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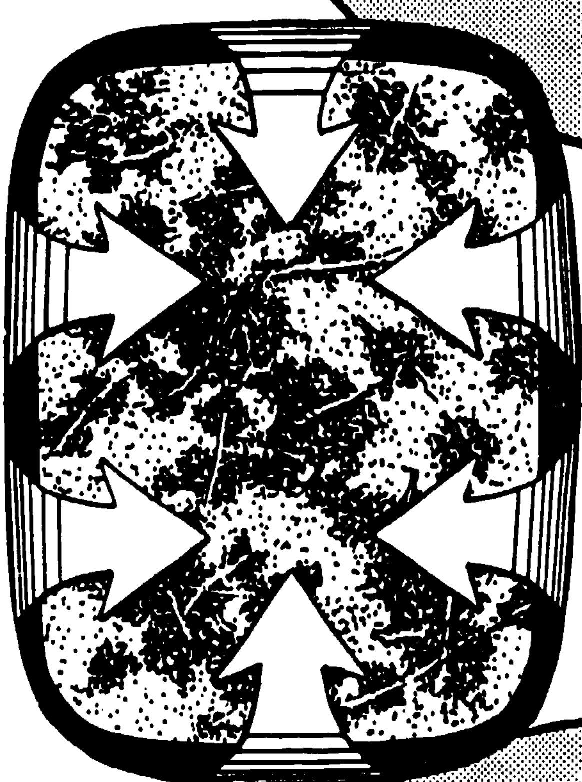
ABSTRACT

This instructor's guide contains materials needed to teach a four-lesson unit on anaerobic digestion control. These materials include: (1) unit overview; (2) lesson plans; (3) lecture outlines; (4) student worksheets for each lesson (with answers); and (5) two copies of a final quiz (with and without answers). Lesson 1 is a review of the theory of anaerobic digestion. Topics covered include the nature of raw sludge, purposes of anaerobic digestion, the biological process, and the results of digestion. Lesson 2 covers classification of digesters and system components. Classification on the basis of function and structure is discussed. The components of the mixing, heating, and gas system are also covered. Lesson 3 deals with process control. The factors which affect operation, control parameters, and sampling and testing are addressed. Lesson 4 is on mathematics calculations relating to process control. Lessons 1, 2, and 3 are supported by a set of 35mm slides (which are indicated in the lecture outlines for these lessons). (JN)

Biological Treatment Process Control

Anaerobic Digestion



Instructor's Guide

Linn-Benton Community College
Albany, Oregon 1984

BIOLOGICAL PROCESS TREATMENT CONTROL

ANAEROBIC DIGESTION

Instructor's Guide

Outline Developed By:
E.E. "Skeet" Arasmith
Linn-Benton Community College
Albany, Oregon

Edited By:
John W. Carnegie, Ph.D.
Linn-Benton Community College
Albany, Oregon

Instructional Design By:
Priscilla Hardin, Ph.D.
Priscilla Hardin Instructional Services
Corvallis, Oregon

Developed Under:
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ANAEROBIC DIGESTION

Instructor's Guide

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ANAEROBIC DIGESTION

Overview

This unit on anaerobic digestion process control is divided into four lessons. Lesson 1 is a review of the theory of anaerobic digestion. Topics covered include the nature of raw sludge, purposes of anaerobic digestion, the biological process, and the results of digestion. Lesson 2 covers classification of digesters and system components. Classification on the basis of function and structure is discussed. The components of the mixing, heating, and gas systems are well covered. Lesson 3 deals with process control. The factors which affect operation, control parameters, and sampling and testing are addressed. Lesson 4 is on math calculations relating to process control.

Lessons 1, 2 and 3 are supported by 35 mm slides. Most of these slides were developed by LBCC for use in EPA Course #166, Solids Handling and Treatment. They are used in this unit in a different order and with expanded written material. The Course #166 slide/tape program and written material on Anaerobic Digestion can be obtained from:

Water/Wastewater Department
Linn-Benton Community College
6500 SW Pacific Blvd.
Albany, OR 97321
(503) 928-3620

The text in the student manual is excerpted from EPA Manual 430/9-76-001, "Operations Manual; Anaerobic Sludge Digestion," EPA-IRC, Ohio State Univ., Columbus, OH, 1976.

Lesson Plans

Lesson 1 - Process Theory

- Assign text Sec. 1 "Anaerobic Sludge Digestion" ahead of time if possible
- Lecture using slides (30 min)
- Assign worksheet (10 min)
- Correct and discuss worksheet (15 min)

Lesson 2 - Types and Components

- Assign text Sec. 1 "Anaerobic Sludge Digestion" ahead of time, if possible (if not already assigned above).
- Lecture using slides (30 min)
- Assign worksheet (10 min)
- Correct and discuss worksheet (15 min)

Lesson 3 - Process Control

- Assign text Sec. 2 "Digested Process Control" ahead of time, if possible
- Lecture using slides (45 min)
- Assign worksheet (10 min)
- Correct and discuss worksheet (15 min)

Lesson 4 - Calculations

- Refer students to portions in text which discuss calculations. Portions are spread throughout the first and second sections.
- Explain calculations and work example problem. Use overheads of formulas provided. (30 min)
- Assign worksheet (30 min)
- Correct and discuss worksheet (15 min)
- Assign final quiz (20 min)

Additional suggestions -

- Obtain samples of raw and digested sludge. Samples of well and poorly digested sludge would be valuable.
- Display examples of gas safety and control equipment; flame traps, heat sensitive valves, meters, manometers, etc.

ANAEROBIC DIGESTION

Lecture Outline

Lesson I - Process Theory

Slide #	
#1 & #2	Title & Credit Slide
	Functions of Anaerobic Digestion
#3	5 Main Functions:
	- Stabilizes volatile matter 40-60% reduction
	- Reduces mass and/or volume of sludge
	- Reduces offensive odor
	- Reduces number of pathogenic organisms
	- Conditions sludge - changes nature of sludge to make it more readily dewaterable
#4	Results - Usable By-products
	Methane gas
	Digested sludge
	- Supernatant which must be recirculated through plant
	Nature of Sludge Fed to Digester
#5	Raw - Primary Clarifier
#6	2-5% solids
#7	60-80% volatile
#8	Volatility depends on age and nature
#9	Biological - Waste Activated Sludge
	- Organic

#10 Chemical - Inorganic precipitates

- Pho , horus removal

Primary clarifier solids are the most common type digested anaerobically

Types of Digestion

#11 Anaerobic

Advantages - useful gas produced
- effective treatment
- low operating cost

Disadvantages - slow digestion
- upset easily by sudden changes

#12 Aerobic

Advantages - treat WAS better
- treat high water content (thin) sludge better
- inexpensive to construct

Disadvantages - high operating cost - air
- no useful by-products

The Digestion Process

Partially digested sludge subjected to further digestion - by anaerobic bacteria

#13 Two Stages

#14 Acid Formers

Convert absorbed organics (V.S.) into volatile acids (50-300 mg/L)

Mostly acetic acid

#15 Methane Formers

Use volatile acids as food

Produce CO_2, CH_4, H_2O & alkalinity

#16 Alkalinity (1500-3000 mg/L)

Buffers & neutralizes

Strict anaerobes

Results of Digestion

#17 Reduced (stabilized volatile solids) 40-60% less V.S.

Inert (nonvolatile) solids are not touched

#18 Gas and useful sludge produced

Supernatant high in SS and BOD must be treated

#19 The Digester Zones

Gas, Scum, Supernatant, Sludge

#20 Gas

#21 Methane CH_4

Carbon dioxide CO_2

Moisture & minor gases (H_2S, N_2)

65-70% CH_4

#22 12-18 ft^3 gas/lb V.S. digested

#23 600-800 BTU's/ft^3

Commercial gas 1000-1100 BTU's/ft^3

Gas System

#24 Collects gas for heating, mixing, or wasting

#25 Uses of Surplus Gas

#26, #27, #28 Heating digester & buildings

Heat exchange

#29 Fueling engines & blowers, generators

#30 Mixing

#31 Explosive nature of gas

Explosive range air to methane 20:1 to 5:1

Corrosive - CO_2 creates carbolic acid

#32 Scum

#33 More prominent in unmixed tanks

Caused by uplift of gas

Tend to reduce mixing

Concentrates food

5-15 feet thick

Contains - petroleum products
- rubber material
- plastics
- cigarette filter tips
- hair
- grit

#34 Supernatant

Two sources - carrier water
- disrupted (dead) bacterial cells

#35 High BOD - 1000-10,000 mg/L

High SS - 5000-15,000 mg/L

Can cause severe loading via sidestream to headworks

Supernatant depends on type of feed sludge

Good settling critical

#36 Active Sludge Zone

#37 Good sludge - black, no green or gray streaks

#38 - dewaters easily
- no noxious odors
- 40-60% lower V.S. than feed

#39 Digested sludge can be disposed of by land application, landfill or incineration (less common)

#40 Summary and Review

ANAEROBIC DIGESTION

Lecture Outline

Lesson II - Types and Components

Slide #	
#1 & #2	Title & Credit Slides
	Two Major Types
#3	Old, open top, unmixed
	Imhoff Tanks
#4	Covered tanks with mixing
	Classification of Digesters
#5	Function
#6	Primary Digester
	Site of most of the digestion
#7	Secondary and Gas Holding
	Serves as storage for sludge and gas
#8	Roof Design
#9, #10	Fixed Roof Design
	Roof - steel, concrete
#11	Internal pressure - 8" of water
	Must control gas removal and liquid level
#12, #13, #14	Floating Roof Design
#15	Volume can fluctuate, empty periodically
	Roof rides on liquid and gas
	Corbels stop roof from going too far down
	Internal pressure - 8-11" of water
#16	Usually used as secondary digesters

#17, #18 Gas Holding Roof Design

Used for gas storage

#19 Roof floats on gas pressure

#20 Temperature

Psychrophilic

Mesophilic

Thermophilic

Components

#21 Commercial gas storage

On hand for emergency and start-up use

Cannot store digester gas

Heat Exchangers

Internal

#22, #23 Steam injection

#24 Internal heat exchangers

#25, #26 Direct Gas - extremely dangerous

#27 - #33 External

Uses methane fueled boilers and heat exchangers

#34 Mixing

Gas

Mechanical

Combination

#35 Gas System Components

#36 Flame Arrestors

#37 Heat Sensitive Valve

#38 Pressure Valves

#39 Moisture & Sediment Traps

#40 Manometer

#41 Gas Meter

#42 Wasting Burners

#43, #44 Sludge Pumps

Piston Pumps

Progressive Cavity

ANAEROBIC DIGESTION

Lecture Outline

Lesson III - Operational Control

<u>Slide #</u>

#1 & #2	Title & Credit Slides
#3	Digestion Control Factors - Outline slide
#4	Digestion Control Factors - Bacteria
#5	Seed Sludge Need 20 times more seed than food by wt. of volatile matter Acid formers are facultative anaerobes - present in wastewater sludge Methane formers - strict anaerobes takes time to develop population
#6	Digestion Control Factors - Food
#7	Quality of Food Should be 5-8% solids Non-toxic Stable pH Feed at a steady rate & frequency Keep excess water at a minimum Sludge usually less dense at night Quality, not quantity is important Remove grit and grease Typical sludge concentrations

Primary Raw	5-8%
WAS	1.5-2%
T.F.	1-3%
Mixed Primary/A.S.	3-5%

#8 Digestion Control Factors - Loading

#9 Load on basis of V.S./ft^3 (F/M)

0.03-0.1 lbs/ft^3

Load on basis of V.S. feed/V.S. in digester

1:20

Hydraulic loading

Affects detention time

Maintain good buffering by controlling withdrawal

Maintain buffering by recycling from bottom of secondary 50% of raw feed/day

#10 Digestion Control Factors - Mixing

#11 Organisms must come in contact with food

Types of Mixing

Natural - Gas

- Loading of sludge

#12 Artificial - Gas

- Mechanical

- Combination

#13 Digestion Control Factors - Environment

pH - buffering capacity

Maintain Volatile Acid to Alkalinity Ratio

$$\frac{VA}{Alk} = 0.25 \text{ or less}$$

#14 Temperature

Best range 95-98^{o} F

phychrophilic - less than 68^{o} F

mesophilic - 68-113^{o} F

thermophilic - above 113^{o} F

Best temperature established by CO_2 production at 30% or lower

#15 Vary by not more than 1^{o} F/day

#16 Control temperature for energy efficiency

#17 pH

6.8-7.2 best

6.4-7.4 tolerable

Volatile Acids

50-300 mg/L

Alkalinity

3000-6000 mg/L

#18 Digestion Control Factors - Time

Control detention time by feed, pumping rate and withdrawal rate

Scum Blanket Control

Provide adequate mixing

Try to less than 24" thick

Supernatant Control

Monitor BOD and SS, keep both less than 5000 mg/L

Allow ample settling time, 8-12 hrs

Select and maintain level in digester

#19 Monitoring

Sample points

Raw

Supernatant

Gas

Digested Sludge

#20 Digesting Sludge - Thief hole

#21 Tests

Flow

Alkalinity

pH
Volatile Acids
Temperature
% Moisture
Volatile Solids

#22 pH and Temperature
- Feed
- Supernatant
- Digested Sludge
- Digesting Sludge

#23 Flow
- Feed
- Digested Sludge
- Digesting Sludge

#24 Total & Volatile Solids, % Moisture
- Feed
- Supernatant
- Digested Sludge
- Digesting Sludge

#25 CO_2
- Gas

BOD, Suspended Solids
- Supernatant

#26 pH and VA/Alk
- Digesting Sludge

#27 Review of Monitoring

#28 Trend Chart Test Data

#29 Safety

Rubber soled shoes
No open flames, no smoking
Light waste burner cautiously

#30

Fix gas leaks immediately

Check for gas in air before entering empty digester

ANAEROBIC DIGESTION

Lecture Outline

Lesson IV - Calculation

1. Calculate pounds T.S. in Feed or Supernatant per day

   T.S., lbs/day = T.S., mg/L X Flow, Mgal/day X 8.34

2. Calculate pounds T.S. in Digester

   T.S., lbs = T.S., mg/L X Vol, Mgal X 8.34

3. Calculate Hydraulic Detention Time

   $$\text{D.T., days} = \frac{\text{Vol, gal}}{\text{Feed, gal/day}}$$

4. Calculate pounds Volatile Solids in feed per day

   V.S., lbs/day = T.S., lbs/day X % Volatility

5. Calculate Volatile Solids Loading in $lbs/day/ft^3$

   $$\text{Loading, lbs/day/ft}^3 = \frac{\text{V.S., lbs/day}}{\text{Dig. Vol, ft}^3}$$

6. Calculate Volatile Solids Reduction in Percent

   $$\text{V.S. reduction, \%} = \frac{\text{V.S. in - V.S. out}}{\text{V.S. in - (V.S. in X V.S. out)}} \times 100\%$$

7. Calculate pounds of Volatile Solids Digested

   V.S. digested, $lbs/day/ft^3$ = Loading, $lbs/day/ft^3$ X V.S. Reduction %

8. Determine pounds of lime to adjust pH

   Do bucket test on a small sample

   Use ratio to determine pounds for total digester

9. Determine pounds of lime required to neutralize volatile acids

   lbs of lime = Dig Vol, Mgal X V.A., mg/L X 8.34

10. Determine pounds of lime required to neutralize if volatile acids and alkalinity are known

Usually want 500 mg/L excess alkalinity

Alkalinity is equal to 0.833 times V.A.

Steps to determine

1. Determine alkalinity to neutralize V.A.

   Alk = 0.833 X V.A.

2. Subtract alkalinity present

3. Add excess alkalinity (500 mg/L)

4. Ammonia = 2.78 X Dig Vol, Mgal X Alk, mg/L

5. Anhydrous Ammonia usually 80% ammonia

I-AND-17

$$\text{TOTAL SOLIDS}_{\text{LBS}} = \text{T.S.}_{\text{MG/L}} \times \text{VOL}_{\text{MGAL}} \times 8.34$$

I-AND-18

$$\text{TOTAL SOLIDS}_{\text{LBS/DAY}} = \text{T.S.}_{\text{MG/L}} \times \text{FLOW}_{\text{MGAL/DAY}} \times 8.34$$

I-AND-19

$$\text{VOLATILE SOLIDS}_{\text{LBS/DAY}} = \text{T.S.}_{\text{LBS/DAY}} \times \text{\% VOLATILITY}$$

$$\text{DETENTION TIME}_{\text{DAYS}} = \frac{\text{VOL}_{\text{GAL}}}{\text{FEED FLOW}_{\text{GAL/DAY}}}$$

I-AND-21

$$\text{LOADING},_{\text{LBS/DAY/FT}^3} = \frac{\text{V.S.},_{\text{LBS/DAY}}}{\text{DIG. VOL.},_{\text{FT}^3}}$$

I-AND-22

$$\text{V.S. DIGESTED}_{\text{LBS/DAY/FT}^3} = \text{LOADING}_{\text{LBS/DAY/FT}^3} \times \text{V.S. REDUCTION}_{\%}$$

30

$$\text{VOLATILE SOLIDS REDUCTION, \%} = \frac{\text{V.S., IN} - \text{V.S., OUT}}{\text{V.S., IN} - (\text{V.S., IN} \times \text{V.S., OUT})}$$

ALKALINITY = 0.833 x VOLATILE ACIDS

$$\text{POUNDS LIME} = \text{DIG VOL,}_{\text{MGAL}} \times \text{V.A.,}_{\text{MG/L}} \times 8.34$$

ANAEROBIC DIGESTION

Answers to Worksheet 1 - Process Theory

1. List four purposes of anaerobic digestion of sewage sludge.

   a. Stabilize volatile matter

   b. Reduce mass and/or volume

   c. Reduce odor

   d. Reduce pathogens

   Condition sludge

2. Raw sludge from a primary clarifier contains 60 to 80 % volatile matter.

3. List one advantage and one disadvantage which anaerobic digestion has over aerobic digestion.

   a. Advantage — Useful gas produced; Effective treatment; Low operating cost

   b. Disadvantage — Slow digestion; Easily upset

4. The anaerobic sludge digestion process is a two stage process.

5. Volatile solids in raw sludge are attacked by acid forming (anaerobic) organisms to form volatile (low molecular weight) acids.

6. Methane formers then feed off of the volatile acids to form CO_2 (carbon dioxide), CH_4 (methane), H_2O (water) and alkalinity.

7. Which of the two types of major bacteria involved in the anaerobic digestion process is a strict anaerobe?

   Methane formers

8. Stabilizing waste by digestion should reduce the volatile content by 40 to 60 %.

9. The gas produced by a digester is mainly 65-70 % methane and 30-35 % CO_2.

10. 12 to 18 ft^3 of gas will be produced for each lb of volatile solids digested.

11. One ft^3 of digester gas will produce 600 to 800 BTU of heat.

12. Name three uses of digester gas:

    a. Heating Digesters

    b. Heating buildings

    c. Fuel for engines, blowers, generators
       Mixing

13. Methane can explode when the ratio of air to methane is between 20:1 and 5:1.

14. Why is digester gas corrosive?

    Because CO_2 mixes with water to form HCO_3 (carbolic acid)

15. What causes the scum layer in a digester?

    The uplifting of material by the gas

16. Water (supernatant) in a digest may come from:

    a. carrier water

    b. water from killed bacterial cells

17. Digester supernatant can have a BOD of 1000 to 10,000 mg/L and a SS of 5000 to 15,000 mg/L.

18. What are the characteristics of good quality digester sludge?

    Black, no green or gray streaks
    Dewaters easily
    No noxious odors
    40-60% lower V.S. than feed

Worksheet 2 - Types and Components

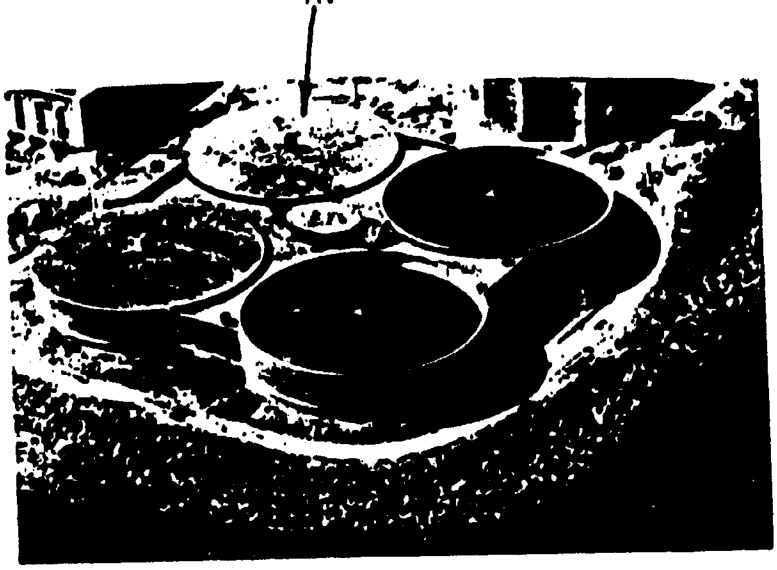
1. Identify the following digesters by cover type (fixed, floating or gas holding).

   a. fixed

   b. gasholding

   c. floating

A.



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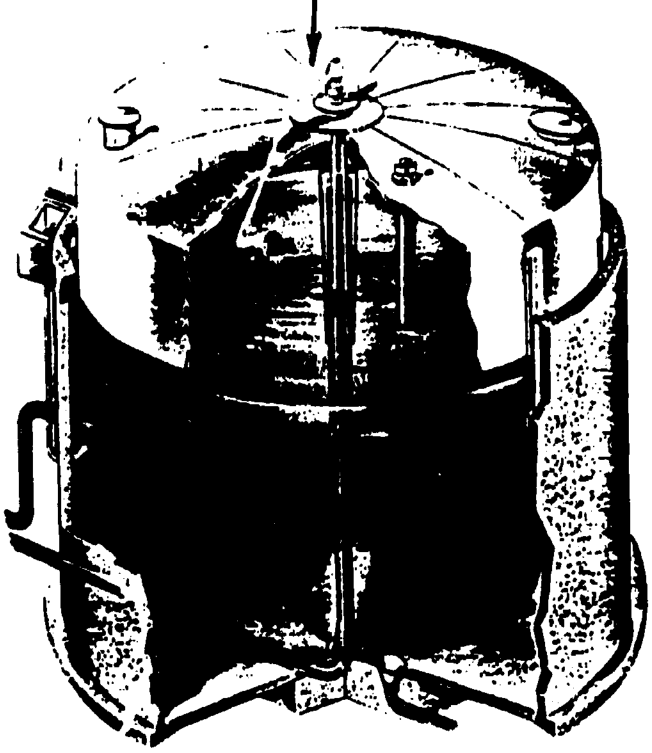
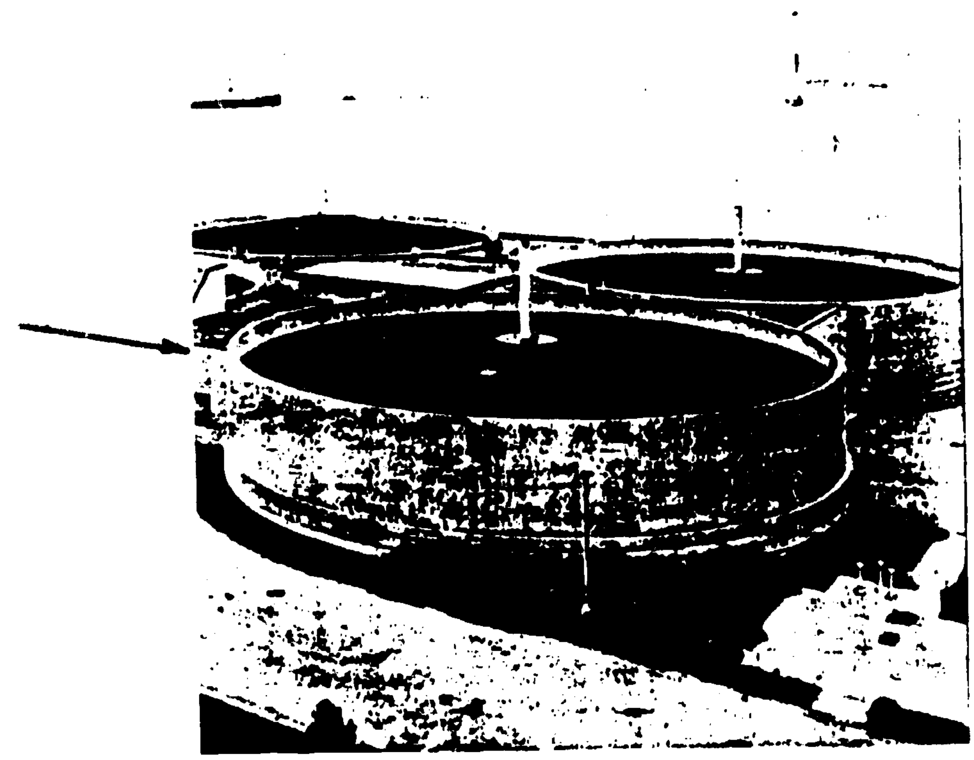
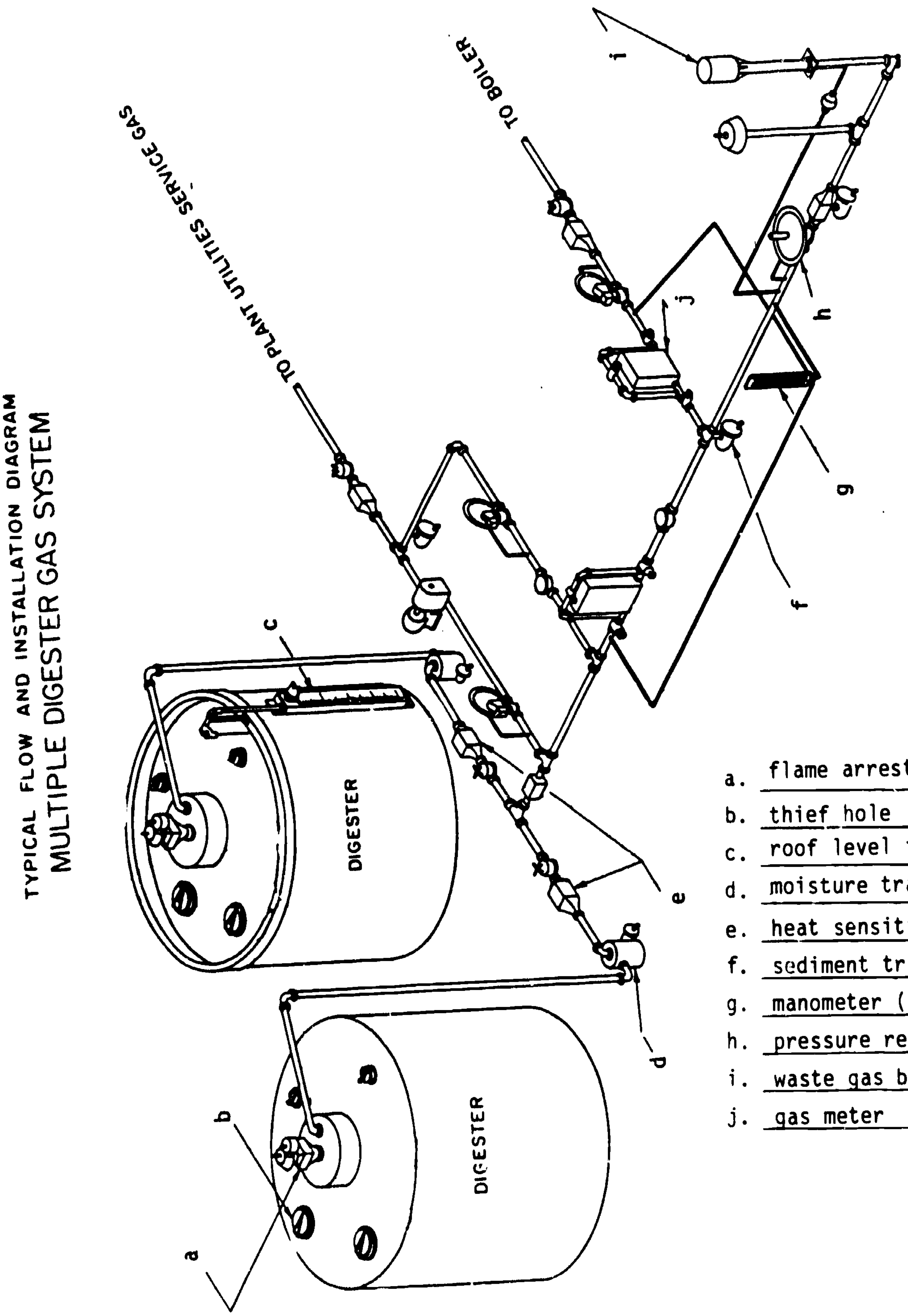


C.



2. Identify the components of the digester gas system indicated.



a. flame arrestor
b. thief hole
c. roof level indicator
d. moisture trap
e. heat sensitive valves
f. sediment trap
g. manometer (pressure gauge)
h. pressure regulator
i. waste gas burner
j. gas meter

3. The roof of a fixed roof digester may be made of ___steel___ or ___concrete___.

4. Internal pressure of a fixed roof digester should not exceed ___8___ inches of water.

5. Digester heat exchangers may be either ___internal___ or ___external___.

6. Digester sludge may be mixed with digester ___gas___, mechanical ___mixed___ or with ___combinations___.

7. Internal pressure on a floating roof digester should be between ___8___ and ___11___ inches of H_2O.

8. Name the three temperature zones used to classify digesters.

   a. ___Psychrophilic___

   b. ___Mesophilic___

   c. ___Thermophilic___

9. Why is it necessary to have commercial natural gas on hand?

   For emergency and start up use.

10. Name two types of sludge pumps.

    piston pumps

    "Moyno" type pumps

    "hose" pumps

    centrifugal

ANAEROBIC DIGESTION

Answers to Worksheet 3 - Operational Control

1. Name 6 factors which affect digester operation.

   a. bacteria — toxics
   b. food
   c. loading
   d. mixing
   e. temperature
   f. pH

2. There should be 20 times for seed sludge (bacteria) than food by weight of volatile matter.

3. List 3 characteristics of good quality feed sludge.

   a. 5-8% solids
   b. non-toxic
   c. stable pH
      feed at steady rate and frequency

4. Give the normal operating ranges for each of the following:

VA/Alk ratio	less than 0.25
V.S./ft^3 loading	0.03 - 0.1
temperature	95 - 98°F
pH	6.8 - 7.2
feed sludge conc.	5 - 8%

5. How does hydraulic loading affect detention time?
   Higher flows decrease detention time

6. How is the optimum operating temperature determined?
   By optimizing CO_2 production at 30% or lower

7. Digester temperature should be changed no more than 1 °F/day.

8. Volatile acid concentrations in the digester can fall in the range of 50 to 300 mg/L.

9. Alkalinity in the digester can fall in the range of 3000 to 6000 mg/L.

10. How is detention time controlled?

    By adjusting feeding and withdrawal pumping rates.

11. If digester supernatant BOD and SS concentration exceeds 5000 mg/L, the biological system of the plant may become overloaded.

12. List the 5 sample points of a typical digester.

    a. Raw feed
    b. Supernatant
    c. Gas
    d. Digested Sludge
    e. Digesting Sludge

13. For the following tests indicate the samples upon which they should be run:

    pH and temperature -

    Feed, Supernatant, Digested Sludge, Digesting Sludge

    Flow -

    Feed, Digested Sludge, Digesting Sludge

    Solids (Total, Volatile & % Moisture) -

    Feed, Supernatant, Digested Sludge, Digesting Sludge

    CO_2 -

    Gas

    BOD & SS -

    Supernatant

    Volatile Acids & Alkalinity -

    Digesting Sludge

Answers to Worksheet 4 - Calculations

Consider the following data for an anaerobic digester.

	Raw	Digested	Supernatant
Quantity	12,000 gal/day		12,000 gal/day
Total Solids, mg/L	40,000 mg/L (4%)	60,000 mg/L	4,000 mg/L
Volatile Solids (% of T.S.)	70%	45%	60%
Digester Volume	250,000 gal (33,400 ft^3)		
Digesting Sludge	2% (20,000 mg/L)		

1. Calculate pounds T.S. in digester.

   T.S., lbs = T.S., mg/L X Vol, MGal X 8.34

   = 20,000 X 0.25 X 8.34

   = 41,700 lbs

2. Calculate pounds T.S. in raw feed sludge.

   T.S., lbs/day = T.S., mg/L X Flow, MGal/day X 8.34

   = 40,000 X 0.012 X 8.34

   = 4000 lbs/day

3. Calculate pounds T.S. in supernatant

   T.S., lbs/day = T.S., mg/L X Flow, MGal/day X 8.34

   = 4000 X 0.012 X 8.34

   = 400 lbs/day

4. Calculate Hydraulic Detention Time.

$$\text{Hyd. Det. Time, days} = \frac{\text{Vol, gal}}{\text{Raw feed, gal/day}}$$

$$= \frac{250{,}000 \text{ gal}}{12{,}000 \text{ gal/day}}$$

$$= 20.8 \text{ days}$$

5. Calculate pounds Volatile Solids fed.

V.S., lbs/day = T.S., lbs/day X % Volatile

= 4000 X 0.7

= 2800 lbs/day

6. Calculate volatile solids loading in lbs/day/ft^3.

$$\text{Loading, lbs/day/ft}^3 = \frac{\text{V.S., lbs/day}}{\text{Dig. Vol., ft}^3}$$

$$= \frac{2800 \text{ lbs/day}}{33{,}400 \text{ ft}^3}$$

$$= 0.083 \text{ lbs/day/ft}^3$$

7. Calculate volatile solids loading in lbs V.S./day per lb V.S. in digester.

$$\text{Loading lbs/day/lb} = \frac{\text{V.S., lbs/day}}{\text{V.S. in Dig, lbs}}$$

$$= \frac{2800 \text{ lbs/day}}{41{,}700 \text{ lb X } 0.45}$$

$$= 0.15 \text{ lbs/day/lb}$$

8. Calculate Volatile Solids Reduction.

$$\text{V.S. reduction, \%} = \frac{\text{V.S. in - V.S. out}}{\text{V.S. in - (V.S. in X V.S. out)}} \times 100\%$$

$$= \frac{.70 - .45}{.70 - (.70 \times .45)} \times 100\%$$

$$= \frac{.25}{.38} \times 100\%$$

$$= 66\%$$

9. Calculate pounds of volatile solids digested.

$$\text{V.S. digested, lbs/day/ft}^3 = \text{Loading, lbs/day/ft}^3 \times \text{V.S. Reduction \%}$$

$$= 0.083 \times 0.66\%$$

$$= 0.055 \text{ lbs/day/ft}^3$$

10. A digester has a volume of 250,000 gal. Lab tests show that 0.075 lbs of lime is necessary to bring the pH of a 5 gal sample up to 6.8. How many lbs of lime are necessary to adjust the pH of the entire digester?

$$\frac{5 \text{ gal}}{0.15 \text{ lbs}} = \frac{250{,}000 \text{ gals}}{X \text{ lbs}}$$

$$X \text{ lbs} = \frac{250{,}000 \text{ gal} \times 0.075 \text{ lbs}}{5 \text{ gal}}$$

$$= 3750 \text{ lbs}$$

11. If a digester of Vol. 250,000 gal has 2000 mg/L of Volatile Acids, how many lbs of lime will be needed to neutralize the V.A.'s?

lbs = Vol, Mgal X V.A., mg/L X 8.34

= 0.250 X 2000 X 8.34

= 4170 lbs

12. If a digester of Vol. 250,000 gal, the alkalinity is 2000 mg/L and the volatile acids is 3500 mg/L, how many lbs of 80% anhydrous ammonia are needed to neutralize the V.A.'s? (Assume an excess of 500 mg/L alkalinity needed.)

Alk. needed to neutralize VA = 0.833 X VA

= 0.833 X 3500

= 2915 mg/L

Need to Add Alk. = 2915 - 2000

= 915 mg/L

To have 500 mg/L excess = 915 + 500

= 1415 mg/L

Ammonia, lbs = 2.78 X Dig. Vol, Mgal X Alk needed mg/L

= 2.78 X 0.25 X 1415

= 983.4

Anhydrous NH_4, lb $= \frac{983.4}{0.8}$

= 1229 lbs

ANAERBOIC DIGESTION

Final Quiz

1. Match the letters on the diagram with their description:

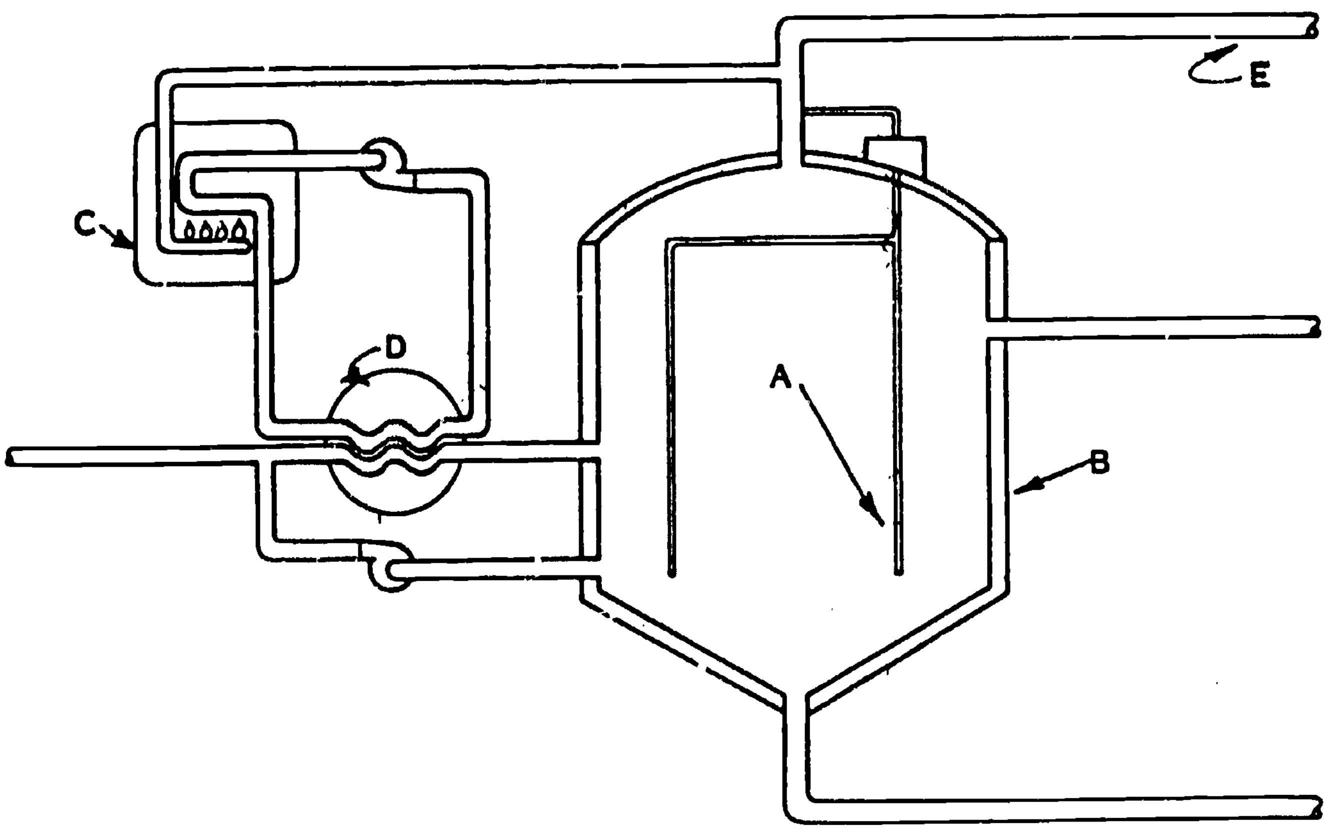
_____ gas collection and removal system

_____ boiler

_____ mixing

_____ tank

_____ heat exchanger



2. Which of the following are considered valid purposes of anaerobic digestion? (select five)

_____ a. reduce water consumption
_____ b. increase volatile content
_____ c. reduce volatile content
_____ d. reduce odor
_____ e. prevent reliquification
_____ f. produce usable gas
_____ g. reduce mass of sludge
_____ h. condition sludge
_____ i. improve plant efficiency
_____ j. reduce numbers of pathogenic organisms

3. The volatility of sludge is an indication of:

_____ a. heat production capabilities.
_____ b. sludge food value.
_____ c. weight of the sludge.
_____ d. the difference between the weight of the sludge and the weight of an equal volume of water.
_____ e. all of the above.

4. Anaerobic digestion is basically a ______ step process.

_____ a. 4
_____ b. 3
_____ c. 2
_____ d. 6
_____ e. none of the above

5. The first stage of digestion converts ________ to ____________.

_____ a. volatile solids to methane
_____ b. methane to acid formers
_____ c. volatile acid to methane and CO_2
_____ d. volatile solids to volatile acids
_____ e. none of the above

6. During the second stage of digestion there is a conversion of:

_____ a. volatile acids to pH.
_____ b. volatile acids to methane.
_____ c. volatile solids to volatile acids.
_____ d. microorganisms to food.
_____ e. all of the above.

7. During the second stage of digestion a buffering material is produced. This buffering material is usually called:

_____ a. alkalinity.
_____ b. CO_2.
_____ c. pH.
_____ d. acid.
_____ e. none of the above.

8. The most acceptable pH range for anaerobic digestion is between:

_____ a. 6.5 and 7.5
_____ b. 6.4 and 8.4
_____ c. 6.8 and 7.2
_____ d. 5 and 8
_____ e. none of the above.

9. When a digester contains such items as petroleum products, plastic, rubber goods and etc., these materials may form a layer on the top of a digester. This layer is usually called:

_____ a. upper layer.
_____ b. supernatant.
_____ c. scrapings.
_____ d. scum blanket.
_____ e. none of the above.

10. The BOD range for digester supernatant would probably run between:

_____ a. 2,500 and 1,000,000 lbs/day.
_____ b. 1,000 and 100,000 mg/kg.
_____ c. 10,000 and 100,000 mg/l.
_____ d. 1,000 and 10,000 mg/l.
_____ e. all of the above.

11. Supernatant from an anaerobic digester could have a S.S. level between:

_____ a. 5,000 and 15,000 mg/l.
_____ b. 500 and 1,500 mg/l.
_____ c. 500 and 1,500 kg/g.
_____ d. 500 and 15,000 kg/l.
_____ e. none of the above.

12. A description of properly digested sludge might be:

_____ a. green and contain black and gray streaks.
_____ b. gray and contain streaks of black and dark green.
_____ c. black and contain no green or gray streaks.
_____ d. black and contain a few green or gray streaks.
_____ e. none of the above.

13. The volatility of properly digested sludge should be reduced by:

_____ a. 20 - 40%.
_____ b. 40 - 60%.
_____ c. 60 - 80%.
_____ d. 50 - 70%.
_____ e. none of these.

14. If the digester is operated properly, the gas production will usually contain methane at:

_____ a. 65 - 70%.
_____ b. 40 - 65%.
_____ c. 30 - 40%.
_____ d. 70 - 80%.
_____ e. none of these.

15. For each 1 pound of volatile material that is reduced by digestion gas is produced. The approximate volume produced for each pound would be:

_____ a. 12 - 18 mg/l.
_____ b. 12 - 18 kg.
_____ c. 12 - 18 cubic yards.
_____ d. 12 - 18 cubic feet.
_____ e. none of the above

16. Digestion may be classified by function. On the list below, place an "X" beside the three terms used to describe these three functions:

_____ a. digestion

_____ b. primary

_____ c. solids reduction

_____ d. conditioning

_____ e. secondary

_____ f. gas production

_____ g. energy cost savings

_____ h. gas producers

_____ i. gas holding

17. Select the proper name for the most common digester operating range.

_____ a. mesophilic

_____ b. psychrophilic

_____ c. esophilic

_____ d. thermophilic

_____ e. none of the above

18. Select the temperature range for the most common digester operating range.

_____ a. 65-78° F

_____ b. 79-95° F

_____ c. 95-98° F

_____ d. 98-108° F

_____ e. none of the above.

19. For a normally operated anaerobic digester operating within the typical temperature range, complete sludge digestion should take place in:

_____ a. 10-20 days

_____ b. 20-30 days

_____ c. 30-35 days

_____ d. 40-50 days

_____ e. none of the above.

20. In order to maintain an anaerobic digester in optimum condition, the digester sludge temperature should not change more than _________ degrees F. per day.

_____ a. 4
_____ b. 3
_____ c. 2
_____ d. 1
_____ e. none of the above.

21. From the list below, select the three most common types of heat exchangers.

_____ a. internal combustion engine
_____ b. direct gas flame
_____ c. low pressure
_____ d. coil type
_____ e. internal
_____ f. draft tube
_____ g. external
_____ h. boiler

22. The major purpose for mixing is to: (select one)

_____ a. bring food and microorganisms into contact.
_____ b. break up the scum blanket.
_____ c. reduce energy requirements by circulating heated sludge.
_____ d. release gas from the sludge particles.

23. The most common volatile acids to alkalinity ratio for an anaerobic digester would be:

_____ a. > 0.25
_____ b. > 150
_____ c. 0.4
_____ d. < 0.25
_____ e. < 0.4

24. Using the diagram below, indicate what material is being sampled at each point.

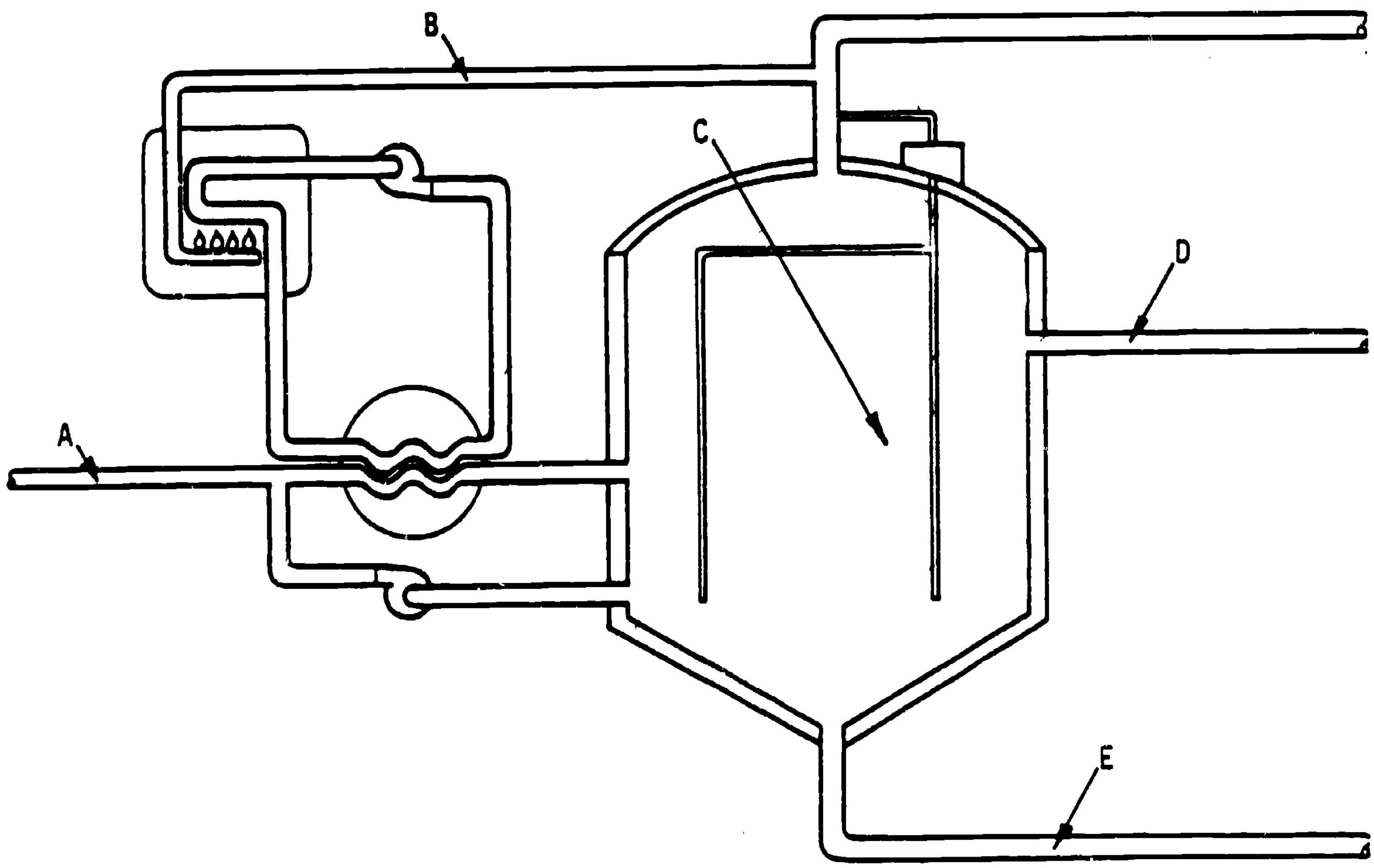
_____ supernatant

_____ raw sludge

_____ digesting sludge

_____ gas

_____ digested sludge



25. Typical volatile solids/ft^3 loadings for an anaerobic digester might be:

_____ a. 0.004 to 0.04 lbs/ft^3

_____ b. 0.04 to 0.4 lbs/ft^3

_____ c. 0.03 to 0.1 lbs/ft^3

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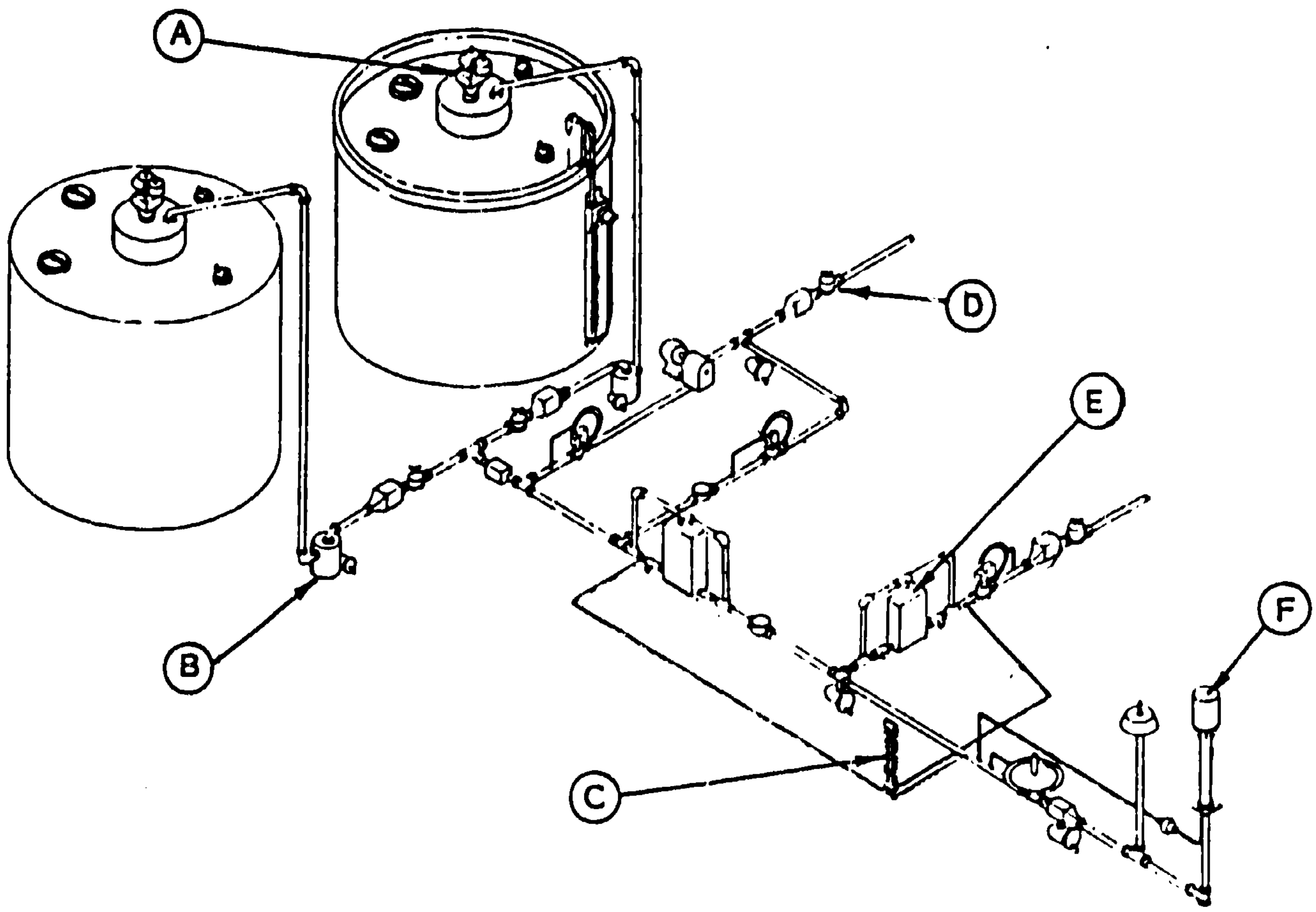

26. Using the drawing above, match the items indicated with the description.

_____ flame arrester

_____ waste gas burner

_____ gas meter

_____ heat sensitive va've

_____ moisture and sediment traps

_____ manometers

27. Calculate hydraulic detention time if the digester contains 185,000 gal and the feed rate is 9500 gal/day.

_____ a. 17.6 hrs

_____ b. 19.5 days

_____ c. 20.3 days

_____ d. 19.5 min.

28. Calculate pounds of T.S. in feed per day if the T.S. is 3.6% (36,000 mg/L), the % volatility is 68% and the feed rate is 9500 gal/day.

_____ a. 1940 lbs/day

_____ b. 615 lbs/day

_____ c. 2050 lbs/day

_____ d. 5130 lbs/day

29. Calculate loading in lbs/day/ft^3 for the plant described in Problems 27 and 28.

_____ a. 0.15 lbs/day/ft^3

_____ b. 0.019 lbs/day/ft^3

_____ c. 0.078 lbs/day/ft^3

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30. Calculate % volatile solids reduction if the V.S. of the feed is 68% and the V.S. of the digested sludge is 40%.

_____ a. 45%

_____ b. 51%

_____ c. 62%

_____ d. 68%

ANAERBOIC DIGESTION

Answers to Final Quiz

1. Match the letters on the diagram with their description:

   E gas collection and removal system
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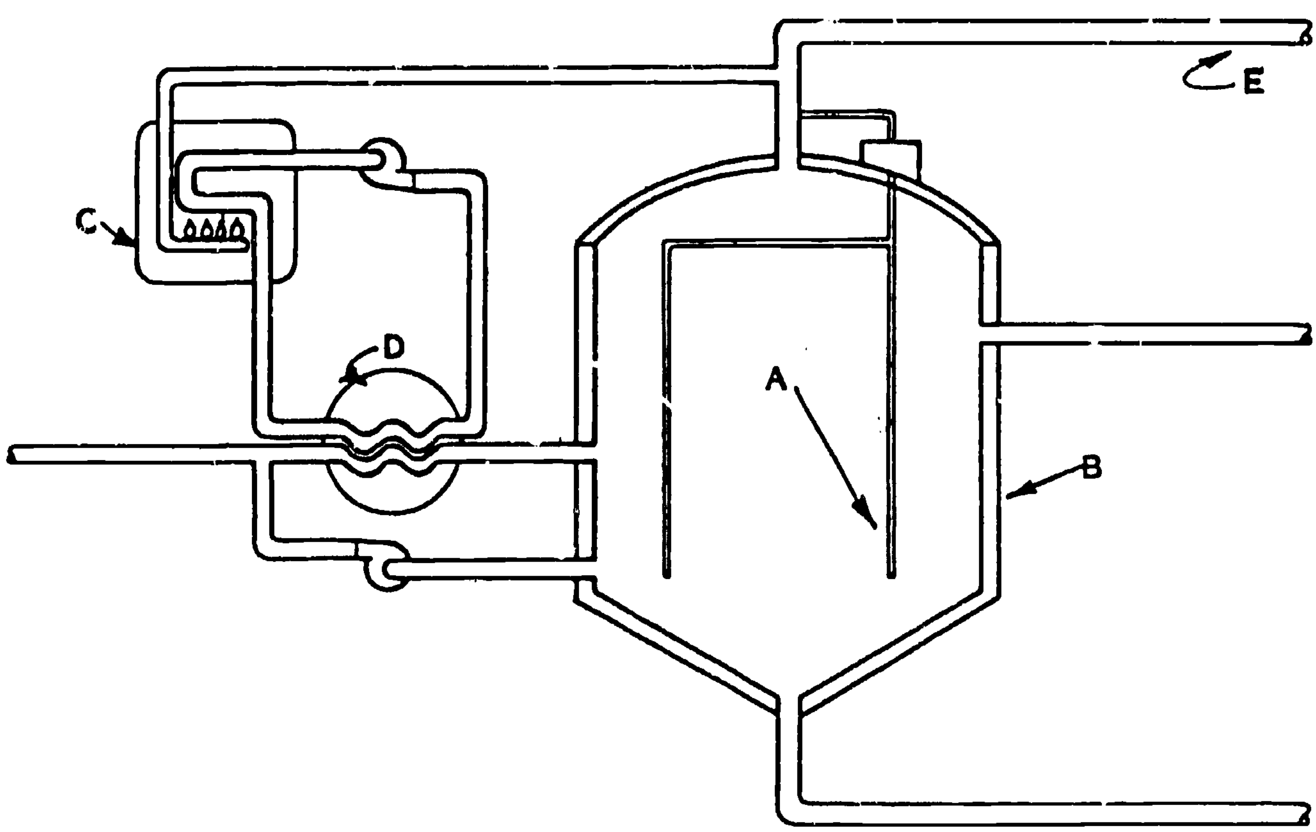

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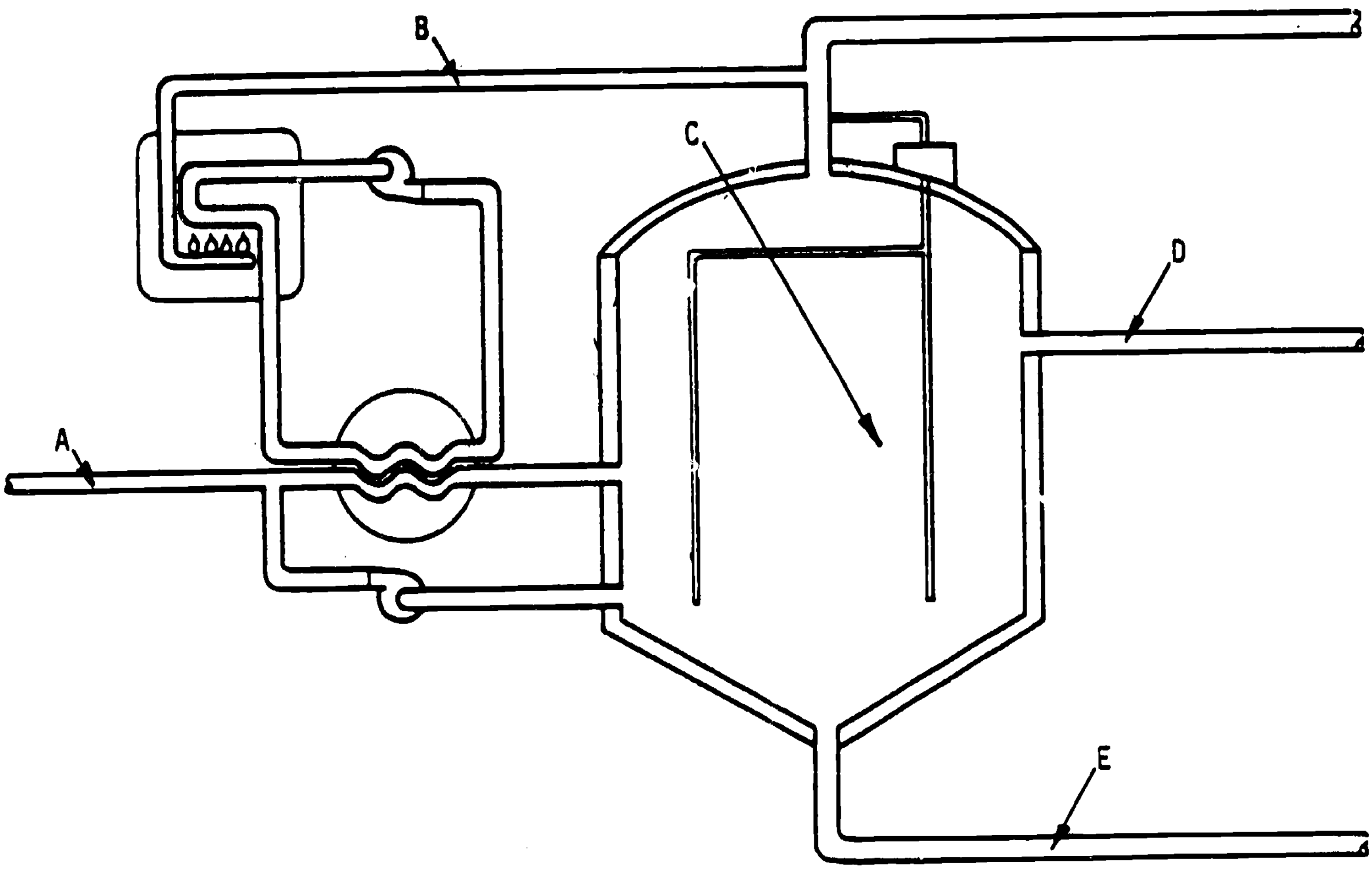

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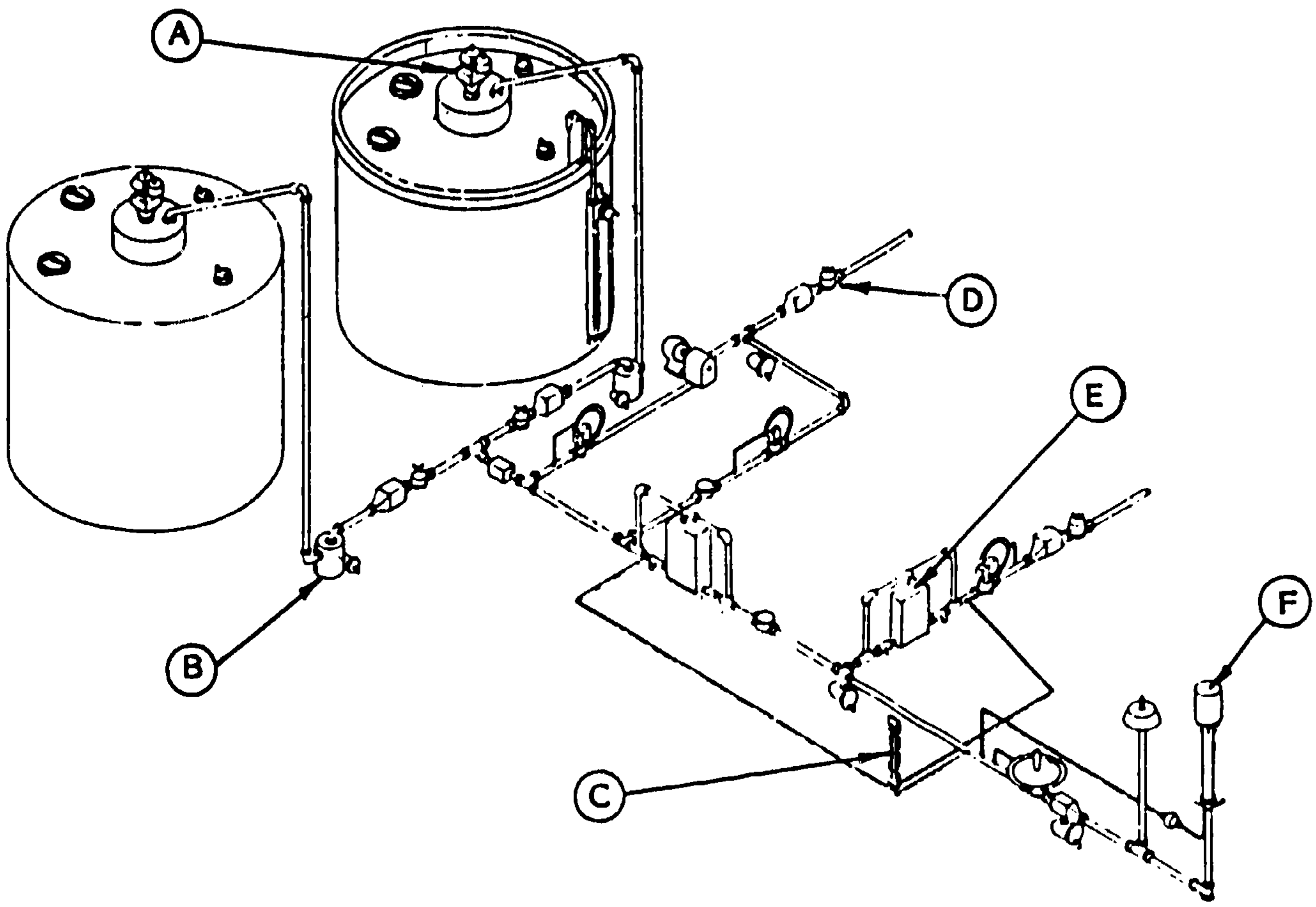

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27. Calculate hydraulic detention time if the digester contains 185,000 gal and the feed rate is 9500 gal/day.

_____ a. 17.6 hrs
__X__ b. 19.5 days
_____ c. 20.3 days
_____ d. 19.5 min.

$$\text{Hyd. Det. Time, days} = \frac{\text{Vol, gal}}{\text{Feed Rate, gal/day}}$$

$$= \frac{185{,}000}{9500}$$

$$= 19.5 \text{ days}$$

28. Calculate pounds of V.S. in feed per day if the T.S. is 3.6% (36,000 mg/L), the % volatility is 68% and the feed rate is 9500 gal/day.

__X__ a. 1940 lbs/day
_____ b. 615 lbs/day
_____ c. 2050 lbs/day
_____ d. 5130 lbs/day

V.S., lbs/day = T.S. mg/L X Flow, Mgal/day X 8.34 X % Volatility

= 36000 X 0.0095 X 8.34 X 0.68

= 1940 lbs/day

29. Calculate loading in lbs/day/ft^3 for the plant described in Problems 27 and 28.

_____ a. 0.15 lbs/day/ft^3
_____ b. 0.019 lbs/day/ft^3
__X__ c. 0.078 lbs/day/ft^3
_____ d. 0.553 lbs/day/ft^3

$$\text{Loading, lbs/day/ft}^3 = \frac{\text{V.S., lbs/day}}{\text{Dig. Vol, ft}^3}$$

$$= \frac{1940 \text{ lbs/day}}{185{,}000 \text{ gal} \times \dfrac{\text{ft}^3}{7.48 \text{ gal}}}$$

$$= 0.078 \text{ lbs/day/ft}^3$$

30. Calculate % volatile solids reduction if the V.S. of the feed is 68% and the V.S. of the digested sludge is 40%.

_____ a. 45%

_____ b. 51%

_____ c. 62%

__X__ d. 68%

$$\text{V.S. Reduction, \%} = \frac{\text{V.S. in} - \text{V.S. out}}{\text{V.S. in} - (\text{V.S. in} \times \text{V.S. out})}$$

$$= \frac{0.68 - 0.40}{0.68 - (0.68 \times 0.40)}$$

$$= 68\%$$