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ABSTRACT

An introductory description of the use of centrifuges in the process of volume reduction is provided in this lesson. Three basic centrifuges, their theory of operation, quality of cake and centrate, and operational control testing are discussed. The lesson includes an instructor's guide and student workbook. The instructor's guide contains a description of the lesson, estimated presentation time, instructional materials list, suggested sequence of presentation, reading lists, objectives, lecture outline, narrative of the slide/tape program used with the lesson, and student worksheet (with answers). The student workbook contains plant flow diagrams, objectives, glossary, text material (presented in sections titled: theory of centrifugation, disc centrifuge, solid bowl centrifuge, and comparisons and testing), references, and worksheet. (JN)

# SLUDGE TREATMENT

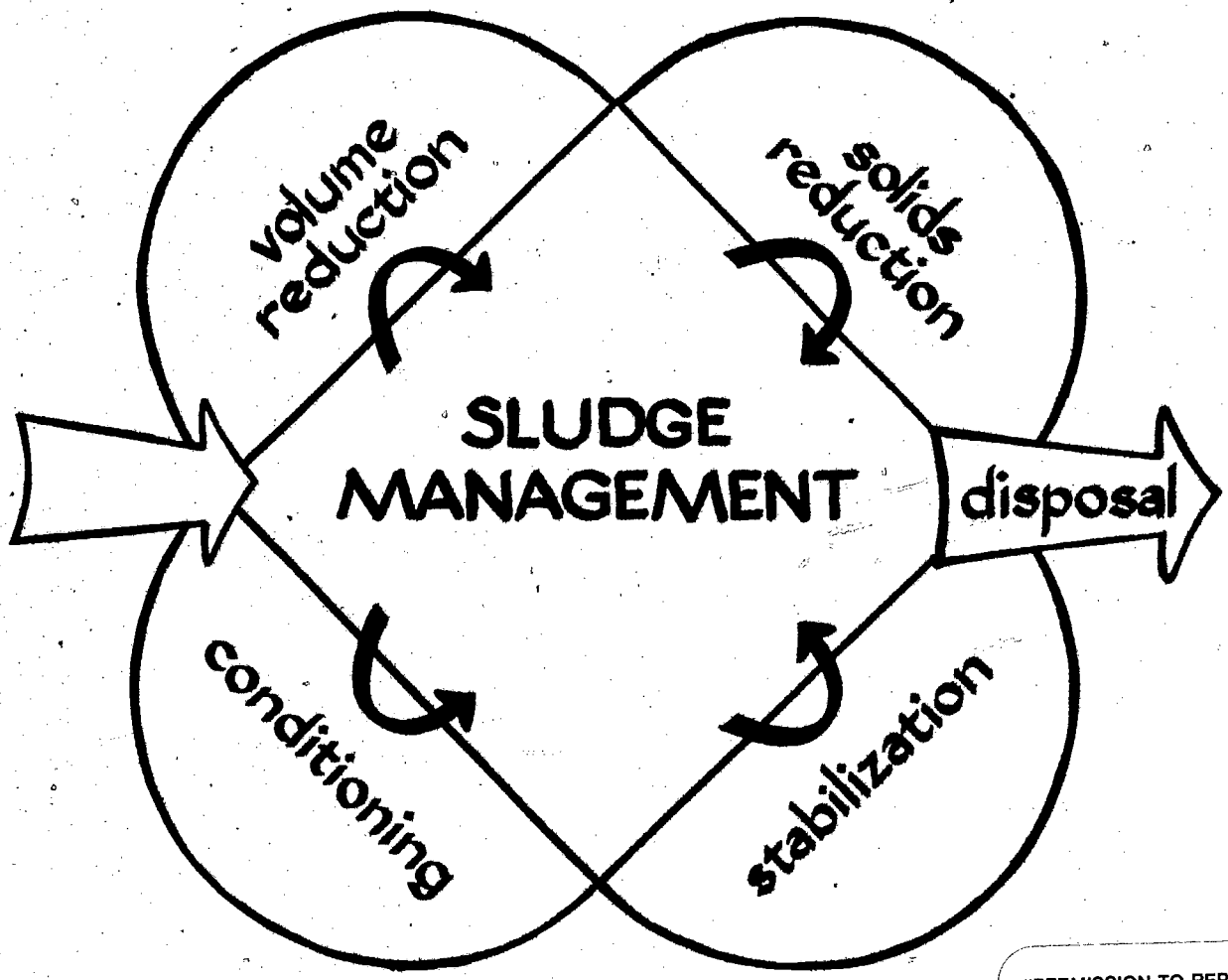
and

# DISPOSAL

## COURSE # 166

## CENTRIFUGATION






## INSTRUCTOR'S GUIDE



Prepared by
Linn-Benton Community College
and
Envirotech Operating Services

# CENTRIFUGATION

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# CENTRIFUGATION

## CONTENTS

# CENTRIFUGATION

## LESSON DESCRIPTION

This lesson is an introductory description of the use of centrifuges in the process of volume reduction. The lesson discusses the three basic centrifuges, their theory of operation, the quality of cake and centrate along with operational control testing.

## ESTIMATED TIME

| | |
|---|---|
| Student Preview | 10 - 15 Minutes |
| Presentation | 40 - 75 Minutes |
| Discussion - Demonstration | 15 - 30 Minutes |
| Worksheet | 15 - 20 Minutes |

## INSTRUCTIONAL MATERIALS LIST

1. Student text "Centrifugation"
2. Slide set "Centrifugation"
3. Slide projector
4. Screen
5. Examples of feed sludge, centrate and sludge cake
6. Small centrifuge with 50 ml tubes

## SUGGESTED SEQUENCE OF PRESENTATION

1. Assign reading - emphasis on flow diagram, glossary and objectives.
2. Lecture with slides.
3. Open discussion
   a. Show samples of sludge, centrate and sludge cake.
   b. Spin a sample of sludge in a small centrifuge to show separation.
4. Assign worksheet.
5. Correct worksheet.

## REQUIRED READING

Lesson - "Centrifugation"

## REFERENCE READING

Map 11 - Pages 312 - 314

# CENTRIFUGATION

## OBJECTIVES

Upon completion of this lesson the student should be able to do the following:

1) Recall the theory of operation of centrifuges.
2) State the classification of centrifuges in the Solids Management System.
3) State the name of the clear liquid that is separated from the solids.
4) State the name of the fluid layer in a centrifuge.
5) Identify the three types of centrifuges.
6) Identify flow pattern, solids discharge, centrate, recycle stream and disc for a disc centrifuge.
7) Describe how nozzle size and recycle rate will affect sludge dryness.
8) Identify characteristics of the three common centrifuges.
9) Identify the flow pattern, knife, liquid skimmer, weir and centrate on a basket centrifuge.
10) Identify the flow patterns, beach, conveyer, discharge nozzles, centrate, and pool on a solids bowl centrifuge.
11) Describe the results on sludge cake for operation changes in the solids bowl centrifuge.
12) Compare the solids recovery ability of the three types of centrifuges.
13) Compare the cake dryness of the three centrifuges when handling waste activated sludge (WAS).
14) Recall proper testing for each sample location.

CENTRIFUGATION
LESSON OUTLINE

I. BASICS
   A. Solids separation
      1. Centrifugal force
   B. Volume reduction
   C. Basic compounds
      1. Drum
      2. Sludge
      3. Spun at high RPM
      4) Centrifugal force up to 1300 g
         a. Forms a pool
   D. Separation
      1. Solids against wall
      2. Heavy particles first
      3. Clear liquid on top - Centrate
      4. Develop cake
   E. Basic objective - Maximize solids yield - Minimize cake moisture

II. TYPES
   A. Disc
      a. Clarifier bowl
      b. Stainless steel
      c. 50 Conical disc
      d. Top feed
      e. Flow up and out against disc
      f. Sludge discharge - nozzles 0.05 to 0.1 inches
      g. Centrate returned to plant
      h. Control
         1. Nozzle size
            i. Increase - dryness decreases
         2. Hydraulic loading
            i. Increase loading - decreases dryness
         3. Hydraulic loading controlled by recycle rate

i. Results
   1. WAS 0.1 to 1.0%
   2. 5 to 5.5% Sludge
   3. 90% Recovery

j. Problems
   1. Prone to plugging
   2. Improve results with polymers

B. Basket Centrifuge
   1. Equipment
      a. Top loading
      b. Batch process
      c. Weir
      d. 1300 x g
      e. Bottom feed
      f. Skimmer
      g. Knife
   2. Process
      a. Batch
      b. Feed until centrate deteriorates
      c. Skim liquid
      d. Decelerate
      e. Scrape sludge
      f. Restart
   3. Special Considerations
      a. Hard to dewater sludge
      b. Polymers - improve centrate quality
   4. Removals
      a. WAS 0.7%
      b. Solids 9 - 10%
      c. Recovery 70 - 90%
   5. Problems
      a. Slow - batch
      b. Trimmer settings

C. Solid Bowl Centrifuge

1. Most Common
2. Two flow patterns
   a. Countercurrent
   b. Concurrent
3. Components
   a. Bowl
   b. Screw conveyer
   c. Drive unit
   d. Beach
   e. Weirs
4. Operation Countercurrent
   a. 3000 g
   b. Flow
   c. Pool
   d. Separation
   e. Movement by conveyer
   f. Solids up beach
   g. Centrate out weirs
5. Concurrent
   a. Same equipment
   b. Sludge enters through center
   c. Sludge and liquid move same direction
   d. Skimmer
   e. Beach
6. Operational Control
   a. Conveyer speed
      1. Difference in speed
      2. Decrease speed - wetter cake
      3. Increase speed - dryer cake
   b. Weir Plate
      1. Lower - dryer cake
      2. Higher - wetter cake

c. Feed Rate - Detention Time
    1. Lower - dryer cake
    2. Higher - wetter cake

7. Removal
    a. 0.4 - 0.7% WAS
    b. 5 - 7% Solids
    c. 80 - 90% Recovery

III. COMPARISON and TESTING

| | |
|---|---|
| A. Rate | |
| 1. Disc | 30 - 150 gpm |
| 2. Basket | 33 - 50 gpm |
| 3. Solid bowl | 75 - 100 gpm |
| B. Recovery | |
| 1. Disc | 90% |
| 2. Basket | 70 - 90% |
| 3. Solid bowl | 80 - 90% |
| C. Cake | |
| 1. Disc | 5 - 5.5% |
| 2. Basket | 9 - 10% |
| 3. Solid bowl | 5 - 7% |

D. Improved Recovery with Polymers

E. Testing
    1. % Moisture - Feed, cake
    2. Solids recovered
    3. Flow - Feed, cake, centrate
    4. Centrate - SS, BOD and VSS

F. Maintenance
    1. Constant
    2. Vibration

Slide #

1. Centrifugation of sewage sludges is a solids handling technique to reduce sludge volume.

2. This module was written by R. A. Best and edited by E. E. Arasmith. Instructional design was managed by Priscilla Harden. Mr. Paul Klopping served as project director.

3. In the overall solids management system, centrifugation is classified as a volume reduction process. Therefore, it can be used for dewatering or sludge thickening, which are both used to reduce volume.

4. The centrifuge is composed of a container into which is placed a volume of sludge. This container is then spun at high RPM.

5. The spinning generates a centrifugal force which throws the liquid sludge toward the outer wall of the container.

6. As a result of the centrifugal force, the heavier material is moved toward the wall compacting into a cake and leaving behind a clear fluid called centrate.

7. The objective here is to remove as much of the solids as possible from the sludge. The result would be a sludge cake that is low in moisture content and a centrate that is low in solids content.

8. There are three basic types of centrifuges used in thickening sewage sludges. They are the basket centrifuge, the disc centrifuge, and the solid bowl conveyor centrifuge.

9. All types of centrifuges offer solids separation; however, there is considerable difference in feeding and removal of cake and centrate. Therefore, we should discuss each type separately in terms of equipment and operations. Let's start first with the basket centrifuge.

10. The basket centrifuge is the simplist of the centrifuges.

11. It appears as an oversized, top-loading washing machine. In fact, it has some similarities. One similarity is the fact that the basket centrifuge is a batch process.

12. The basket centrifuge is composed of an outer shell inside of which is a bowl or basket.

13. With the basket spinning, sludge is fed into the bottom of the basket and directed at the wall.

14. Centrifugal force holds the sludge to the inside of the wall of the basket. This same force causes the liquid sludge to stratify with the heaviest material being forced next to the basket wall.

15. As the sludge depth increases, centrate exits over the weir at the top of the bowl to reenter the plant as a sidestream.

16. The operator observes the centrate. When the solids begin to flow out with the centrate the sludge feed is shut down and the basket continues to spin.

17. After a period of time a skimmer (usually a hose or pipe with a nozzle) is swung into the liquid portion of the sludge and the centrate is pumped off.

18. After the removal of the liquid the basket decelerates and a knife swings into the solids cake scraping it from the bowl. The cake is discharged out of the bottom of the centrifuge for disposal. The cycle is complete and can be started all over again.

19. The batch process lowers overall feed rates for the basket centrifuge. This makes the basket centrifuge a poor selection as a primary dewatering device.

20. However, the basket centrifuges are widely used to handle hard to dewater sludges. This is due to the machine's ability to give high solids recovery without a chemical addition.

21. When polymers are added there is excellent improvement in centrate quality and solids recovery. Therefore, most facilities are at least given the option of chemical feed.

22. Properly setting the timers to control feed time and thus centrate quality is the major operational problem associated with the basket centrifuge.

23. Let's turn our attention to the disc centrifuge. The most common uses of the disc centrifuge are in the separation of cream from milk and the separation of oil from water.

24. The disc centrifuge used to handle sewage sludge appears as a round, stainless steel container usually less than three feet in diameter.

25. Inside the outer shell is a solid bowl which contains up to fifty conical discs.

26. Sludge is fed into the top of the centrifuge and piped to the bottom.

27. The sludge is then forced outward by centrifugal force and upward by hydraulic force. Centrifugal force drives the solids toward the outside of the bowl.

28. Solids that move upward with the liquid are forced against the under sides of the discs and then forced down and toward the outside by a centrifugal force.

29. The sludge is discharged through a series of nozzles which range from 0.05 to 0.1 inches in diameter. A portion of the sludge is recycled to control hydraulic loading.

30. The clear centrate is discharged through the top of the bowl and may be returned to the primary portion of the plant.

31. Operation of a disc centrifuge requires control of the dryness of the solids and the quality of the centrate. This is done by increasing the recycle rate of the solids cake.

32. Detention time influences sludge dryness. Changes in nozzle size and hydraulic loading influence detention time.

33. Centrate quality is a function of sludge dryness. The drier the sludge the poorer the centrate quality.

34. The best balance between clear centrate quality and sludge dryness comes from controlling the solids recycle rate rather than physically changing the nozzle size. Control of the recycle stream is the primary operational control.

35. In conclusion, it is important to understand that disc centrifuges are rarely used in sludge treatment except to thicken fine secondary sludges. Disc centrifuges are prone to plugging when handling coarse or fiberous material.

36. The last centrifuge we will look at is the solid bowl centrifuge which is the most common and most successful centrifuge for dewatering sewage sludges.

37. There are two types of solid bowl centrifuges: the countercurrent and the concurrent flow types. We will discuss the countercurrent flow type since it is the most common.

38. The solid bowl centrifuge has an outer casing, a rapidly spinning cylindrical bowl, and a screw conveyor, which are supported by pillow-block bearings. The drive mechanism for both bowl and conveyor may either be a gear and motor or a belt and motor assembly.

39. Sludge enters the bowl through openings part-way down the central shaft.

40. Centrifugal force throws it against the wall of the bowl forming a whirling pool. The greater concentration of solids is against the wall of the bowl.

41. Then hydraulic pressure drives the centrate toward the large end while the screw conveyor drags the solids toward the tapered end.

42. The centrate exits the bowl through adjustable weirs which control the depth of the pool. By locating the holes closer to the wall of the bowl the pool depth is made shallower.

43. The screw conveyor drags the solids in the opposite direction up an inclined plane out of the pool. The inclined plane, called the beach, guides the solids out of the end of the bowl.

44. While both the bowl and the screw conveyor rotate in the same direction, the conveyor turns faster than the bowl. This produces the scraping action that drags the solids up the beach.

45. The solids drop out the bottom of the centrifuge and are carried away for ultimate disposal. And finally, the centrate is returned to the treatment plant as a side stream.

46. As with the disc and basket centrifuges, the basic goal of operation is to achieve a good sludge dryness and a high quality of centrate. However, as sludge dryness is increased, centrate quality will decrease. Operational balance between the two must be achieved.

47. Operational control of sludge dryness and centrate quality is basically a function of detention time. To influence detention time operators adjust feed rate, conveyor speed, and/or weir settings. Let's look at how each of these adjustments influences detention time.

48. Longer detention time gives centrifugal force more time to act on the sludge, which results in a drier cake and poorer quality centrate.

49. Many solid bowl centrifuges have conveyor speed adjustments. Changes in the difference between the speed of the bowl and the speed of the conveyor influence detention time. When the speed difference is greater the cake moves faster producing a wetter cake.

50. Adjustment of weir settings influences sludge cake dryness. Higher settings produce wetter cake, while lower settings produce dryer cake.

51. Let's stop for a minute and look at why this happens. When the weir setting is lowered the pool becomes shallower and the beach, longer. This allows the sludge to be out of the water longer and the result is dryer sludge.

52. In comparing the three types of centrifuges the basket has feed rates of 33 to 50 gallons per minute. The solid bowl feeds at 75 to 100 gallons per minute, and the disc in the range of 30 to 150 gallons per minute depending upon the sludge type.

53. From the solids recovery standpoint, the disc is best at 90%, and the basket and solid bowl are about even at 70% to 90% and 80% to 90%, respectfully.

54. In dealing with waste activated sludge the disc will produce the wettest cake at 5% to 5.5%. The solid bowl is next at 5% to 7%. The basket is dryest at 9% to 10%.

55. Generally, an improved solids recovery and an improved centrate quality can be obtained with the use of polymers.

56. In order to maintain quality control, sample the feed sludge and sludge cake to monitor percent of moisture and total pounds of solids recovered.

57. The quantity of feed, cake, and centrate would also be monitored. Centrate should be evaluated for suspended solids, BOD, and volatile suspended solids.

58. Due to the high RPM and the abrasive nature of sludge all centrifuges require constant maintenance.

59. Because of their high RPM their main safety consideration is vibration. Any vibration is cause for shutdown and investigation.

60. During this lesson, we have discussed the three types of centrifuges, their theory of operation, and their basic mechanical differences.

61. We also discussed the cake and centrate quality in operational control and testing.

# CENTRIFUGATION
## WORKSHEET

1. The theory that helps to explain the process of solids separation in a centrifuge is called

   _____ a. High pressure
   _____ b. Pressure force relationship
   X c. Centrifugal force
   _____ d. Centrifugal separation

2. Centrifugation is what type of solids management system?

   _____ a. Solids reduction
   _____ b. Conditioning
   _____ c. Stabilization
   X d. Volume reduction

3. When solids are separated in a centrifuge, the liquid side stream that is removed is called the _____

   _____ a. Pool
   X b. Centrate
   _____ c. Supernatant
   _____ d. Counter flow
   _____ e. None of the above

4. When sludge is introduced into a centrifuge, it forms a _____ on the inner wall of the centrifuge.

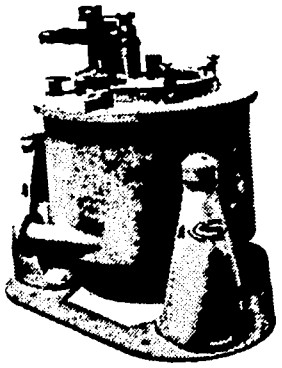
   X a. Pool
   _____ b. Liquid separation layer
   _____ c. Sludge cake
   _____ d. Centrate
   _____ e. None of the above

5. Identify the centrifuges below.

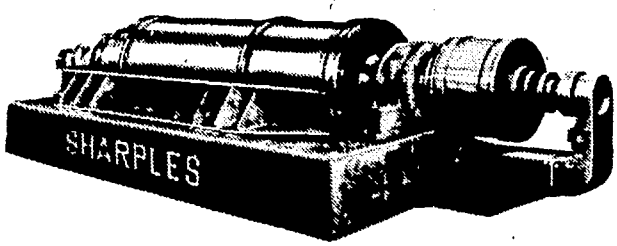
b Solid bowl

a Basket

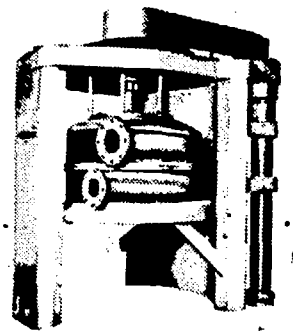
c Disc



A




B



C

6. Using the drawing, match the letters to the description.

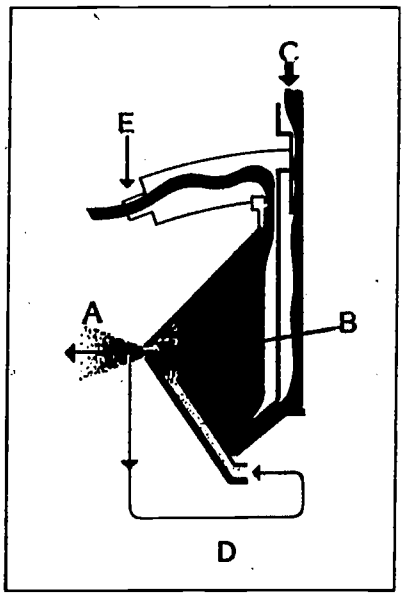
c Sludge in

d Recycle stream

a Solids out

e Centrate

b Disc



7. For a disc centrifuge, match the changes on the left with the results on the right.

| | | |
|---|---|---|
| b | Increase nozzle size | a. Increase sludge dryness |
| b | Increase recycle rates | b. Decrease sludge dryness |
| a | Decrease nozzle size | |
| a | Decrease recycle rate | |

8. Match the characteristics on the left with the centrifuges on the right.

| | | |
|---|---|---|
| c | Most common | a. Disc |
| a | Conical disc | b. Basket |
| b | Uses a knife | c. Solid bowl |
| b | Batch process | |
| a | Prone to plugging | |
| c | Screw conveyer | |
| a | Least common | |
| b | Used to handle hard to dewater sludge | |
| c | Has a beach | |
| a | Used to separate milk and cream | |
| a | Uses discharge nozzles | |
| c | Differential speed | |
| b & c | Discharge weir | |

9. Identify the following:

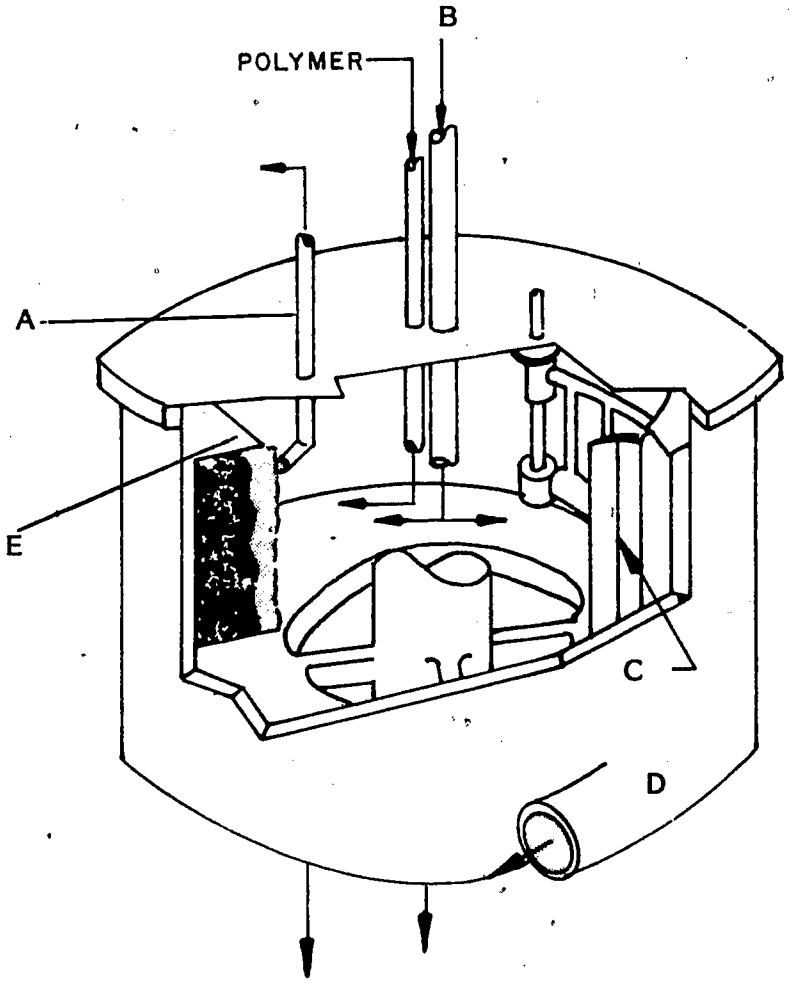
b Flow in

c Knife

a Liquid skimmer

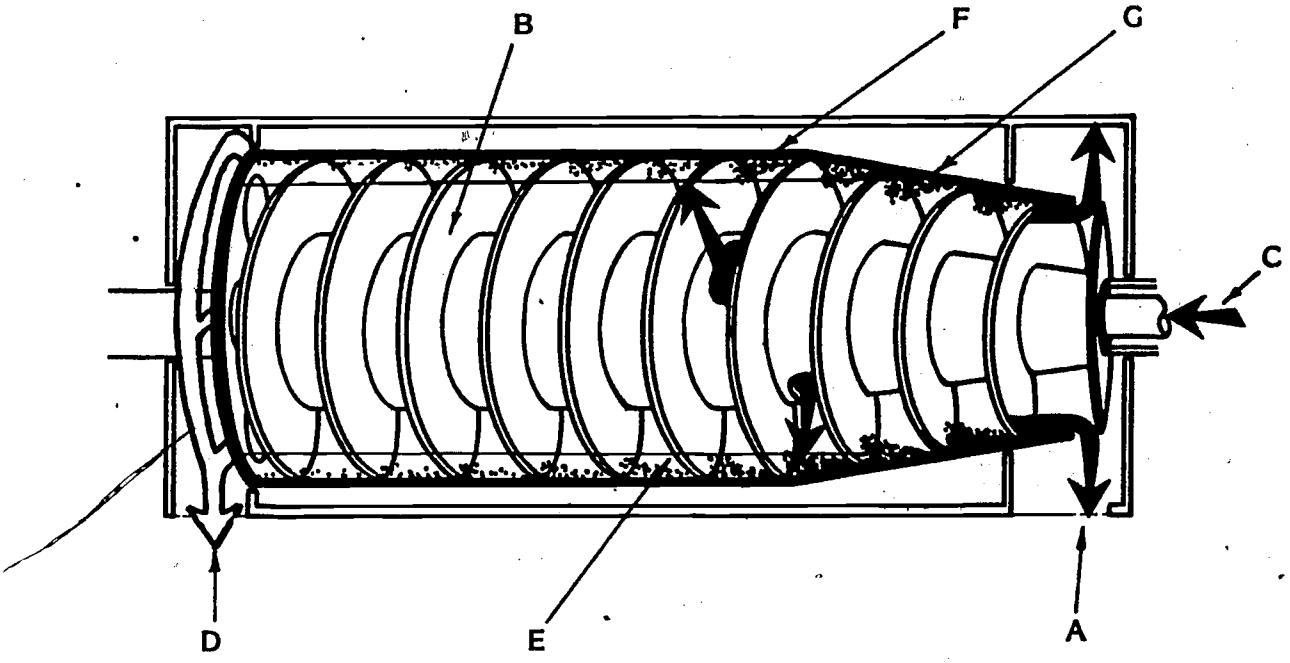
e Weir

d Centrate



10. Identify the following:

__c__ Flow in
__f__ Bowl
__g__ Beach
__b__ Screw conveyor
__a__ Solids discharge
__d__ Centrate discharge
__e__ Pool




11. Match the changes on the left with the conditions on the right for a solid bowl centrifuge.

__a__ Lower weir setting
__a__ Decrease in feed rate
__b__ Increase in feed rate
__b__ Higher weir setting

a. Dryer cake
b. Wetter cake

12. Rank the abilities of the three centrifuges to produce a dry cake with WAS. (one is best)

__2__ Solids bowl

__3__ Disc

__1__ Basket

13. On the diagram in Problem #10, match the sample points with the required test.

__c & b__ Percent moisture

__a,b,c__ Flow

__a__ SS

__a__ BOD

__a__ VSS

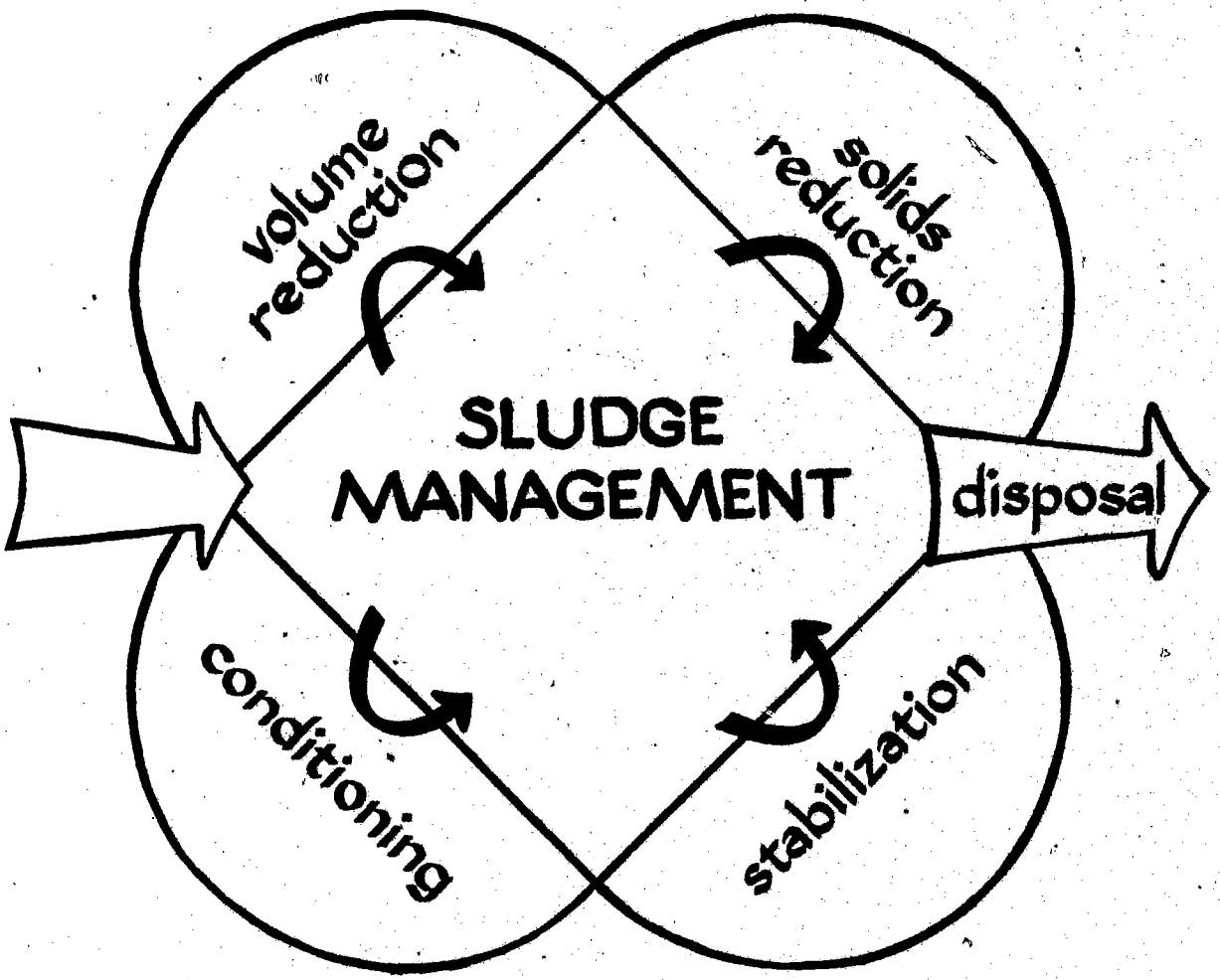
# SLUDGE TREATMENT

and

# DISPOSAL

## COURSE # 166

## CENTRIFUGATION




## STUDENT WORKBOOK



Prepared by
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# CENTRIFUGATION

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# CENTRIFUGATION

## CONTENTS

# CENTRIFUGATION

## OBJECTIVES

What will you learn from this lesson?

Upon completion of this lesson you should be able to do the following:

1) Recall the theory of operation of centrifuges.
2) State the classification of centrifuges in the Solids Management System.
3) State the name of the clear liquid that is separated from the solids.
4) State the name of the fluid layer in a centrifuge.
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13) Compare the cake dryness of the three centrifuges when handling waste activated sludge (WAS).
14) Recall proper testing for each sample location.

# CENTRIFUCATION

## GLOSSARY

Beach - The conical cone on the end of the solid bowl centrifuge. The solids are removed over the beach.

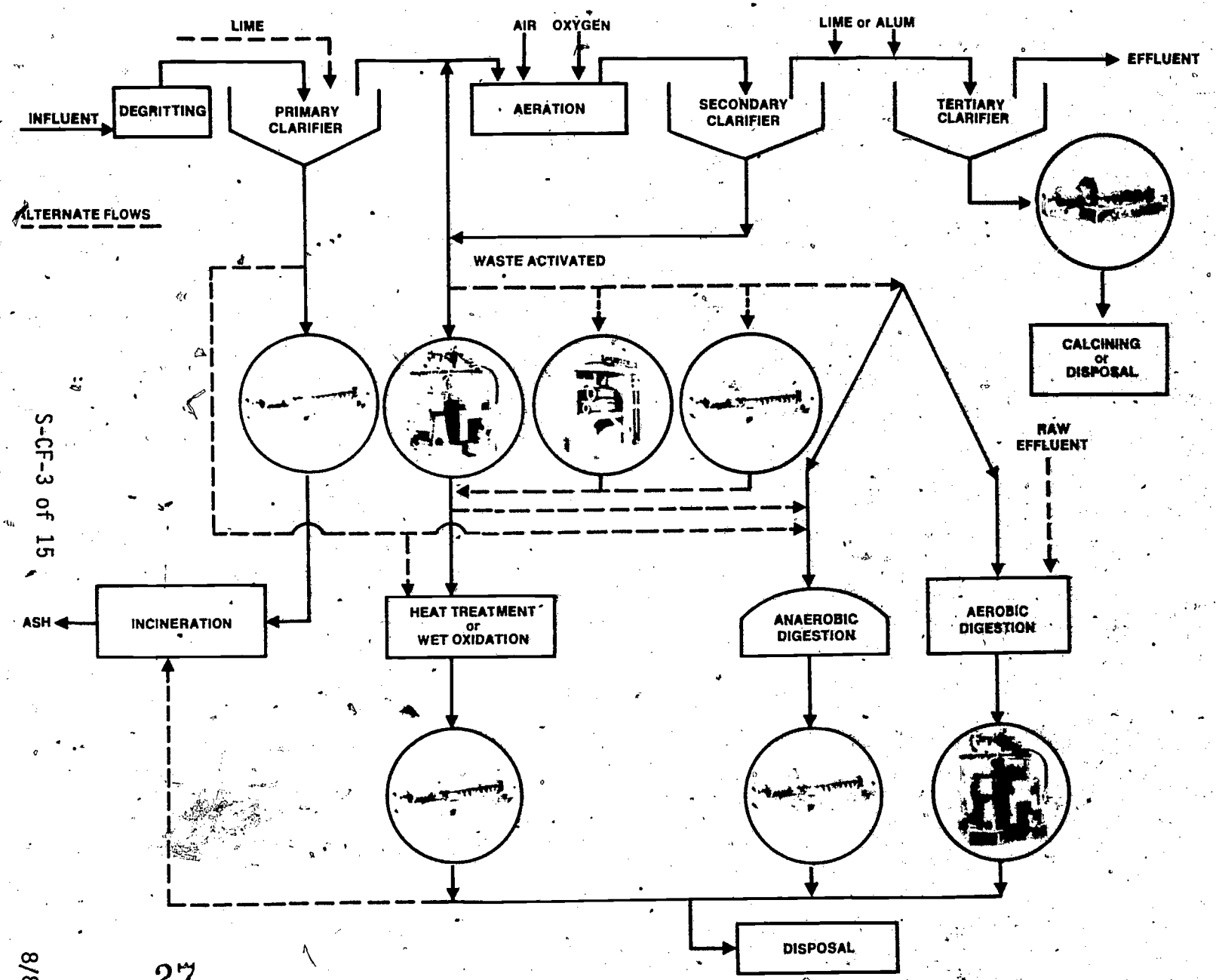
Centrate - The relatively clear liquid that is removed from sludge during the process of centrifugation. The centrate is usually returned to the plant flow.

Concurrent - The movement of solids and liquid in the same direction.

Conical - A cone-shaped object.

Countercurrent - The movement of solids and centrate in opposite directions.

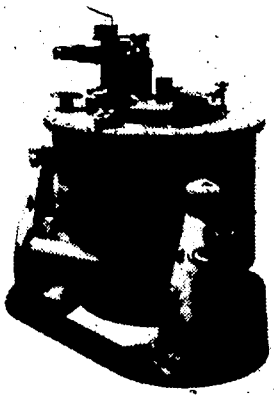
Pool - The layer of fluid sludge inside the centrifuge.



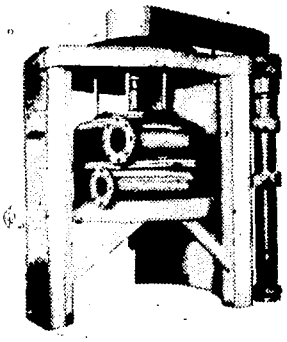

FLOW DIAGRAM--Showing typical applications of centrifugation in wastewater treatment

S-CF-3 of 15

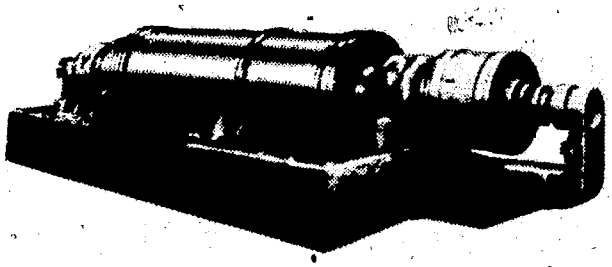
## THEORY



Basket Centrifuge



Disc Centrifuge



Solid Bowl Centrifuge

Centrifugation of sewage sludges is a solids handling technique used to reduce sludge volume.

This module was written by R. A. Best and edited by E. E. Arasmith. Instructional design was managed by Priscilla Harden. Mr. Paul Klopping served as project director.

In the overall solids management system, centrifugation is classified as a volume reduction process. Therefore, it can be used for dewatering or sludge thickening, which are both used to reduce volume.

The centrifuge is composed of a container into which is placed a volume of sludge. This container is then spun at high RPM.

The spinning generates a centrifugal force which throws the liquid sludge toward the outer wall of the container.

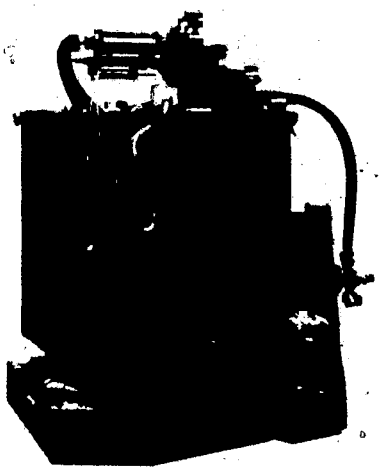
As a result of the centrifugal force, the heavier material is moved toward the wall compacting into a cake and leaving behind a clear fluid called centrate.

The objective here is to remove as much of the solids as possible from the sludge. The result would be a sludge cake that is low in moisture content and a centrate that is low in solids content.

There are three basic types of centrifuges used in thickening sewage sludges. They are the basket centrifuge, the disc centrifuge, and the solid bowl conveyor centrifuge.

All types of centrifuges offer solids separation; however, there is considerable difference in feeding and removal of cake and centrate. Therefore, we should discuss each type separately in terms of equipment and operations. Let's start first with the basket centrifuge.

## BASKET CENTRIFUGE



Basket Centrifuge

The basket centrifuge is the simplist of the centrifuges.

It appears as an oversized, top-loading washing machine. In fact, it has some similarities. One similarity is the fact that the basket centrifuge is a batch process.

The basket centrifuge is composed of an outer shell inside of which is a bowl or basket.

With the basket spinning, sludge is fed into the bottom of the basket and directed at the wall.

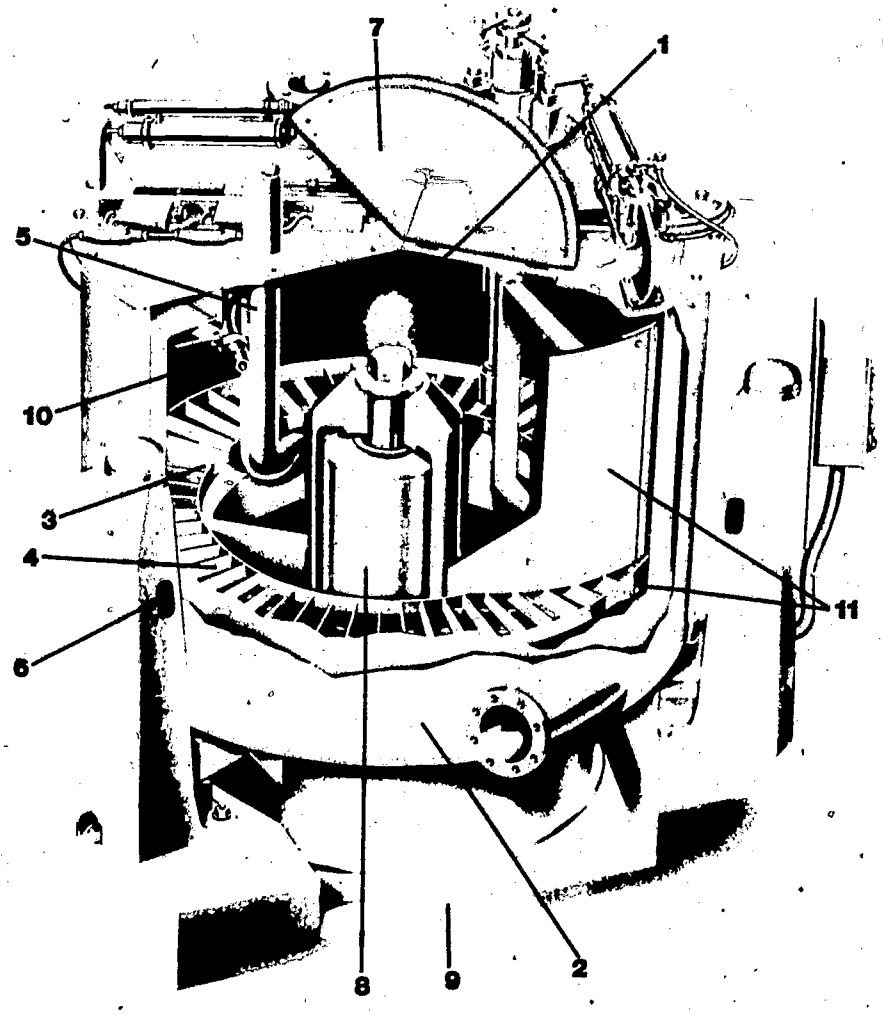
Centrifugal force holds the sludge to the inside of the wall of the basket. This same force causes the liquid sludge to stratify with the heaviest material being forced next to the basket wall.

As the sludge depth increases, centrate exits over the weir at the top of the bowl to reenter the plant as a sidestream.

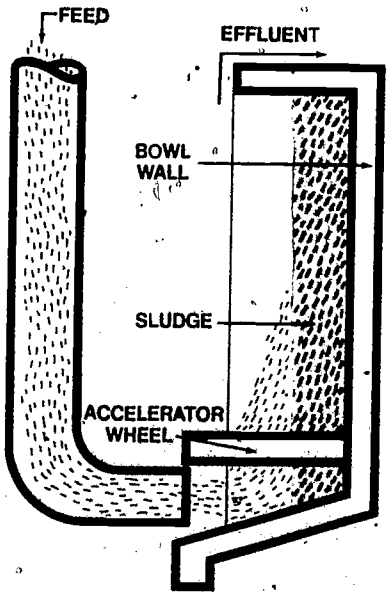
The operator observes the centrate. When the solids begin to flow out with the centrate the sludge feed is shut down and the basket continues to spin.

Components of
Basket Centrifuge

1-bowl
2-outside shell
3 & 4-accelerator wheel
5-sludge feed
6-frame
7-lid
8-drive assembly
9-base
10-nozzle

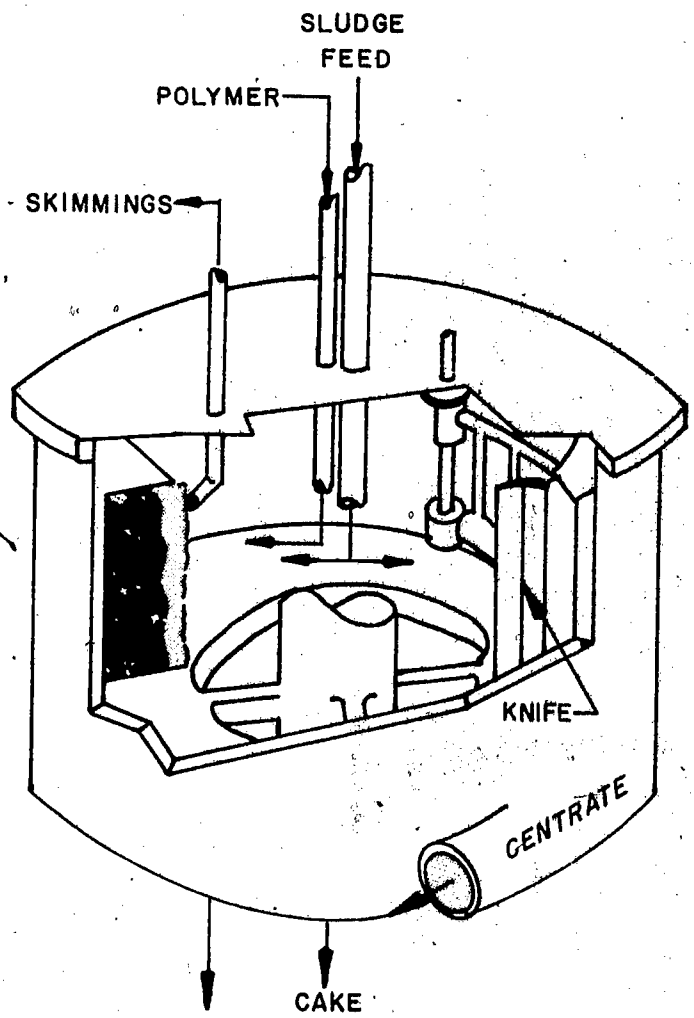



BASKET CENTRIFUGE
TYPICAL FLOW DIAGRAM




After a period of time a skimmer (usually a hose or pipe with a nossle) is swung into the liquid portion of the sludge and the centrate is pumped off.

After the removal of the liquid the basket decelerates and a knife swings into the solids cake scraping it from the bowl. The cake is discharged out of the bottom of the centrifuge for disposal. The cycle is complete and can be started all over again.




The batch process lowers overall feedrates for the basket centrifuge. This makes the basket centrifuge a poor selection as a primary dewatering device.

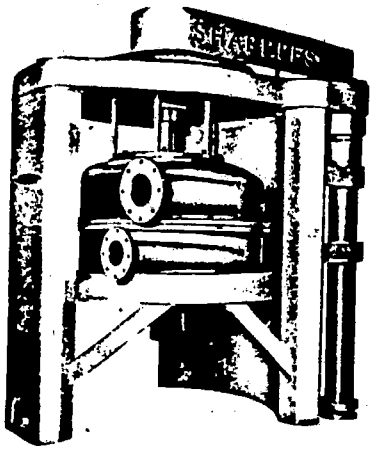
However, the basket centrifuges are widely used to handle hard to dewater sludges. This is due to the machine's ability to give high solids recovery without a chemical addition.

When polymers are added there is excellent improvement in centrate quality and solids recovery. Therefore, most facilities are at least given the option of chemical feed.

Properly setting the timers to control feed time and thus centrate quality is the major operational problem associated with the basket centrifuge.

## DISC CENTRIFUGE

Let's turn our attention to the disc centrifuge. The most common uses of the disc centrifuge are in the separation of cream from milk and the separation of oil from water.



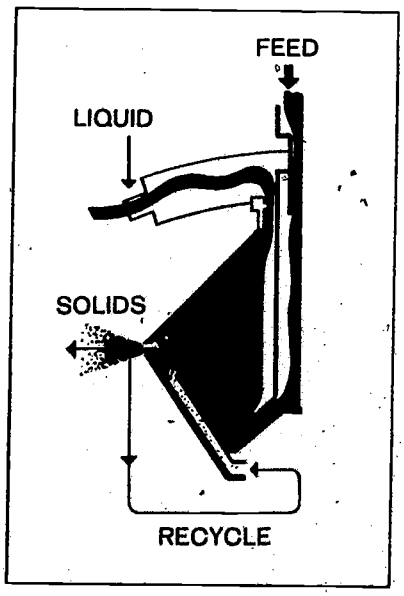
Disc Centrifuge

The disc centrifuge used to handle sewage sludge appears as a round, stainless steel container usually less than three feet in diameter.

Inside the outer shell is a solid bowl which contains up to fifty conical discs.

Sludge is fed into the top of the centrifuge and piped to the bottom.

The sludge is then forced outward by centrifugal force and upward by hydraulic force. Centrifugal force drives the solids toward the outside of the bowl.




Cross-section of Disc Centrifuge

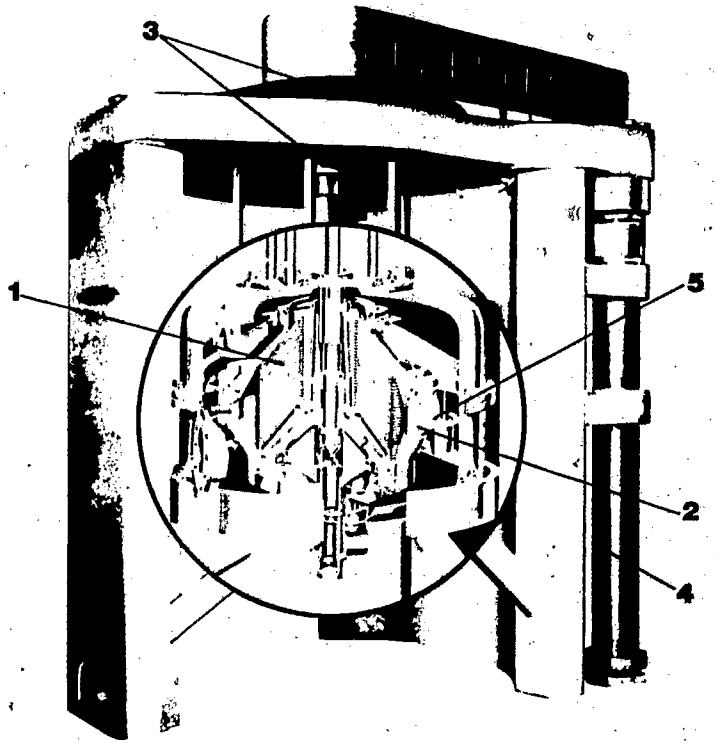
Solids that move upward with the liquid are forced against the under sides of the discs and then forced down and toward the outside by a centrifugal force.

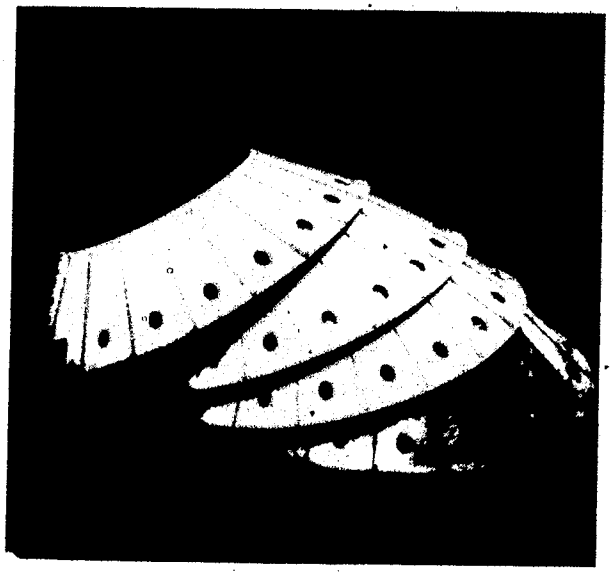
The sludge is discharged through a series of nossles which range from 0.05 to 0.1 inches in diameter. A portion of the sludge is recycled to control hydraulic loading.

The clear centrate is discharged through the top of the bowl and may be returned to

## DISC CENTRIFUGE COMPONENTS

1-conical disc
2-bowl
3-drive assembly
4-hydraulic lift
5-nozzle



CONICAL DISC

the primary portion of the plant.

Operation of a disc centrifuge requires control of the dryness of the solids and the quality of the centrate. This is done by increasing the recycle rate of the solids cake.

Detention time influences sludge dryness. Changes in nossle size and hydraulic loading influence detention time.

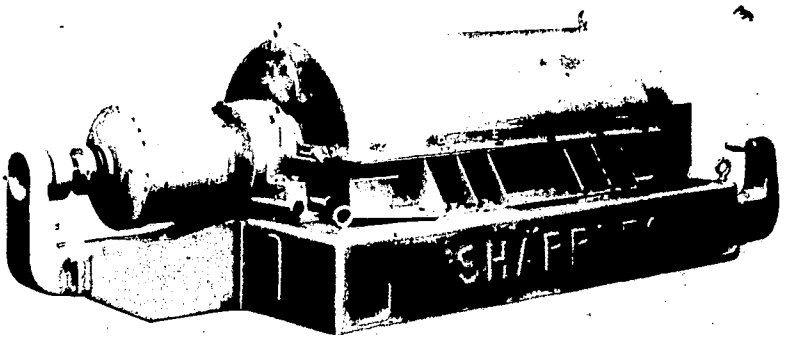
Centrate quality is a function of sludge dryness. The drier the sludge the poorer the centrate quality.

The best balance between clear centrate quality and sludge dryness comes from controlling the solids recycle rate rather than physically changing the nossle size. Control of the recycle stream is the primary operational control.

In conclusion, it is important to understand that disc centrifuges are rarely used in sludge treatment except to thicken fine secondary sludges. Disc centrifuges are prone to plugging when handling coarse or fiberous material.

## SOLID BOWL CENTRIFUGE

The last centrifuge we will look at is the solid bowl centrifuge which is the most common and most successful centrifuge for dewatering sewage sludges.



SOLID BOWL CENTRIFUGE

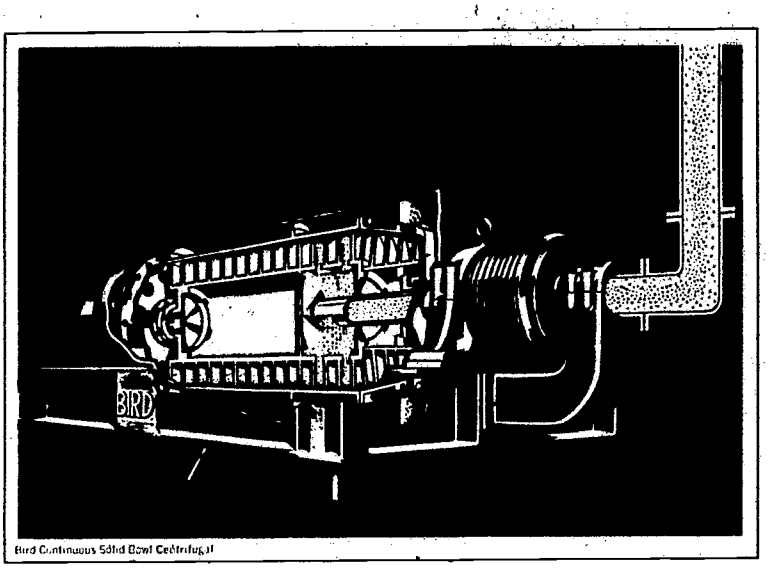
There are two types of solid bowl centrifuges: the countercurrent and the concurrent flow types. We will discuss the countercurrent flow type since it is the most common.

The solid bowl centrifuge has an outer casing, a rapidly spinning cylindrical bowl, and a screw conveyor, which are supported by pillow-block bearings. The drive mechanism for both bowl and conveyor may either be a gear and motor or a belt and motor assembly.

Sludge enters the bowl through openings partway down the central shaft.

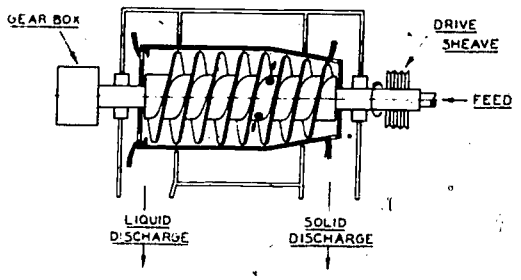
Centrifugal force throws it against the wall of the bowl forming a whirling pool. The greater concentration of solids is against the wall of the bowl.

Then hydraulic pressure drives the centrate toward the large end while the screw conveyor drags the solids toward the tapered end.




Bird Continuous Solid Bowl Centrifugal

**SOLID BOWL CENTRIFUGE**
**Countercurrent Flow**




**Cross-section, Solid Bowl Centrifuge**

The centrate exits the bowl through adjustable weirs which control the depth of the pool. By locating the holes closer to the wall of the bowl the pool depth is made shallower.

The screw conveyor drags the solids in the opposite direction up an inclined plane out of the pool. The inclined plane, called the beach, guides the solids out of the end of the bowl.

While both the bowl and the screw conveyor rotate in the same direction, the conveyor turns faster than the bowl. This produces the scraping action that drags the solids up the beach.

The solids drop out the bottom of the centrifuge and are carried away for ultimate disposal. And finally, the centrate is returned to the treatment plant as a sidestream.

As with the disc and basket centrifuges, the basic goal of operation is to achieve a good sludge dryness and a high quality of centrate. However, as sludge dryness is increased, centrate quality will decrease. Operational balance between the two must be achieved.

## OPERATIONAL CONTROL

Increased Feed Rates
Produce Wetter Cake

Higher Weir Settings
Produce Wetter Cake

Operational control of sludge dryness and centrate quality is basically a function of detention time. To influence detention time operators adjust feed rate, conveyor speed, and/or weir settings. Let's look at how each of these adjustments influences detention time.

Longer detention time gives centrifugal force more time to act on the sludge, which results in a drier cake and poorer quality centrate.

Many solid bowl centrifuges have conveyor speed adjustments. Changes in the difference between the speed of the bowl and the speed of the conveyor influence detention time. When the speed difference is greater the cake moves faster producing a wetter cake.

## COMPARISONS AND TESTING

FEED RATE

| | |
|---|---|
| Basket | 33 - 55 gpm |
| Solid Bowl | 75 - 100 gpm |
| Disc | 30 - 150 gpm |

RECOVERY

| | |
|---|---|
| Disc | 90% |
| Basket | 70 - 90% |
| Solid Bowl | 80 - 90% |

SLUDGE CAKE FROM ACTIVATED SLUDGE

| | |
|---|---|
| Disc | 5 - 5½% |
| Solid Bowl | 5 - 7% |
| Basket | 9 - 10% |

Adjustment of weir settings influences sludge cake dryness. Higher settings produce wetter cake, while lower settings produce dryer cake.

Let's stop for a minute and look at why this happens. When the weir setting is lowered the pool becomes shallower and the beach, longer. This allows the sludge to be out of the water longer and the result is dryer sludge.

In comparing the three types of centrifuges the basket has feed rates of 33 to 50 gallons per minute. The solid bowl feeds at 75 to 100 gallons per minute, and the disc in the range of 30 to 150 gallons per minute depending upon the sludge type.

From a solids recovery standpoint, the disc is best at 90%, and the basket and solid bowl are about even at 70% to 90% and 80% to 90% respectfully.

In dealing with waste activated sludge the disc will produce the wettest cake at 5% to 5.5%. The solid bowl is next at 5% to 7%. The basket is the dryest at 9% to 10%.

Generally, an improved solids recovery and an improved centrate quality can be obtained with the use of polymers.

In order to maintain quality control, sample the feed sludge and sludge cake to monitor percent of moisture and total pounds of solids recovered.

The quantity of feed, cake and centrate should also be monitored. Centrate should be evaluated for suspended solids, BOD, and volatile suspended solids.

Due to the high RPM and the abrasive nature of sludge all centrifuges require constant maintenance.

Because of their high RPM their main safety consideration is vibration. Any vibration is cause for shutdown and investigation.

During this lesson, we have discussed the three types of centrifuges, their theory of operation, and their basic mechanical differences.

We also discussed the cake and centrate quality in operational control and testing.

REFERENCES

1. Process Design Manual for Sludge Treatment and Disposal, USEPA, EPA 625/1-79-011, Cincinnati, 1979.

2. Map 11 - Operation of Wastewater Treatment Plants - WPCF

3. Operation of Wastewater Treatment Plant, Sacramento State College

# CENTRIFUGATION
## WORKSHEET

1. The theory that helps to explain the process of solids separation in a centrifuge is called

   _____ a. High pressure
   _____ b. Pressure force relationship
   _____ c. Centrifugal force
   _____ d. Centrifugal separation

2. Centrifugation is what type of solids management system?

   _____ a. Solids reduction
   _____ b. Conditioning
   _____ c. Stabilization
   _____ d. Volume reduction

3. When solids are separated in a centrifuge, the liquid side stream that is removed is called the _____

   _____ a. Pool
   _____ b. Centrate
   _____ c. Supernatant
   _____ d. Counter flow
   _____ e. None of the above

4. When sludge is introduced into a centrifuge, it forms a _____ on the inner wall of the centrifuge.

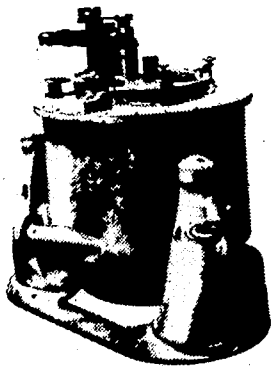
   _____ a. Pool
   _____ b. Liquid separation layer
   _____ c. Sludge cake
   _____ d. Centrate
   _____ e. None of the above

5. Identify the centrifuges below.

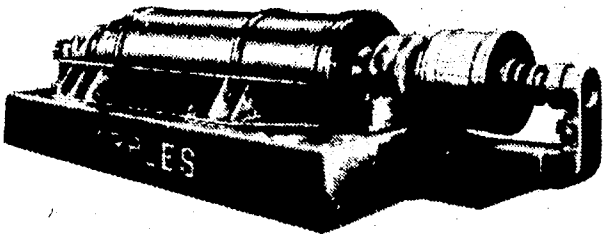
_____ Solid bowl

_____ Basket

_____ Disc



A



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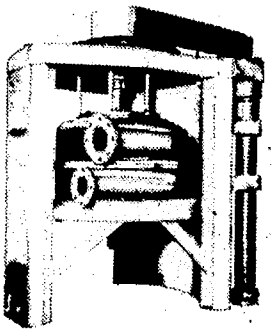


C

6. Using the drawing, match the letters to the description.

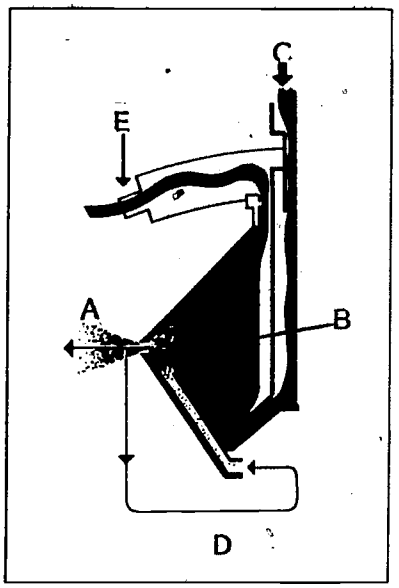
_____ Sludge in

_____ Recycle stream

_____ Solids out

_____ Centrate

_____ Disc



7. For a disc centrifuge, match the changes on the left with the results on the right.

| | | |
|---|---|---|
| _____ | Increase nozzle size | a. Increase sludge dryness |
| _____ | Increase recycle rates | b. Decrease sludge dryness |
| _____ | Decrease nozzle size | |
| _____ | Decrease recycle rate | |

8. Match the characteristics on the left with the centrifuges on the right.

| | | |
|---|---|---|
| _____ | Most common | a. Disc |
| _____ | Conical disc | b. Basket |
| _____ | Uses a knife | c. Solid bowl |
| _____ | Batch process | |
| _____ | Prone to plugging | |
| _____ | Screw conveyer | |
| _____ | Least common | |
| _____ | Used to handle hard to dewater sludge | |
| _____ | Has a beach | |
| _____ | Used to separate milk and cream | |
| _____ | Uses discharge nozzles | |
| _____ | Differential speed | |
| A | Discharge weir | |

9. Identify the following:

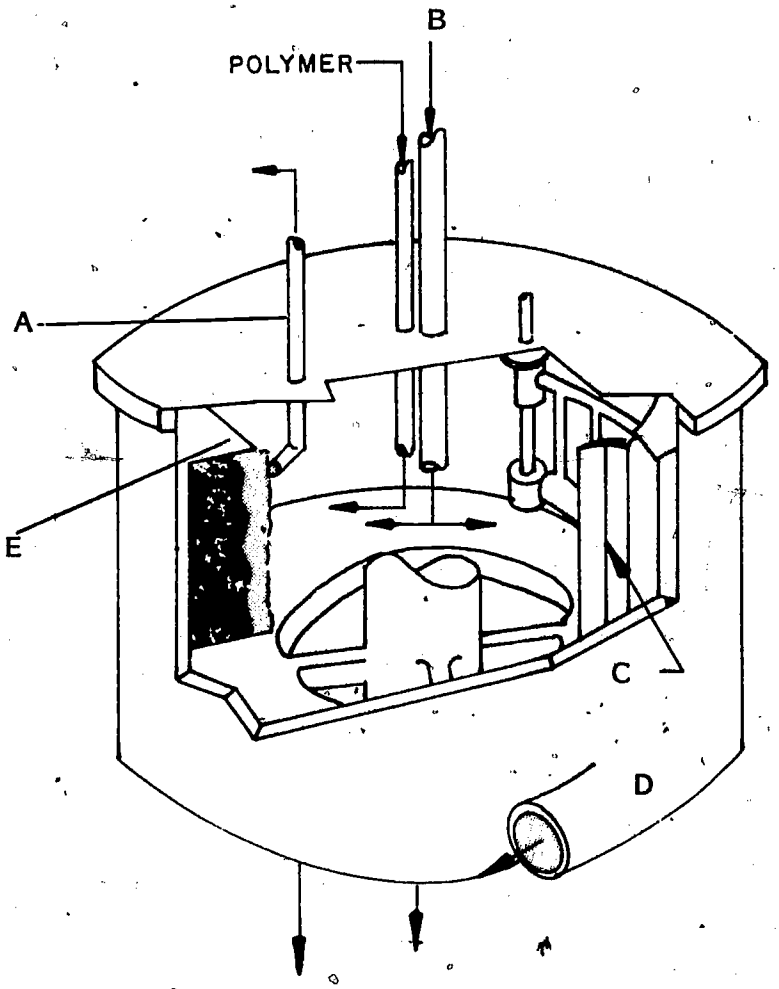
_____ Flow in

_____ Knife

_____ Liquid skimmer

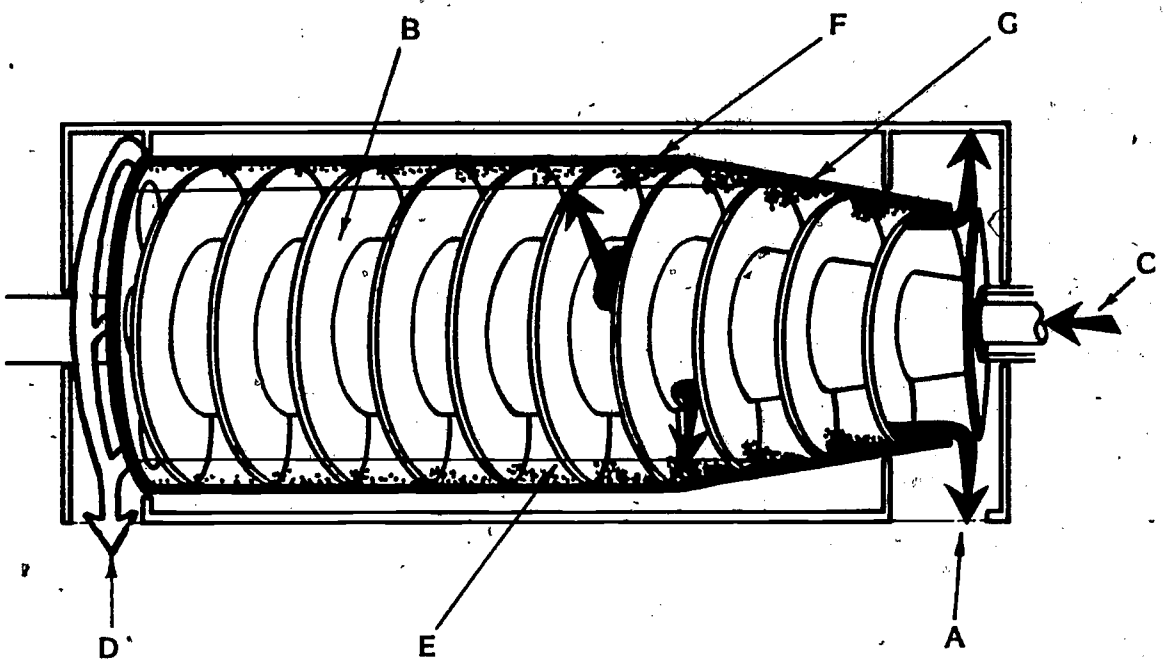
_____ Weir

_____ Centrate



10. Identify the following:

_____ Flow in
_____ Bowl
_____ Beach
_____ Screw conveyor
_____ Solids discharge
_____ Centrate discharge
_____ Pool




11. Match the changes on the left with the conditions on the right for a solid bowl centrifuge.

_____ Lower weir setting
_____ Decrease in feed rate
_____ Increase in feed rate
_____ Higher weir setting

a. Dryer cake
b. Wetter cake

12. Rank the abilities of the three centrifuges to produce a dry cake with WAS. (one is best)

_____ Solids bowl

_____ Disc

_____ Basket

13. On the diagram in Problem #10, match the sample points with the required test.

_____ Percent moisture

_____ Flow

_____ SS

_____ BOD

_____ VSS