UNIT 3 CLEANING AND GRADING

Structure

3.0 OBJECTIVES

By the time you have studied this unit, you should be able to:

- understand the importance of cleaning and grading in the food processing operations;
- know the cleaning and grading devices and their operating principles; and
- should be able to select a suitable cleaning and grading device for any given operation.

3.1 INTRODUCTION

Cleaning and grading are important post harvest operations undertaken to remove foreign and undesirable materials from the produce and to separate the produce into various fractions. The comparative commercial value of food products is dependent on their grade factors. These grade factors further depend upon (1) physical characteristics like size, shape, moisture content, colour, etc., (2) chemical characteristics like odour, and (3) biological factors like insect damage.

It is difficult to clearly differentiate between the processes of cleaning and grading because these are carried out simultaneously with the common procedures. The operation of cleaning and grading of the products are performed by exploiting the differences in engineering properties of the materials. These products may be used either for food or seed purposes.

3.2 DEFINITIONS AND OBJECTIVES OF CLEANING

Cleaning and grading both are the processes of separation. Cleaning generally means the removal of foreign and undesirable material from desired grains / products. The objective is to reduce the cost of further handling as unnecessary fraction would have been separated. Besides the clean material fetches higher prices. In this sense, cleaning is a value addition operation.

Grading refers to the classification of the cleaned product into various quality functions depending upon the commercial value and usage. For example, separating ripe tomatoes from unripe ones. This also is a value addition operation.

3.3 METHODS OF CLEANING

The undesirable material from the mixture could be removed by wet, dry or a combination of wet and dry methods.

3.3.1 Wet Method

The wet method of cleaning consists of spraying clean water over the mixture in a trough of water to remove the undesirables. Then the desirable washed material is appropriately dried to remove the adhering moisture. It is important in this process that the desirable material should not get affected by the washing treatment and that the water used for washing is clean so as not to leave any residue after washing and drying.

3.3.2 Dry Method

The dry methods of cleaning are based on the specific properties of the constituents of the mixture such as:

1. Size
2. Shape
3. Specific gravity or weight
4. Surface roughness
5. Aerodynamic properties
6. Ferro-magnetic properties
7. Colour
8. Electrical properties

Cleaners based upon size

Screen cleaners/graders: It performs the separation according to size alone. The mixture of grain and foreign matter is dropped on a screening surface, which is vibrated either manually or mechanically. A single screen can make the separation into two fractions. The screening unit may be composed of two or more screens as per the cleaning requirement.

A hand-operated screen cleaner (Figure 3.1) is made of mild steel. The separation takes place due to difference in size of grain and foreign matter. The cleaner is operated by hanging on an elevated point with the help of four ropes. Produce is fed on the screening surface in batches. The screens can be changed as per the grain to be handled. The cleaner is swung to and fro till all the grain is screened. The cleaned grain is retained by the bottom sieve which can be discharged by pulling a spring loaded shutter. Impurities of larger size, stubbles, chaff etc. are retained on the top sieve and can be removed easily. Down stream from the bottom sieve consists of dust, dirt, brokens, shrivelled produce etc. drop down during the operation.

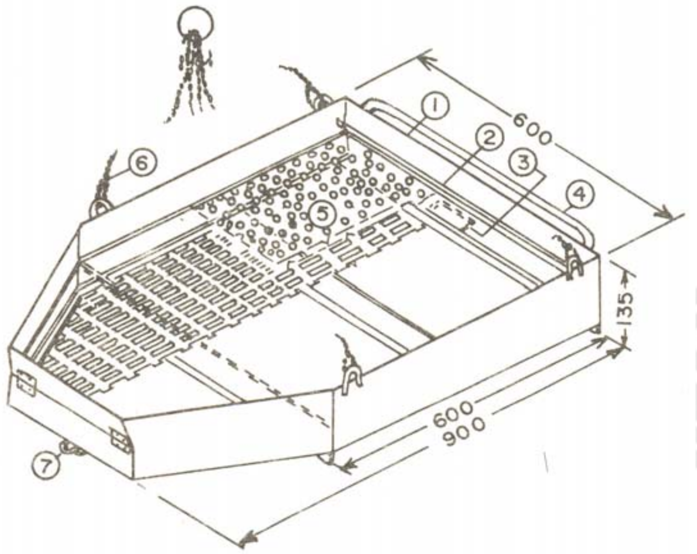

Figure 3.1: Hand operated double screen grain cleaner. 1) frame 2) draper rod 3) screen handle 4) handle 5) scalper and grader screens 6) rope attachment 7) shutter opening attachment

Air screen cleaners: The screens used in combination with air blast performs satisfactory cleaning and separation operations for most of the granular materials. The air-screen cleaner uses three cleaning systems: blowing or aspiration, scalping screens and grading lower screens. The air-screen grain cleaner can be classified in two distinct types: *(i)* vibratory screen, *(ii)* rotary screen, based on movement of the screening surface.

Vibratory air-screen cleaner: The screening unit is composed of double or multiple (up to 8 number) screens. These screens are tightened together and suspended by hangers in such a manner that these have horizontal oscillating motion and slightly vertical motion. These two motions in combination move the grain down the screen and at the same time toss sufficiently above the screen so that the bed of grain is properly stirred. The slope of the screen is adjustable to control the rate of downward travel of the grain. The screens are available in various shapes like; round, triangular or slotted holes as discussed earlier. Sometimes the holes of the screen are clogged when the machine makes fine degree of sorting. To avoid the clogging, the screens are generally fitted with a brush which moves under the screen and pushes the clogged material back through the screen. Other such devices can also be used for this purpose. A simple vibratory type air-screen cleaner is shown in Fig. 3.2.

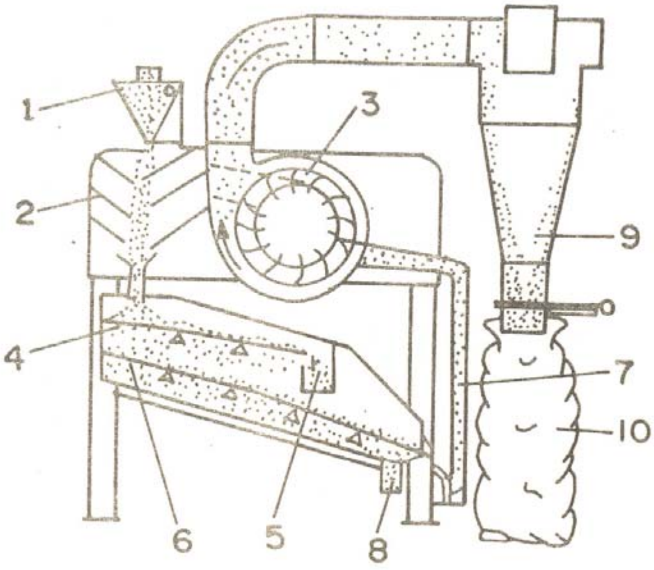

Figure 3.2: Schematic diagram of a vibratory air screen cleaner. 1) Feed Hopper, 2) Baffle plate, 3) Blower, 4) Upper screen, 5) Discharge channel, 6) Sand sifter, 7) Ascending separator, 8) Discharge funnel, 9) Centriclone, 10) Dust Bag

Rotary screen cleaner: The rotary screen cleaner has normally circular decks. Their motion is circular in horizontal plane. These have either single or double drum. A single drum rotary screen cleaner is shown in Figure 3.3. The machine consists of a rotary screen, aspirator and hopper and equipped with an electric motor, which gives drive to the rotary screen and the aspirator. The mixture is fed into the hopper. The sound grains pass through the screen perforation into the centre of the screen drum, whereas oversized material is retained above and pass out though an outlet. The sound grains come out at the centre side of the screen drum rotating at low speed and fall onto the vibratory screen which remove the dirt particles. The light particles like straw and dust are sucked away by the aspirator and discharged through the aspirator outlet. The cleaned grains are delivered through the discharge chute.

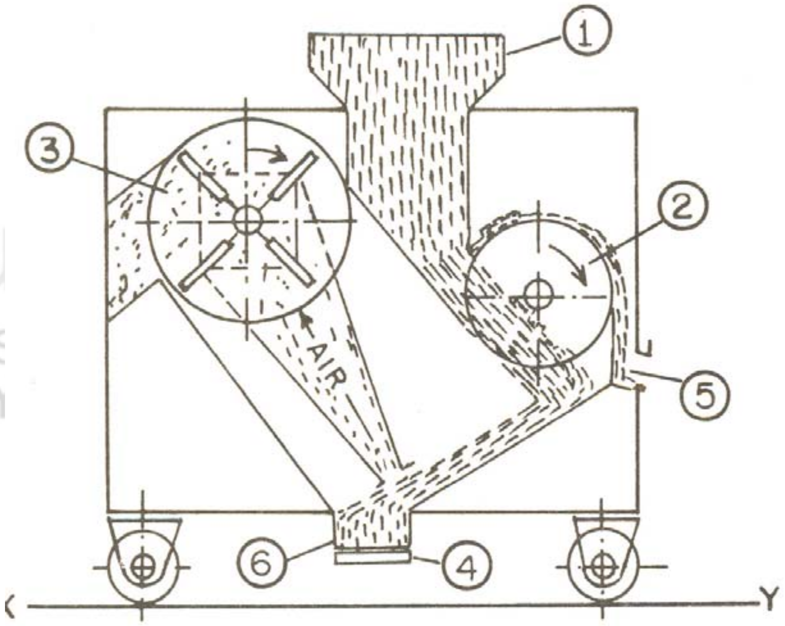

Figure 3.3: Diagram of a single drum rotary screen cleaner. 1) Feed hopper, 2) Rotary screen, 3) Aspirator, 4) Discharge chute, 5) Over size foreign matter outlet, 6) Vibratory screen

Specific gravity cleaners

The specific gravity separator makes the separation according to difference in density or specific gravity of the materials. This separator works on two principles, (1) the characteristics of grains to flow down over an inclined surface, (2) the floatation of the particle due to upward movement of air.

The main part of the device is a triangular-shaped perforated deck. The deck is properly baffled underneath to ensure uniform distribution of air over it. The pressure or terminal velocity of the air rising through the deck can be controlled very closely within a wide range (Figure 3.4).

The mixture of produce is fed into the feed box. The air is blown up through the porous deck surface and bed of the grain by a fan at such a rate that the material is partially lifted from contact with the deck surface. The lightest materials are lifted to the top of the stratified mass. The air does not lift the heavier particles. The stratified mass moves along the direction of conveyance due to oscillating motion of the deck and is discharged at the right edge of the deck.

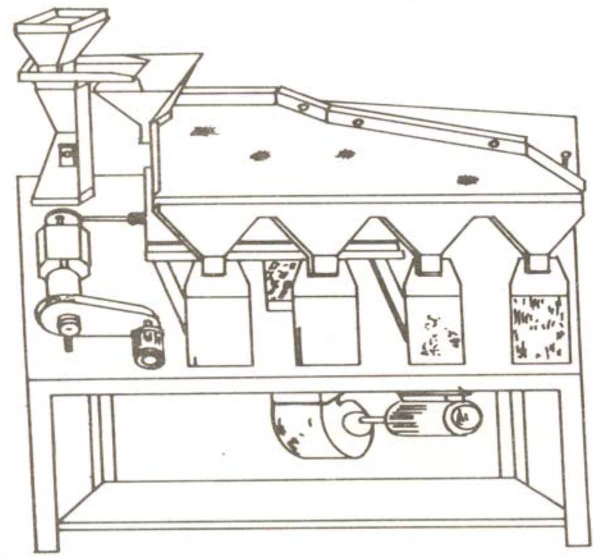

Figure 3.4: Specific gravity separator

Aerodynamic cleaners

The pneumatic separation is based on the difference in aerodynamic properties of various constituents of the mixture. The aerodynamic properties of a particle depend upon its shape, size, density, surface and orientation with respect to air current. Both the aspirator and the pneumatic separator use terminal velocity of the grain to separate different fractions. This refers to the velocity of air required to suspend particles in a rising air current.

In a pneumatic separator, the fan is placed at the intake end of the machine, which creates higher pressure than the atmospheric pressure. The high pressure air blast separates the materials. The mixture of products is introduced into a confined rising air stream; the air current lifts the particles with low terminal velocities whereas the particles with higher terminal velocities than air velocity fall down. The air velocity can be adjusted by altering the speed of fan or by changing the opening of air inlet (Figure 3.5).

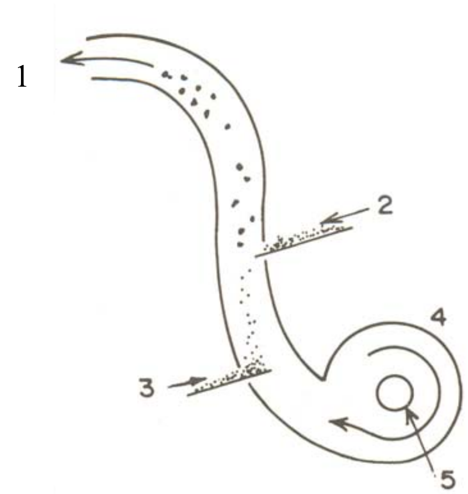

Figure 3.5: Diagram of a pneumatic separator. 1) Undersirable material removal, 2) Uniform feeder, 3) Clean grain outlet, 4) Centrifugal blower, 5) Control for air intake

3.4 METHODS OF SEPARATION

We often encounter mixtures of food materials, which need to be separated into different fractions for either subsequent marketing or processing. Fruits harvested from an orchard are normally of different sizes, which would fetch lower prices as compared to the graded fruits packed nicely. There are several similar situations where it is necessary to separate different fractions from a mixture. This separation could be achieved by utilizing one or more of the properties of the constituents of the mixture. The most common property is the size. The other properties normally utilized for separation are weight, specific gravity, surface roughness, optical properties and magnetic properties. The basic principles of the operation of different separators are being presented in the following sections.

3.4.1 Size Based Separators

The bulk food material such as a basket of fruits or vegetables is fed to a container from which the individual food items are segregated on the basis of their diameter or length or any other significant dimensions. In case of handy materials such as dry fruits and nuts, even oscillating sieves could be used for the separation. However, fresh fruits and vegetables get easily damaged, therefore, they need to be carefully handled. The relative motion between the food items and the separator is minimized. A grader for separating mangoes on size basis is shown in Figure 3.6. As you may note the fruits roll on the continuously diverging channel and, thus, the separation takes place.

Figure 3.6: Size based mango grader

3.4.2 Specific Gravity Separators

Some materials, when separated on size basis do not give the correct classification, for example, some groundnut pods may attain a particular size, the kernels in them remain immature. Obviously, such pods are not desirable and need to be separated from the pods that have bold kernels. This separation could be achieved by letting the mixture float in a fluid. Based on the specific gravity, the fractions will settle down differently. A cream separator in dairy processing is also categorized under specific gravity separators.

3.4.3 Colour Separators

The colour separator separates the fruits, vegetables or grains due to difference in colour or brightness. The colour separators are generally used for larger crop seeds like peas and beans. These seeds differ in colour because of varietal differences and also due to immaturity or disease. The mud balls and discoloured or defective seeds can be removed with the help of electronic separator. The material mixture is fed uniformly into the optical chamber of the separator.

Two photocells are fixed at a particular angle, which direct both beams to one point of the parabolic trajectory of the grains. A needle is placed on the other side, which is connected to a high voltage source (Figure 3.7). When a beam falls on a dark object through photoelectric cells, current is generated on the needle. The needle end receives a charge and imparts it to the dark seeds. The grains are then passed between two electrodes with a high potential difference between them. The seed is compared with a selected background or colour range, and is separated into two fractions according to difference in colour. Since this machine views each produce individually, the capacity is low.

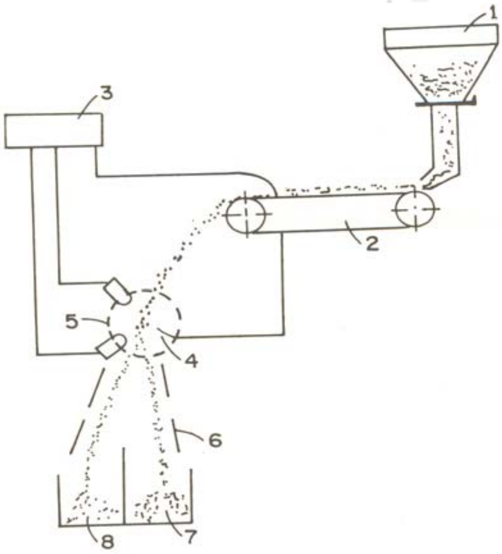

Figure 3.7: Schematic of a colour separator 1) hopper, 2) belt conveyor, 3) amplifier, 4) charging needle, 5) optical chamber, 6) deflecting electrodes, 7) foreign material, 8) desired material

3.4.4 Weight Based Separators

Certain food items are of regular shape or size. They are separated on weight basis. The food items are conveyed over a set of pan balances arranged in such a way that the lowest weight objects travels farthest. Heavier object tips the balances earlier and get collected in a trough. The lighter object passes on these balances and moves farther till the appropriate balance tips down and the object is picked up for separation into the correct class.

3.4.5 Magnetic Separators

The magnetic separator performs separation on the basis of surface texture and stickiness properties of the grain. Since the grains do not contain any free iron, therefore, are not attracted by the magnet. A selective pre-treatment of mixing finely ground iron powder to feed mass is given. The grain mixture is fed to a screw conveyor or other mixing device that tumbles and mixes the grain with a proportioned amount of water. Due to moisture, iron powder adheres to rough, cracked, broken and sticky seed coats. Moisture does not remain on smooth grains so no iron powder adheres to smooth surfaced grains.

The grain mixture is fed onto the top of a horizontal revolving magnetic drum, the smooth grains that are relatively free of powder fall along the drum simply by gravity. The materials with iron powder are attracted by the magnetic drum and stick to it and are removed by rotary brush or break in the magnetic field as shown in Figure 3.8.

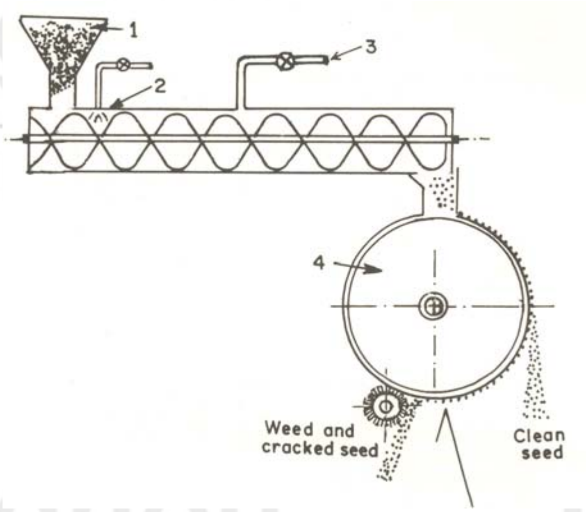

Figure 3.8: Magnetic Separator. 1) Feed hopper, 2) Water spray, 3) Iron powder mixing, 4) Magnetic drum.

3.4.6 Surface Texture/Roughness Separator

The mixture to be separated is fed over the centre of an inclined draper belt moving in upward direction. The round and smooth grains roll or slide down the draper at faster rate than the upward motion of the belt, and these are discharged in a hopper. The flat shape or rough surfaced particles are carried to the top of the inclined draper and dropped off into another hopper. (Figure 3.9). The belts of different degrees of roughness may be used as a draper for separate materials. If rolling tendencies of the grain are predominant, the rough canvas belt may be used. The smooth, plastic belt may be used in case sliding action is desired for the lower fraction. Feed rate, speed of draper and angle of inclination are other important variables for effective separation of dissimilar materials.

The feed rate is kept low enough to give opportunity to each grain for separation. The speed of the draper may be varied to simulate with the length of incline. The angle of inclination is adjusted to assure rolling or sliding of the desired lower fraction. To increase the capacity of the separator, number of belts may be used one above another in a single machine.

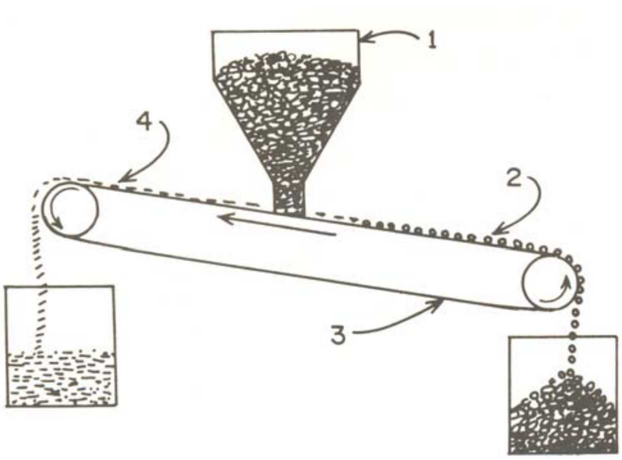

Figure 3.9: Inclined draper. 1) Feed hopper, 2) Round seed, 3) Canvas draper, 4) Flat seed/impurities.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Define cleaning and grading.

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2. Enlist five different characteristics of foods that are used for its separation from unwanted materials.

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3. Describe the working principle of the following:

   i) Air screen separator
   ii) Inclined draper
   iii) Pneumatic separator
   iv) Colour sortor

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3.5 SCREENS

The basic purpose of any screen is to separate a mixture of particles / items of different sizes into two distinct fractions. These fractions are, (1) the - underflow, the particles that pass through the screen, and (2) the overflow or oversize, the materials that are retained over the screen. A screen can be termed as **ideal** screen that separates the mixture in such a way that the largest particle of underflow is just smaller than screen opening, while the smallest particle of overflow is just larger than the screen opening. But in practice a given screen does not gives perfect separation as stated above, and is called **actual** screen. The underflow may contain material coarser than screen size, whereas the overflow may contain particles smaller than screen size as shown in Figure 3.10.

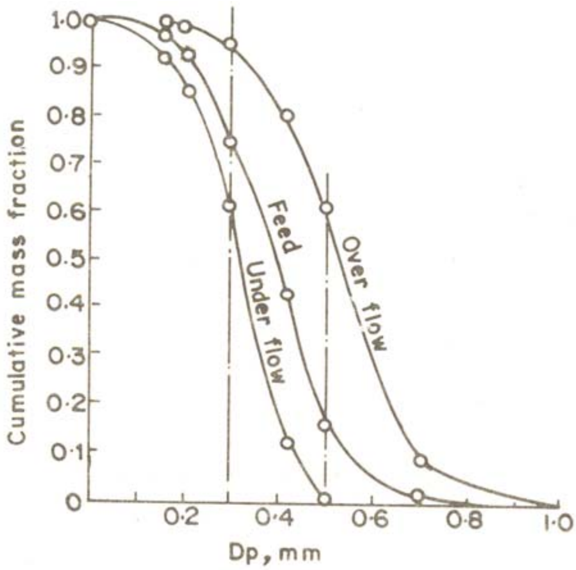

Figure 3.10: Graphical representation of various flows of a screen

In most screens the grain/ seed drops through the screen opening by gravity. Coarse grains drop quickly and easily through large opening in a stationary surface. With finer particles, the screening surface must be agitated in some way. The common ways are, (1) revolving a cylindrical screen about a horizontal axis and (2) shaking, gyrating or vibrating the flat screens.

3.5.1 Grizzly

The grizzly is a simple device consisting of a grid made up of metal bars, usually built on a slope, across which the material is passed. The path of material flow is parallel to the length of bars. The bars are usually so shaped that the top is wider than the bottom. The grizzly is often constructed in the form of a short endless belt so that the oversize is dumped over the end while the sized material passes through. In this case bar length is transverse to the path of materials. The grizzly is used for coarsest and rough separations.

3.5.2 Revolving Screen/Cylinder Sorter

Trommel or revolving screen is a cylinder that rotates about its longitudinal axis. The wall of the cylinder is made of perforated steel plate or sometime the cloth wire on a frame, through which the material falls as the screen rotates. The axis of cylinder is inclined along with the feed end to the discharge end. Sizing is achieved by having smallest opening screen at the feed end with progressively larger opening screens towards the discharge end. This type of sorter is simple and compact with no vibration problem. But the capacity of cylinder sorter is lesser than the vibrating screen of same size. Although it is an accurate sizer, it does not perform well with friable material or in cases where particle degradation is undesirable because tumbling produces some autogeneous grinding. The speed of rotation of the trommel is kept within the limit at which the material is carried from bottom to a distance equal to the radius of cylinder before it starts tumbling. The inclination of cylinder sorter for dry granular materials is kept up to 125 mm/m. Changing the speed of operation and the inclination of cylinder can change the capacity, bed depth and efficiency of these screens. Effective screening area (not the total surface of cylinder) is calculated by multiplying the length of cylinder by $\frac{1}{3}$ of the diameter.

3.5.3 Shaking Screen

Like the vibrating screen, shaker is a rectangular surface over which material moves down on an inclined plane. Motion of the screen is back and forth in a straight line. Although in some cases vibration is also given to the screen. Unlike the vibrating screen, the shaker does not tumble or turn material enroute except that some shaking screens have a step-off between surfaces having different size openings, so that there may be two or three tumbles over the full length of the screen. The shaker is widely used as combined screen and conveyor for many types of bulk material.

3.5.4 Rotary Screen

Rotary and gyratory screens are either circular or rectangular decked. Their motion is almost circular and affects sifting action. These are capable of accurate and complete separation of very fine sizes but their capacity is limited. These screens are further classified into two categories.

Gyratory Screens

This is generally a single decked machine. It has horizontal plane motion, which is circular at feed end and reciprocating at the discharge end. The drive mechanism is at the feed end and is either a V-belt or direct coupling. The shaft that imparts motion to the screen is a counter balanced eccentric. The shaft moves about a vertical axis. At the discharge end most rotary screens have linkage to the base frame, usually a self-aligning bearing. Gyratory screens operate with screening surface nearly horizontal.

Circular Screens

These are also rotary screens but their motion in horizontal plane is circular over the entire surface. Similar to the gyratory screens, the screening surface of circular screens is also little bit tilted for allowing the material to move over them.

3.5.5 Vibratory Screen

The vibratory screens are agitated by an eccentric unit. When materials to be separated are put on a vibratory screen, because of its vibration, materials are also agitated and separated during their transit over the screen. The eccentricity is usually of two types, (1) a shaft to which off centre weights are attached, and (2) a shaft that itself is eccentric or off centred. In the later case the eccentricity is balanced by a fly wheel for providing uniform vibration. Most vibrating screens are inclined downward from the feed end. Vibration is provided to the screen assembly only, and the body and other surrounding structure are isolated from vibration. Generally, upto three decks are used in vibrating screens. The capacity of vibrating screen is higher than any other similar sized screen and is very popular for cleaning and grading of granular agricultural products.

3.5.6 Horizontal Screen

Horizontal screens are special case of vibrating screen. These are designed for operation with low head room. They operate absolutely flat without the aid of gravity. All sorting, stratification and material transportation' take place on the strength of a sharp forward thrust which imparts motion to particles with a missile like trajectory, while the return stroke pulls the deck out from underneath the bed. Effectiveness of these screens is higher because material is kept on the screen for a longer period in comparison to inclined screens.

3.5.7 Other Screens

Various other types of screens used for cleaning and separation are listed below:

1. Rotex screens
2. Hummer screens
3. Circular vibrators
4. Symon's rod deck screens
5. Resonant vibrant screens
6. Centrifugal screens

3.5.8 Particle Motions in Separation Equipment

There are four different regime motions that can take place for the rigid particles placed on a moving trough depending upon the frequency of oscillation. The regimes are given below:

1. Particles stationary with respect to trough.

2. Particles slip during part of cycle and remain adherent to the trough during the rest of cycle.

3. As regime (2) with slip and gliding motion.

4. Particles purely in stick and slip motion.

Reciprocatory Motion

This can be either purely in horizontal plane or in an inclined plane. Depending upon the plane, the motion of particles is different as given below:

a) **Horizontal reciprocating motion:** This motion is obtained with an eccentric and a connecting rod and is usually in a path parallel to the horizontal projection of the path of material as it moves from inlet to outlet as shown in Figure 3.11. If the pitch (amplitude) is steep enough the motion has a substantial vertical component to the screen surface, which initiates sliding motion, and a large quantity of material can be moved.

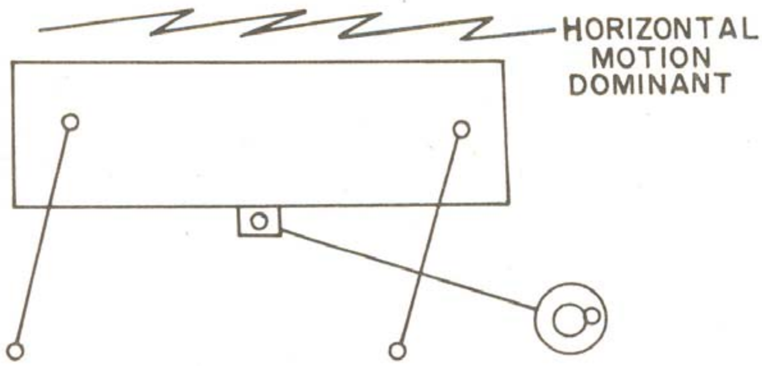

Figure 3.11: Horizontal reciprocating motion

b) **Inclined reciprocating motion:** The screen can be moved in an inclined plane reciprocatingly by eccentric and connecting rod unit (Figure 3.12). Such motion would have a vertical and horizontal components parallel to the horizontal projection of path of moving material. Combined horizontal and vertical motion can also be achieved by a rotary drive attached directly to the screen and operating in a vertical plane parallel to the path of the material flow. The horizontal motion is shown in Fig 3.13b and the vertical motion is shown in Fig 3.13a. The vertical component lifts the material from the screen surface for a fraction of time. The vertical motion can loosen the mass of material thus dislodging finer particles to settle at the bottom. The combined vertical and horizontal motion is also effective in moving large volume of material rapidly over the surface. This technique is useful in coarse sifting or where the screen openings are substantially larger than the particle size.

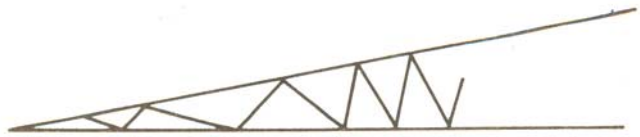

Figure 3.12: Inclined reciprocatory motion

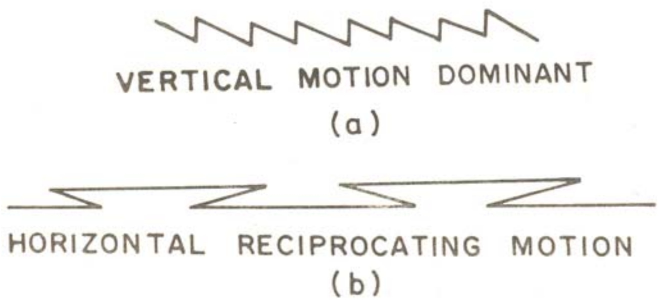

Figure 3.13: a) and b) Vertical and horizontal reciprocating motion

Combined Horizontal and Reciprocating Motion

In this, an eccentric drive is used to change the horizontal reciprocating motion into a rotary motion in a horizontal plane at inlet end, whereas the other end has reciprocating motion. In such arrangement there is a component of reciprocating motion both in parallel and perpendicular to the direction of material flow at inlet and this gradually changes into an elliptical motion at the central section of the screen and finally becomes a true reciprocating motion at the discharge end as shown in Figure 3.14. This section is effective in spreading the material to the sides of screen at the inlet end. The looping path of the material also presents more screen openings since particle moves not only back and forth but also from side to side across the screen surface.

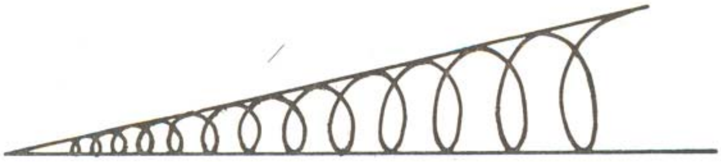

Figure 3.14: Combined horizontal and reciprocating motion

Horizontal Rotary Motion

If the screen surface is rotated in a horizontal plane the material will travel in the overlapping loop path during the passage from inlet to discharge end as shown in Figure 3.15. The multidirectional motion overcomes inter particle friction and maximum number of openings are available, thus screening can be accomplished on a relatively shorter distance. Rotary motion is provided by an off-centred weight attached to the screen through the frame and it is rotated at proper speed in horizontal plane. This imparts desired frequency and motion. The amplitude of movement is controlled by the magnitude and eccentricity of weight as well as the position, which affects its leverage on the screen. Sifters may also be driven by means of one or more directly connected eccentrics. The speed of eccentric and the amount of eccentricity control the frequency and amplitude of motion.

Figure 3.15: Horizontal rotary motion

3.5.9 Perforated Metal Screens

i) **Round openings:** The round openings in a perforated sheet metal screen are measured by the diameter (mm or in.) of the openings. For example, $\frac{1}{18}$ screen has round perforation of $\frac{1}{18}$ in. in diameter or 2 mm.

ii) **Oblong openings:** The oblong or slotted openings in a perforated sheet metal screen are designated by two dimensions; the width and length of the opening. While mentioning oblong openings the dimension of width is listed first then the length as 1.8 x 20 mm. Generally, the direction of the oblong opening is kept in the direction of the grain flow over the screen.

iii) **Triangular openings:** There are two different systems used to measure triangular perforations. The most commonly used system is to mention the length of each side of the triangle in mm, it means, 9 mm triangle has 3 equal sides each 9 mm long. The second system is to mention openings according to the diameter in mm that can be inscribed inside the triangle. This system is identified by the letter Vas 9V, l0V etc.

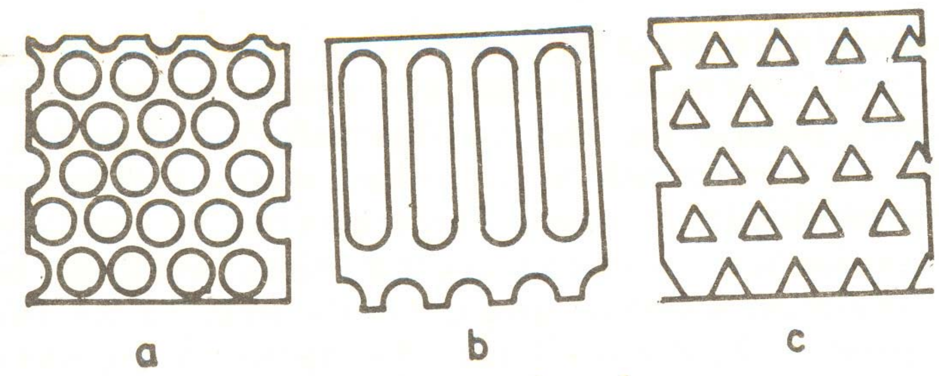

Figure 3.16: Perforated metal screens. a) Round holes, b) Oblong holes, c) Triangular holes

3.5.10 Wiremesh Screens

i) **Square mesh:** The square openings in wire mesh are measured by the number of openings per inch in each direction. A 9×9 screen has 9 openings per inch (Figure 3.17).

ii) **Rectangular mesh:** the rectangular openings in wire mesh screens are measured in the same way as square wire mesh screen. A 3×6 rectangular wire mesh screen will have 3 openings per inch in one direction and 6 openings per inch in the other direction. The rectangles formed by the wire mesh are parallel to the direction of grain flow (Figure 3.18).

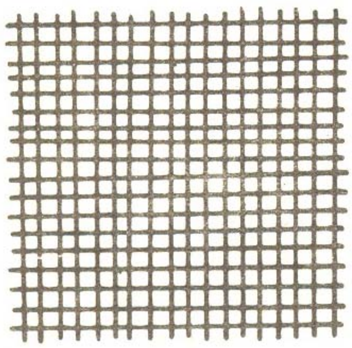

Figure 3.17: Wire mesh screen (square openings)

Figure 3.18: Wire mesh screen (rectangular openings)

3.6 EFFECTIVENESS AND EFFICIENCY OF SCREENS, CLEANERS, GRADERS AND SEPARATORS

The screen effectiveness may be defined as the ability of a screen in closely separating the feed into overflow and underflow according to its size. If the screen functions properly, all material 'O' would be in the overflow, while all the material 'U' would be in the underflow. The material balance in a screening operation can be derived as follows:

F = mass flow rate of feed, kg/hr.
O = mass flow rate of oversize, kg/hr.
U = mass flow rate of undersize, kg/hr.
m_f = mass fraction of material in feed.
m_o = mass fraction of material in overflow.
m_u = mass fraction of material in underflow.

The total quantity of feed is the sum of overflow and underflow

$$F = O + U$$

or,

$$Fm_f = Om_o + Um_u \qquad (3.1)$$

Substituting O = F – U and, U = F – O

$$\frac{O}{F} = \frac{m_f - m_u}{m_o - m_u} \qquad (3.2)$$

and, $$\frac{U}{F} = \frac{m_o - m_f}{m_o - m_u} \qquad (3.3)$$

A common measure of screen effectiveness is the ratio of actual amount of oversize material in the overflow to the amount of oversize material entering with the feed.

Thus,

$$E_o = \frac{Om_o}{Fm_f} \qquad (3.4)$$

and $$E_u = \frac{U(1 - m_u)}{F(1 - m_f)} \qquad (3.5)$$

Overall effectiveness $E = E_o x E_u = \dfrac{OUm_o(1 - m_u)}{F^2 m_f(1 - m_f)}$ (3.6)

Substituting the values of

$$\frac{O}{F} \text{ and } \frac{U}{F}, \; E = \frac{(m_f - m_u)(m_o - m_f)m_o(1 - m_u)}{(m_o - m_u)^2(1 - m_f)m_f} \qquad (3.7)$$

The effectiveness of screening or cleaning efficiency for an air screen cleaner as suggested by Bureau of Indian Standards (BIS) is:

$$\text{Cleaning efficiency} = \frac{E(F - G)(E - F)(1 - G)}{F(E - G)^2(1 - F)} \qquad (3.8)$$

where, E = fraction of clean seed at clean seed outlet

F = fraction of clean seed in feed

and G = fraction of clean seed at foreign matter outlet

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Enlist four types of screen that are available for cleaning and grading of foods. Describe any one of them.

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2. Define screen effectiveness.

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3. During the evaluation of an air screen grain cleaner with two screens the followings were observed.

i) The impurities present in feed were 6.5%.
ii) The impurities present in clean grain were 0.5%.
iii) The outflow of blower contained 0.2% clean seed.
iv) The overflow of the 1st screen contained 1 % clean seed.
v) The underflow contained 0.5% clean seed.

Compute the cleaning efficiency of the cleaner.

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4. During evaluation of an air screen grain cleaner with 2 screens 250*g* samples were collected for analysis of clean seed fraction from different outlets. The data are presented in the following Table. Calculate the cleaning efficiency of the cleaner.

Sample fraction	Feed, g	Clean grain outlet, g	Blower outlet, g	Oversize outlet, g	Undersize outlet, g
Cleaned seed, g	231.25	246.5	1.25	4.5	2.0
Impurities, g	18.75	3.5	248.75	245.5	248.0

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3.7 LET US SUM UP

In this unit, we have learnt the basics of cleaning and grading operations as specialized forms of the separation process. The methods of cleaning and grading are based upon the properties of the materials. Various machines used for the cleaning and grading operations have been introduced. Screens are used very commonly in the separation processes and, therefore, various types of screens have been presented. The analysis of the screened material ultimately provides the basis of determining the cleaning and separation efficiency.

3.8 KEY WORDS

Cleaning : Generally means the removal of foreign and undesirable material from desired grains / products.

Grading : Refers to the classification of the cleaned product into various quality functions depending upon the commercial value and usage.

Cleaning efficiency : It is the ratio of the actual amount of impurities present in a mixture to the impurities obtained during the cleaning process.

Magnetic separator : Uses the magnetic properties of metallic contaminants to separate them from the produce.

Colour sorting : Uses the colour differences between the produce and the unwanted materials for sorting.

Pneumatic separation : Uses the property of terminal velocity to separate materials.

Screen effectiveness : It may be defined as the ability of a screen in closely separating the feed into overflow and underflow according to its size.

3.9 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Cleaning is defined as the method of removal of foreign or undesirable material from the foods whereas grading is defined as the classification of the cleaned produce into various fractions based on qualitative or quantitative parameters.

2. The five characteristics of foods that are used for its separation from unwanted materials include:

   i) Size
   ii) Shape
   iii) Specific gravity or weight
   iv) Surface roughness
   v) Aerodynamic properties

3. i) Air screen separator: Air blast in conjunction with screens is used to achieve the separation. Air blast helps to separate dust and lighter material before the remaining material is separated by screens.

   ii) Inclined draper: The mixture to be separated is fed over the centre of an inclined draper belt moving in upward direction. The round and smooth grains roll or slide down the draper at faster rate than the upward motion of the belt, and these are discharged in a hopper. The flat shape or rough surfaced particles are carried to the top of the inclined draper and dropped off into another hopper. The belts of different degrees of roughness may be used as a draper for separate materials.

   iii) Pneumatic separator: A blower is placed at the inlet of the separator. The mixture is suspended in the air and the different fractions get separated due to their differing terminal velocities.

   iv) Colour sortor: Colour or brightness is sensed by photocells. The photocell gives an output based on the colour/brightness variation and the product is separated if the output is below or above the threshold level.

Check Your Progress Exercise 2

1. Four types of screen that are available for cleaning and grading of foods are:

   a) Horizontal screen
   b) Rotary screen
   c) Grizzly screen
   d) Vibratory screen

Grizzly screen: Grizzly is made up of coarse grid of metal bars usually put on a slope. The path of material flow is parallel to the length of bars. The grizzly is used for rough and coarse separation like crushed stones, ores etc.

2. The screen effectiveness may be defined as the ability of a screen in closely separating the feed into overflow and underflow according to its size.

3. i) fraction of clean seed in feed = 100 - 6.5 = 93.5 or 0.935

   ii) fraction of clean seed in clean grain outlet = 100 - 0.5 = 99.5 or 0.995

   iii) fraction of clean seed in foreign matter outlets = $\frac{0.2}{100} + \frac{1}{100} + \frac{0.5}{100}$

   $= 0.002 + 0.01 + 0.005$

   $= 0.017.$

   Then E = 0.0995, F = 0.935 and G = 0.017

   Therefore, Cleaning efficiency = $\frac{E(F-G)(E-F)(1-G)}{F(E-G)^2(1-F)}$

   $$= \frac{0.995(0.935-0.017)(0.995-0.935)(1-0.017)}{0.935(0.995-0.017)^2(1-0.935)}$$

   = 91.18%

4. i) Fraction of clean seed at clean seed out let, $E = \frac{246.5}{250.0} = 0.986$

   ii) Fraction of clean seed in feed $F = \frac{231.25}{250.0} = 0.925$

   iv) Fraction of clean seed in-foreign matter outlets $G = \frac{1.25}{250.0} + \frac{4.5}{250.0} + \frac{2.0}{250.0} = 0.031$

   Therefore, Cleaning efficiency = $\frac{E(F-G)(E-F)(1-G)}{F(E-G)^2(1-F)}$

   $$= \frac{0.986(0.925-0.031)(0.986-0.925)(1-0.031)}{0.925(0.986-0.031)^2(1-0.925)}$$

   = 82.34%

3.10 SOME USEFUL BOOKS

1. Henderson, S.M. and Perry, R.L. (1976) Agricultural Process Engineering. AVI Publishing Co. West Port Connecticut.

2. McCabe, W.L., Smith, J.C. and Harriott, P. (1993) Unit Operations of Chemical Engineering. McGraw Hill, New York.