gravity separators have five variable adjustments which must be properly adjusted and balanced to obtain optimum separation. These are feed rate, end raise, side tilt, eccentric speed and air control. We will discuss the controls for each of these variables in turn.

FEED RATE. The feed rate control is located on the feeder and controls the amount fed onto the separating deck. The feed rate, whether fast or slow, should be uniform and free of surges. Surges in the incoming feed will show up in the discharge of the machine as a poor quality separation. We suggest the use of surge bins above the feeder if processing will be interrupted.

Generally the average feed rate is determined by the average capacity of the processing line of equipment. For optimum separation on your gravity separator, your feed rate should be as low as possible without falling below the minimum feed rate at which the deck can be kept completely covered. Maximum feed rate is the maximum rate the deck can be fed and still obtain the necessary separation. When starting your gravity separator, always start at the minimum feed rate, obtain your required separation, then increase the feed rate to the desired capacity.

END RAISE. End raise is the slope from the feed end of the deck to the discharge end. This slope determines the rate of flow from the feed end to the discharge end of the deck. Greater end raise means a greater rate of flow and consequently less exposure time for the seed. Less end raise means a slower rate of flow and consequently more exposure time for the seed. Quality of separation can be related to exposure time for the seed. In general, the longer a seed mass is exposed to a separating action, the cleaner it becomes.

End raise and feed rate are closely related controls. As feed rates are increased, end raise must be increased so that the depth of material on the deck will not become too great. As feed rates are decreased, the end raise should be lowered so that the depth of material will not become too thin and the deck will remain completely covered. The end raise control (2) is located at the feed end of an Oliver Gravity separator. To change the end raise, loosen the clamps (3) and screw the adjusting crank up or down as required, then retighten the clamps.

SIDE TILT. Side tilt is the difference in elevation between the high side of the deck and the low side of the deck. Increasing side tilt will cause the material to shift toward the low side of the deck. Decreasing side tilt will cause the material to shift toward the high side of the deck. Normally, the best separations are obtained when side tilt is set at or near the maximum steepness. However, care should be taken not to set side tilt too steep. Side tilt is too steep when material cannot be made to flow toward the high side of the deck by increasing the eccentric speed. The side tilt is adjusted by loosening two clamping knobs (5) and moving the side tilt adjustment handle (4) in towards the machine for more tilt and away from the machine for less tilt.

ECCENTRIC SPEED. As we have seen, eccentric speed and side tilt are closely related. Increasing eccentric speed will cause material to be shifted toward the high side of the deck. Decreasing eccentric speed will cause material to be shifted toward the low side of the deck. Generally by increasing side tilt (which shifts light materials back toward the low side) a more precise separation can be obtained. Too much eccentric speed can be observed when all the material shifts to the high side of the deck despite maximum tilt being used on the side. Eccentric speed is adjusted by turning the "More Speed" control knob (6) located on the side of the machine. Turning the knob clockwise increases the speed and turning the knob counter-clockwise decreases the speed.

AIR ADJUSTMENT. Air regulation is one of the most important adjustments to be made on a gravity separator. The most common mistake in air regulation is the use of too much air. Separation is not made by "blowing" the light material from the heavy but by using a controlled air flow to create the stratified layers which are then separated by the vibrating action of the deck. Too much air will cause a boiling or bubbling action lifting the heavier particles from the deck and mixing them with the lighter top layers. Too little air will cause the material to appear sluggish and pile up at the high side of the deck.

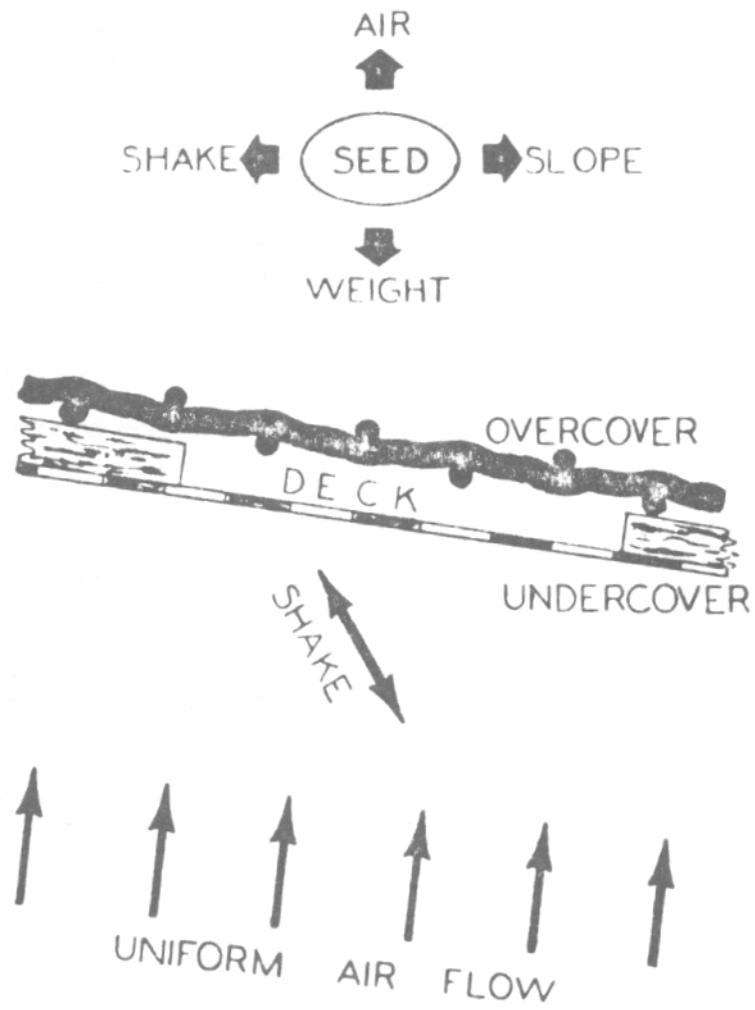
With proper air regulation the bed of material will be almost fluid in appearance. With the exception of the stratifying zone under the feeder, the material on the surface should be agitated and free flowing. Bubbling should be kept to a minimum allowing the vibrating deck to make the separation.

Through experience it was discovered that the air pattern under the deck must be varied when working with different commodities and sometimes even with different lots of the same commodity. To enable these corrections to be made quickly and accurately in the field, Oliver Manufacturing Company developed and patented a system of multiple fans to supply the air for separation. Each fan is individually adjustable to enable the processor to adjust the air pattern and air volume as necessary to make an optimum separation. With other single fan systems and even with the newer vacuum systems, the air patterns are preset at the factory and very little range of adjustment is available to the processor.

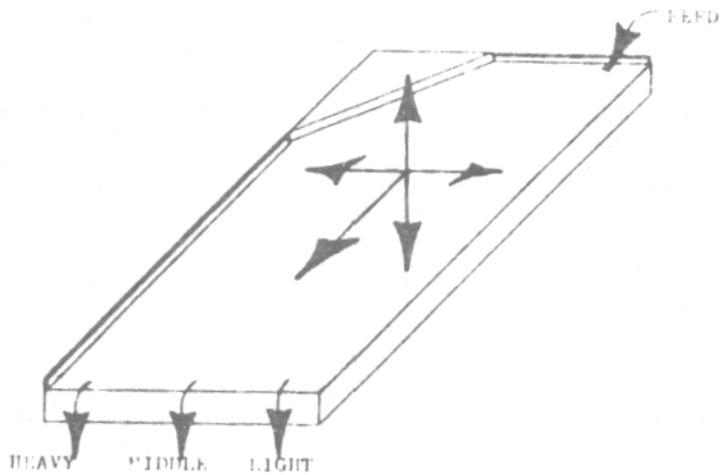
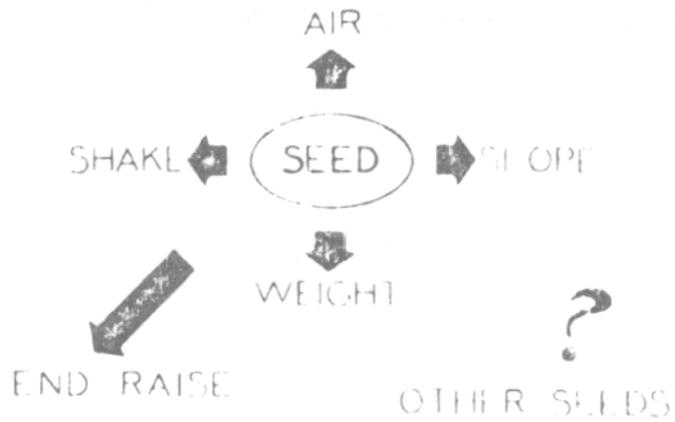
Air on the multiple fans is regulated by turning the "More Air" control knobs (7) clockwise for additional air and counter-clockwise for less air. There are roughly 110 revolutions of the knob between a closed air gate and a fully opened air gate.

All the controls on a gravity separator or stoner serve a purpose and each must be balanced with the others to obtain the optimum separations. The following sketch is a representation of the forces acting on a seed during separation. As illustrated, the weight of the seed tends to move the seed down while the moving air forces the seed up. The shaking action of the deck tends to move the seed to the left and the side slope of the deck tends to move the seed to the right. As long as all the forces are in balance the seed will remain in the same relative position. Lighter seeds will be lifted higher by the moving air and will move toward the right. Heavier seeds will not be lifted as high and will rub the shaking deck more often therefore moving to the left.

FACTORS AFFECTING SEED SEPARATION  
ON GRAVITY SEPARATORS



FORCES AFFECTING SEED SEPARATION ON GRAVITY SEPARATORS

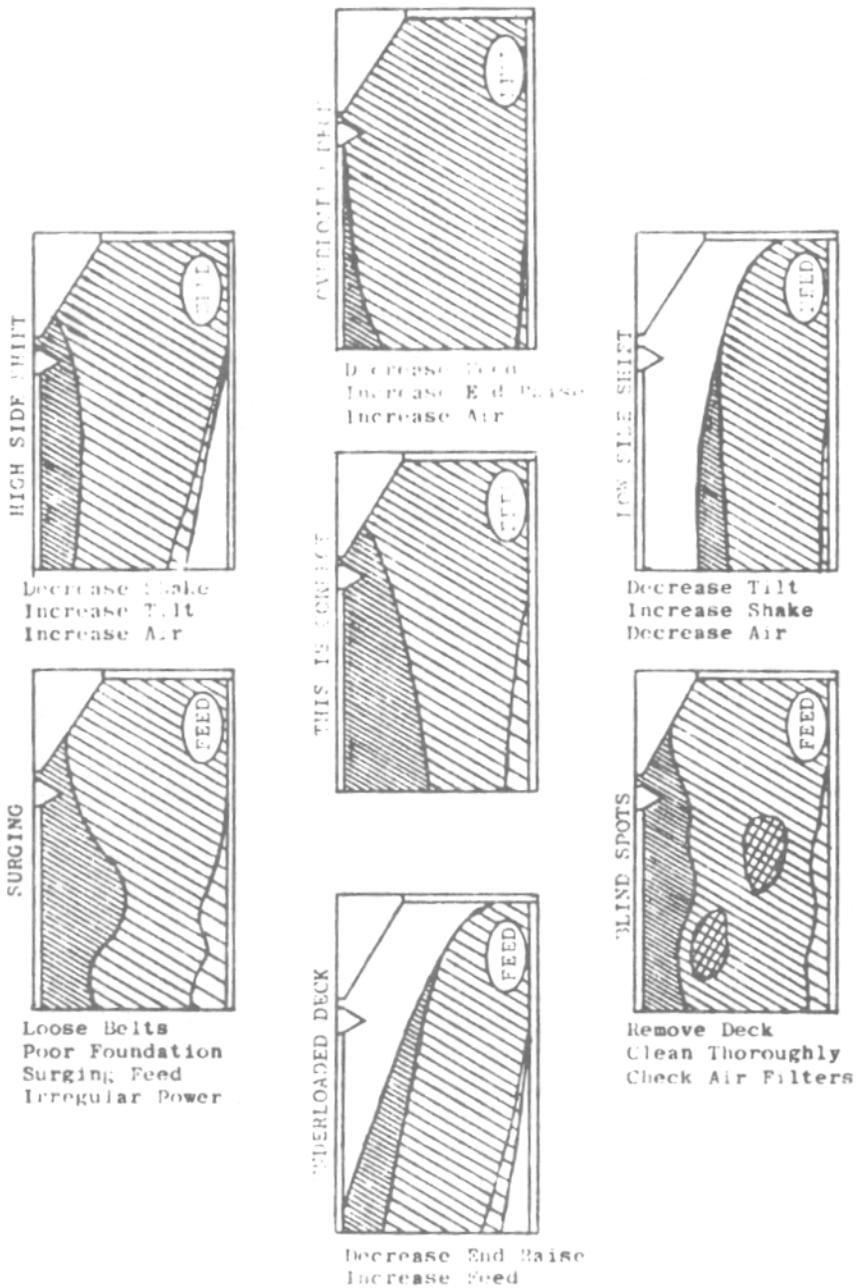


As pictured in the preceding sketch, any change in the air control eccentric speed (shake) control of the side tilt (slope) control produces a direct effect on the seed and consequently has an effect on the quality of separation. However, gravity separators have five adjustments. In the following sketches we have included the end raise and feed rate adjustments.

Feed rate and end raise are very closely associated with capacity whereas side tilt, eccentric speed and air adjustment are more closely associated with quality of separation. In general, increasing capacity decreases the quality and decreasing capacity increases quality of separation.

The following illustrations show some common operating problems and offer some corrections to help clear up the problem.

COMMON OPERATING PROBLEMS



## AUXILLIARY EQUIPMENT

MIDDLING PRODUCT. Many processors ask us what can be done to reduce or reprocess the middling product produced by the Oliver Gravity Separator.

The simplest method of reducing the middle cut is to run the machine at lower capacity. Since capacity and quality are offsetting, it naturally follows that quality of separation will improve when capacity of operation is decreased. By holding material on the deck longer, often separation will be superior enough that the middle product ceases to be a problem.

Many processing plants cannot reduce capacity because of production demands. When adequate storage is available, these plants place the middle and light fractions in a holding bin and reprocess them through their production line during periods when more time is available. The advantage of this system is that it allows a high initial capacity during the processing season and allows a little extra time to process the middle fractions more slowly during slack periods. The disadvantage of this system is that storage space is required to contain the middle fractions until they can be processed.

An *alternative* solution which eliminates the need to store the middle fraction is to run the middle fraction back into the processing line and clean it during the regular separation process. Some operators merely connect an elevator from the middle discharge spout of the gravity and run the material back to the feeder. While this is often an acceptable solution, we feel there is a better way.

If you want to clean the middle fraction with the initial processing run, we suggest you return the material to the feeder of the screen air machine. Normally the middle fraction consists of small heavy particles and large light particles. The screening action of the screen air machine will improve the condition of the middle fraction somewhat before it is fed onto the gravity. The major advantage of this system is that all the material is cleaned in one processing operation and no bin space is required for the middle product. The disadvantage is that the overall production of the plant is reduced by the amount which is fed back into the processing line.

A final alternative is to use a successive line to clean the middle product during the regular processing action. This should consist of a shall screen machine to size the middling product and a gravity separator to finish the separation. This is probably the best solution for large processing plants. It allows for a high capacity primary processing line and a slower more precise secondary line to clean the middle fractions.

## RECTANGULAR OR TRIANGULAR DECKS?

A question which often arises is *whether* rectangular or triangular gravities should be used. Normally the answer is dependant upon individual requirements. The first gravities were triangular types and were developed to concentrate minerals. In the early 1900s, they were re-designed to process seed and grain for agricultural needs. Both stoners and rectangular type gravity separators were developed from these early triangular models to fill a particular need.

In operation, it was quickly discovered that stones were discharged from the high side of the deck along with the good seed. In an effort to separate the stone from the good seed, triangular gravities were refined and corrected until the stoner was developed. In operation, the Stoner had more capacity and made a more precise separation of stone than the triangular gravity separator. However, the stoner did a very poor job of removing light trash, such as stems and hulls from the product. Triangular gravities removed light trash very well but were low in capacity when compared to stoners.

In an effort to increase the capacity of gravity separators, Oliver Steele, one time president of Sutton, Steele and Steele, and president and founder of Oliver Manufacturing Company, developed the rectangular type gravities. Rectangular gravities were found to produce a separation of light trash far superior to triangular machines. In addition, the separation could be made at higher capacities. However, rectangular type separators would not make as good a separation of the stone product as a triangular gravity.

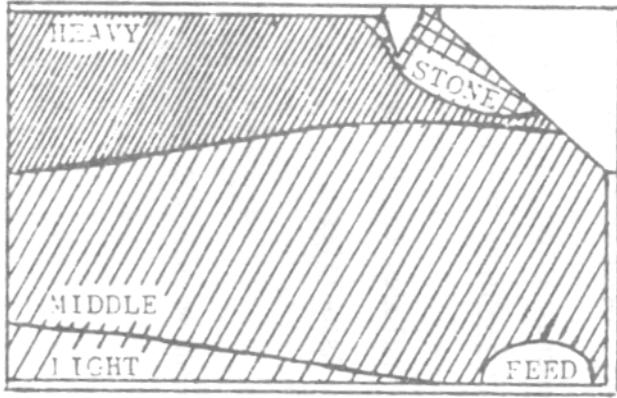
Triangular gravities are general purpose machines. They can be used to separate either stones or light trash. Normally, they do not make optimum separations of both the light trash and the heavy stone at the same time as different setting are required.

Stoners and rectangular gravities are specialized forms of gravity separators.

Stoners are designed to remove a heavy stone product quickly and efficiently. They do a poor job of removal of light trash.

Rectangular gravities are designed to remove light trash. They do a very good job at high capacities. However, they will not produce a stone product which is free of good seed.

The following illustrations show examples of comparative models of triangular gravities, stoners, and rectangular gravities.



RECTANGULAR



STONIER



**SESSION ON EQUIPMENT DEMONSTRATION**

- Ojyard Seeder - J. T. Love Mfg.  
Discussion of adjustments for sowing rates
- Oliver Gravity Separator - Oliver Mfg. (Jim Thomas)  
Demonstration of separating precolored alpine fir seed
- EDC Dewinger - Equipment Development Center (Ben Loman)  
Demonstration of dewinging sand pine seed
- Vacuum air separator - Barnes Tree Improvement Co. (Gerald Barnes)  
Demonstration of cleaning debris from dewinged sand pine seed
- Faxitron X-ray unit - Hewlett-Packard Mfg. (Richard Espejo)  
Demonstration of radiographic technique with several western tree seeds
- Dybvig Macerator - (Melvin Dybvig)  
Discussion of unit and display
- Reforestation Supplies - International reforestation Suppliers (Stew Gibbs)  
Presentation of supplies available
- Ojyard Seeder - J. T. Love Mfg. Demonstration  
of sowing on nursery bed
- Cone Drying equipment - International Forest Seed Co. (Bill Issac)  
Film presentation of equipment in use
- Redwood Seed Cleaning Demonstration - Simpson Timber Co. (Jim Rydelius &  
Earl Belcher)  
Demonstration of all machines for improving full seed percent of  
redwood seed
- Literature Display also included the following  
Crippen Mfg.  
R. W. McPherson and Associates  
Ridge Instrument Co.  
W-W Grinder Co.  
Chantland Co.  
Sortex Co.  
Ballard Seed Packeting Machines Co.