UNIT NINE
SEPARATING WITHOUT HEATING

Special Terms

Size Classification: The process of separating granular or powdered materials into batches of large, intermediate, and small particles.

Grizzly: A size-classification device for large lumps or solids. It consists of inclined metal bars with spaces between them. Any material smaller than the space between the bars will fall through; larger sizes slide to the end of the grizzly where they are collected.

Sieve: A size-classification device made of wire cloth or perforated sheet metal. When the sieve is shaken, small particles fall through the openings and larger particles remain on top. Sieves made of wire cloth are commonly called *screens*.

Sedimentation (Settling): A process in which particles of solids suspended in a liquid are separated by allowing them to settle by the force of gravity.

Thickener: A piece of equipment in which sedimentation is carried out as a continuous process.

Filtration: A process by which solid particles may be separated from a liquid by forcing the liquid through a woven cloth with openings too fine to permit the particles to pass.

Filter Cloth: The special finely woven cloth used for filtration.

Filter Press: A structure on which metal or plastic plates and frames are suspended and pressed together. Filter cloth is placed between the plates and frames; the material to be filtered is forced through the cloth under pressure.

Filtrate: The clear liquid that flows from a filter after the solids have been removed.

Filter Cake (Cake): The solids removed during filtration.

Continuous Filter: A machine for carrying out filtration as a continuous process.

Centrifuge: A machine for separating solids from liquids or for separating two liquids of different densities which cannot mix. The separation is accomplished by the use of *centrifugal force* created by rapid whirling.

Cyclone Separator: A device for separating solid particles from a gas. The cyclone causes the gas to swirl, thereby generating a centrifugal force that causes the particles to move to the wall of the cyclone.

Gas Scrubber: A device that separates solid particles from a gas or one gas from another. It uses a spray of liquid (usually water) that traps the particles or dissolves a gas.

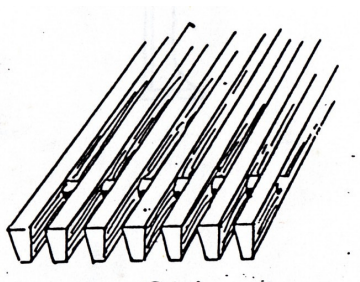
Vocabulary Practice

1. What is meant by *size classification*?
2. Describe a *grizzly*.
3. What is a *sieve*? How is it used? What are wire cloth sieves sometimes called?
4. What is *sedimentation* used for?
5. What does a *thickener* do?
6. Describe the process of *filtration.*
7. What is a *filter cloth*?
8. What is a *filter press*?
9. What is *filtrate*?
10. What is *filter cake*?

11. What is a *continuous filter*?
12. What does a *centrifuge* do?
13. What is a *cyclone separator* used for?
14. What two things is a *gas scrubber* used for? How does it work?

Separating Without Heating

In addition to those processes that use heat for separation, there are a number of processes that don not require heat. Perhaps the simplest of these is ***size classification***, which involves separating large particles, or lumps, of solids from small ones. Large lumps of coal or ore, for example, can be separated from smaller ones by letting the material slide down a chute composed of parallel bars of metal. Small lumps fall between the bars into a container; larger ones slide to the end of the chute where they, too, are collected. Such a device is called a ***grizzly***. It may be shaken to help move the lumps along, and several may be used in series – each having a wider space between the bars – to separate the lumps into a number of size groups.



Grizzly

Grizzlies are used only for large pieces of material. For small particles it is more common to use ***sieves*** made of perforated sheet metal, or a type of sieve made of wire cloth, called a ***screen***. Materials may be passed through a series of sieves, each having holes smaller than the last. In this way, the material is separated into a number of size classes called sieve fractions; each fraction is small enough to pass through the next larger sieve, but too large to pass through the one on which it is finally retained.

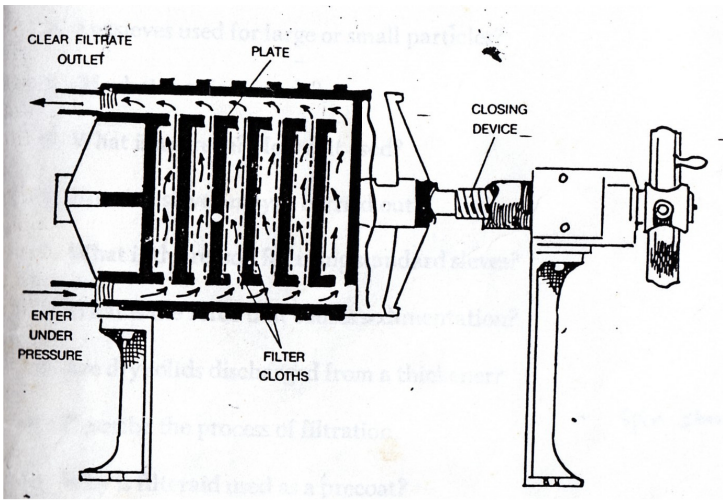
This procedure is sometimes followed in the laboratory: a weighed quantity of granular or powdered material is passed

through a series of vibrating screens; the fraction remaining on each screen is weighed and calculated as a percentage of the original weight. Such a procedure is known as a size analysis or a sieve analysis. Standards have been set up for the series of sieves used so that the results from one laboratory will be comparable to the results from any other laboratory.

Another kind of separation that does not use heat is the removal of suspended solids from a liquid. If the solids have a higher density than the liquid (as is usually the case) they may be removed by simply allowing the liquid to remain in a tank for a period of time. During this time, the force of gravity will settle the solids on the bottom; this is called ***sedimentation***, or settling. There are continuous sedimentation devices in which solids are continuously removed from the bottom of the tank and clear liquid from the top; these are called ***thickeners***. The solids removed from a sedimentation device always contain some liquid; they are watery or muddy and require further treatment if all the moisture is to be removed.

Another heatless method of removing solids from liquid is by a process similar to sieving, called ***filtration***. In this process, the solids-bearing liquid is forced through a material (usually a finely woven cloth) that allows the liquid to pass through but holds back the solids. As a layer of solids builds up on the surface of the ***filter cloth***, the liquid must first pass through this solids layer. Since the openings through the solids layer are usually smaller than the openings in the filter cloth, such a filter will hold back finer particles after it has been in use for a time than when it is clean. Consequently, the first liquid to pass through the filter may be saved and passed through again (recycled) after the solids layer has built up. Another way of accomplishing the same thing is to first coat the filter cloth with a layer of material that will provide finer openings than the filter cloth. These materials are called filteraids, and the initial layer is called a precoat.

Much filtration is done in devices called ***filter presses***. The most common is called a plate-and-frame filter press because it consists of alternating perforated plates and open sections called frames. Filter cloth is placed over both sides of each plate and the



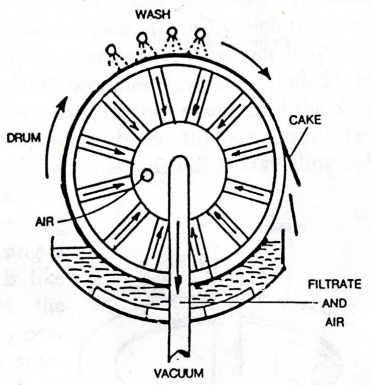
Filter Press

assembly of plates and frames is squeezed together in the press. Holes in the plates and frames act as pipes to distribute the liquid to be filtered into the frame sections, where it passes through the filter cloth into the perforated plate sections, and then out through a discharge opening. The clear liquid discharged is called the ***filtrate***, and the solids trapped in the frames on the surface of the filter cloth are called the ***cake*** or ***filter cake***. Depending on the process, the desired product may be the clear filtrate or the cake; the other material is usually waste. However, in a few filtrations both the filtrate and cake are valuable products.

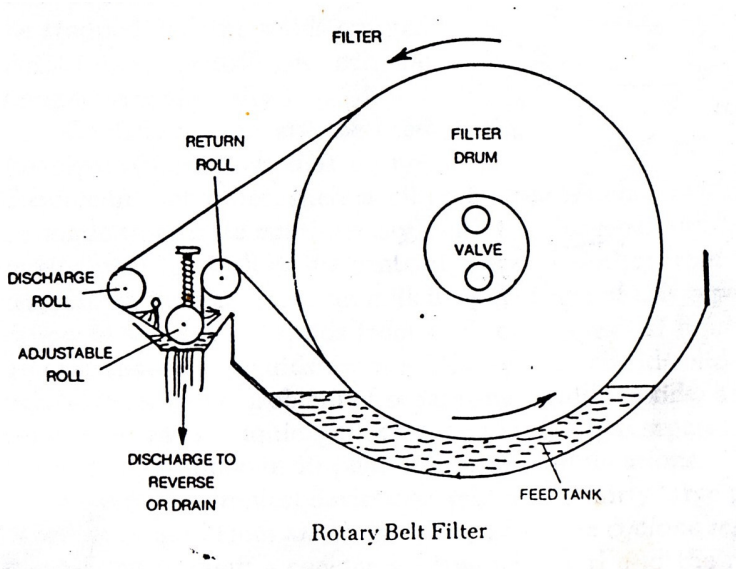
A filter press is normally run until the frames are full of cake; then it is shut down for cleaning. This makes it a batch process. Filter presses can be used in a continuous process plant by providing at least two, so that one can operate while the other is being cleaned. Cleaning is done by opening the press and shaking the frames so that the cake falls into a trough below the filter press. In some filtrations, the cloths must be replaced at each cleaning cycle; in others they may be used for many cycles. The filter press is then closed and is ready for another cycle. If filteraid is used as a precoat, a watery mixture of it will first be made up and pumped through the press until the required thickness is deposited on the filter cloths.

Although filter presses are very common, they have one major disadvantage: cleaning them is a tedious process that requires much hand labor, which can be very expensive. However, they are relatively inexpensive to buy and maintain – there is not much that can go wrong with a filter press.

Continuous filters are also available, but they are much more complex machines. This makes them much more expensive to buy and to maintain. Their advantage is that they require very little labor during operation. The most common continuous filter is the rotary drum type, which consists of a revolving drum covered with filter cloth. Considerable pressure is needed to force the liquid through the filter cloth, so the entire filter may be enclosed in a pressure vessel.



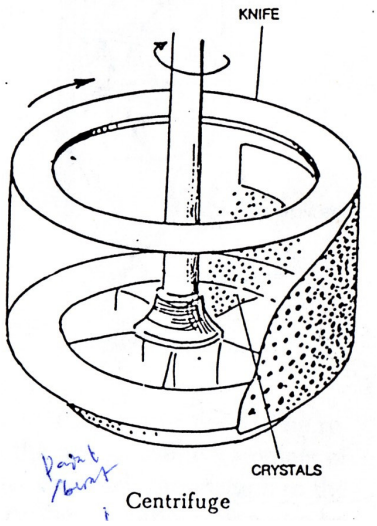
Rotary Drum Filter



Rotary Belt Filter

Otherwise, the interior of the drum may be evacuated (put under a vacuum) so that atmospheric pressure forces the liquid through the filter. As the drum revolves, cake builds up on the surface of the cloth-covered drum. When it reaches a preset thickness, it is shaved off by a fixed blade, called a doctor blade, against which the drum rotates. Continuous filters may be operated for relatively long periods, but eventually the filter cloth becomes clogged ("blinded") by very fine particles, and the filter must be shut down until the cloth is cleaned or replaced. In addition to continuous drum filter, there are many other kinds of machines, including belt filters and rotating disk filters.

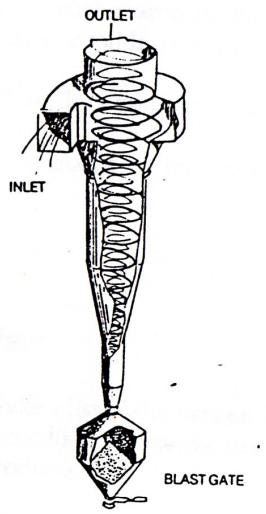
Another way of separating solids from liquids is by using a ***centrifuge***. Centrifugation is like sedimentation, except that the force of gravity is replaced by ***centrifugal force*** generated by spinning the liquid at high speed. In the centrifuge, solids collect at the wall of the spinning container, and clear liquid is removed from the center. When sufficient solids have been collected, the centrifuge must be stopped and the solids scraped out. (Some centrifuges can be scraped automatically.).



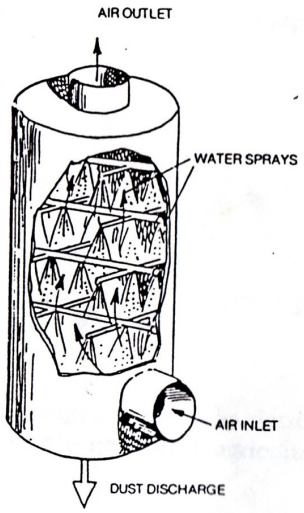
Centrifuge

Centrifuges can also be used for separating liquids that do not dissolve in each other, such as oil and water. Such centrifuges can be made to operate continuously, with the denser liquid being removed near the wall of the centrifuge and the other from the center. Cream is separated from milk in centrifuges of this type. In addition to separating liquids from each other – called liquid/liquid separations – and liquids from solids – called liquid/solid separations – there is the problem of separating liquids, solids, and gases from other gases – liquid/gas, solid/gas, and gas/gas separations. All of these are common in air pollution control applications.

One of the simplest devices for separating fairly large particles of solid or liquid from air or any other gas is the ***cyclone separator***. Air passing through a cyclone is caused to swirl and the resulting centrifugal force drives the particles to the wall where they fall to the bottom and into a container. Clean gas exits from the center at the top.



Cyclone Separator



Liquid Gas Scrubber

Where particles too fine for a cyclone separator need to be removed, the most common solution is the ***gas scrubber.*** Droplets of water are passed through the gas being scrubbed; they attach to the particles and carry them out of the scrubber. Scrubbers can also be used to remove one gas from another if one of the gases is soluble in water or some other solvent. Scrubbers are often used to remove sulfur dioxide or ammonia from air before it is released from a plant.

Discussion

1. What are some materials for which a grizzly might be used?
2. Are grizzlies used for large or small particles?

3. Are sieves used for large or small particles?
4. Of what is a sieve made?
5. What is a screen? How is it used?
6. How is a sieve analysis carried out?
7. What is the reason for using standard sieves?
8. What is the force that causes sedimentation?
9. Are dry solids discharged from a thickener?
10. Describe the process of filtration.
11. Why is filteraid used as a precoat?
12. What is the most common device used for batch filtration?
13. Where is filter cloth used in a plate-and-frame filter press?
14. In what part of a plate-and-frame filter press does cake accumulate?
15. What is the difference between filtrate and filter cake?
16. What must be done when a filter press is full of cake?
17. Why is this process expensive?
18. What are two advantages of filter presses?
19. Why are continuous filters expensive?
20. What is the most common type of continuous filter?
21. What is the name of the blade that shaves cake off a rotating drum filter?

22. How does a centrifuge work?

23. What kinds of materials can centrifuges separate?

24. For what reason might a chemical engineer want to separate gases or solids from air?

25. Describe a cyclone separator.

26. How does a gas scrubber work?

Review

A. Make a list of the various kinds of things that might be classified according to size by using sieves. Do not forget agricultural products.

B. Used lubricating oil from automobile engines contains fine particles of metal and other materials. Discuss how they might be removed from the oil, leaving it clean.

C. Match the terms in the left column with the proper short definition in the right column. Only one definition is appropriate for each term.

1. Sedimentation	____	Separating solids according to size
2. Filtration	____	A kind of sieve
3. Size classification	____	Carries out sedimentation continuously
4. Filtrate	____	A special finely woven cloth
5. Continuous filter	____	Clear liquid from a filter

6. Cyclone separator	____	Filters for a long time without stopping
7. Centrifuge	____	Separates solid from gas using a water spray
8. Filter press	____	Swirls a gas to separate solids from it
9. Grizzly	____	Particles settle by gravity
10. Gas scrubber	____	Liquid is forced through a cloth
11. Screen	____	Parallel bars for size classification
12. Thickener	____	A batch filter
13. Filter cake	____	Uses centrifugal force to separate materials
14. Filter cloth	____	Solids removed during filtration