UPGRADING EXISTING WASTEWATER TREATMENT PLANTS

APWA EDUCATION FOUNDATION

WORKSHOP 6

SEWERAGE AND URBAN DRAINAGE SYSTEMS II

PREPARED BY:

TECHNOLOGY TRANSFER PROGRAM
U. S. ENVIRONMENTAL PROTECTION AGENCY

ACKNOWLEDGEMENT

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UPGRADING EXISTING WASTEWATER TREATMENT

FACILITIES - AN OVERVIEW

1. Approximately $18 Billion for Construction of Municipal Wastewater Treatment Facilities to Meet 1977 Requirements

   A - About one-fourth for upgrading existing secondary plants

   B - All primary plants will require upgrading to secondary

2. 1968 EPA Inventory of Municipal Wastewater Treatment Facilities

   A - Raw sewage discharge - 1,558 communities

   B - Primary treatment - 2,384 communities

   C - Intermediate treatment - 75 communities

   D - Secondary treatment - 9,353 communities

3. Secondary Treatment Facilities Using Conventional Treatment

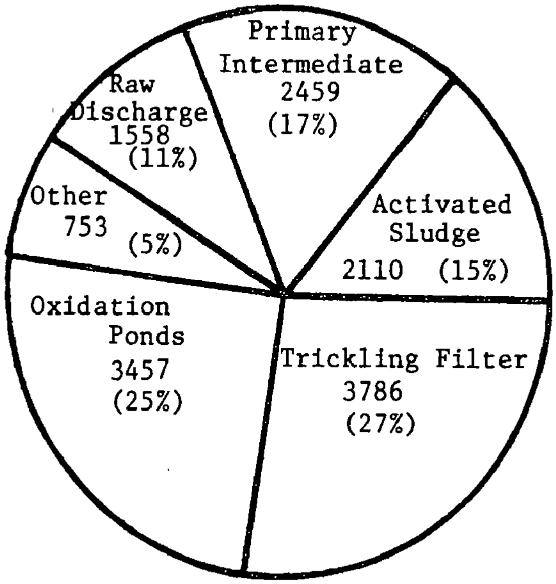
   A -

Treatment System	No. of Plants	Est. Pop. Served
Trickling filters	3,786	28.5 million
Activated sludge	2,110	41.2
Oxidation ponds	3,457	6.1

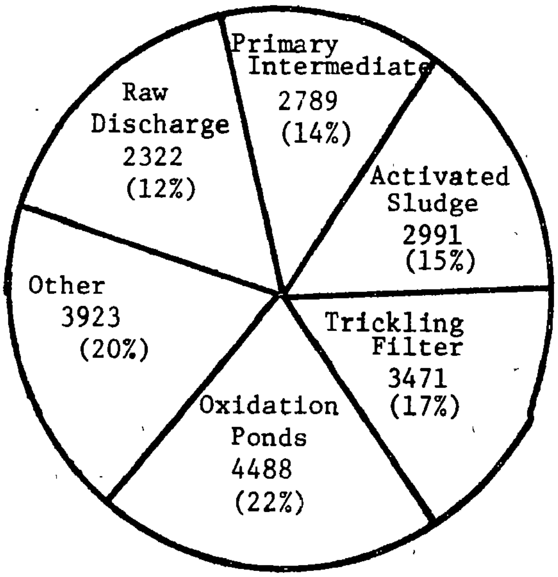
   B - Pie-chart representation of 1968 inventory in Figure 1

   C - No advanced waste treatment in 1968 inventory

   D - Updated 1972 EPA inventory in Figure 1



1968



1972

MUNICIPAL WASTEWATER TREATMENT AND DISPOSAL METHODS

FIGURE 1

(EPA INVENTORY)

4. "Secondary" Treatment Previously Always Indicated Satisfactory Treatment. Many Secondary Treatment Plants Now No Longer Adequate.

A - Lack of proper operation and control

B - Operating at more than design capacity

C - Inadequate plant design

D - Changes in wastewater characteristics

E - Changes in wastewater flow

F - Changes in treatment requirements

5. Basic Categories of Wastewater Treatment Facilities

A - Primary treatment

(1) Screening for removal of floating objects

(2) Comminutor for cutting and shredding of large solids

(3) Clarifier or sedimentation basin to remove settleable solids and portion of suspended solids

(4) Chlorination for disinfection

(5) Approximate total removal efficiencies

5 day BOD: 30-40%

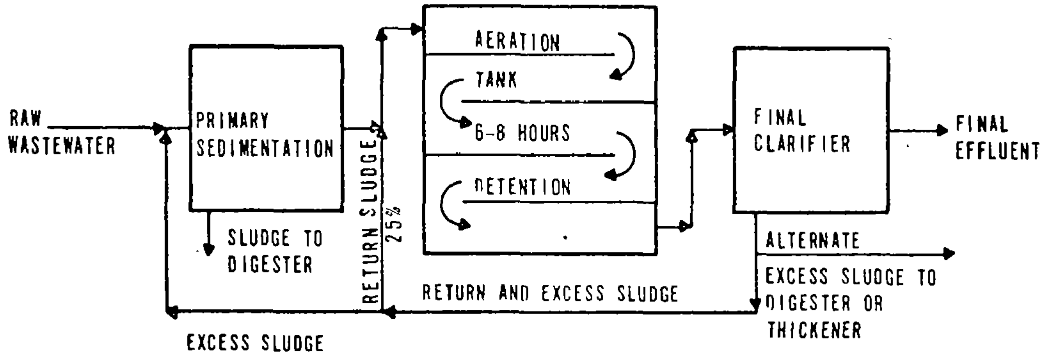
Suspended solids: 50-60%

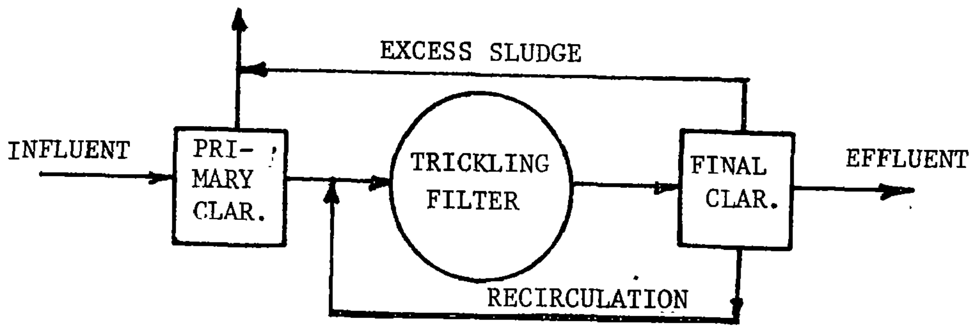
(6) Primary treatment is inadequate

B - Secondary Treatment

(1) Screening, comminution, primary clarification and disinfection as in primary treatment

CONVENTIONAL ACTIVATED SLUDGE FLOW DIAGRAM





TRICKLING FILTER FLOW DIAGRAM

CONVENTIONAL TREATMENT

FIGURE 2

(2) Biological treatment process

(a) Trickling filter

(b) Activated sludge

1) Conventional

2) Step-aeration

3) Extended aeration

4) Contact stabilization

(c) Secondary clarifier or sedimentation basin

(d) Approximate total removal efficiencies

5 day BOD: 85-95%
Suspended solids: 70-95%
COD: 50-80%
Coliform bacteria: 90-98%

C - Oxidation Ponds (Stabilization Ponds, Lagoons)

(1) Aerobic and anaerobic

(2) Long detention periods (3 to 30 days)

(3) Require large land areas

D - Advanced or "Tertiary" Wastewater Treatment

(1) Terms are confusing - "advanced" may be more reliable secondary or greater than secondary

(2) Provide for removal of nutrients

(a) Phosphorus

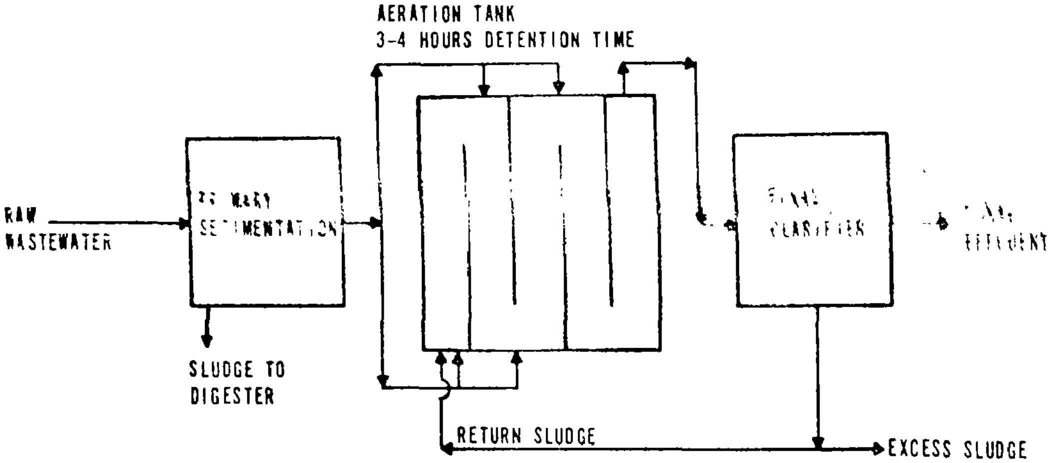
(b) Ammonia nitrogen

(3) Higher degrees of organics removal

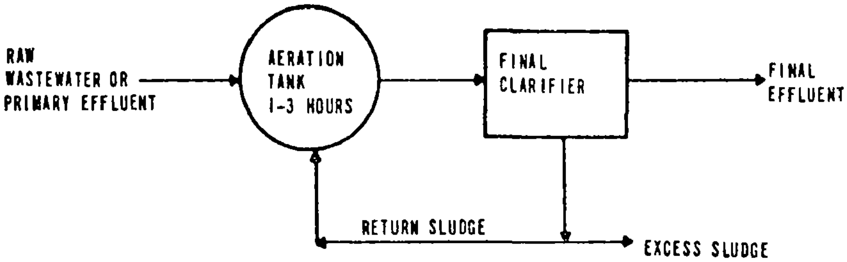
(a) Suspended solids

(b) Dissolved organics

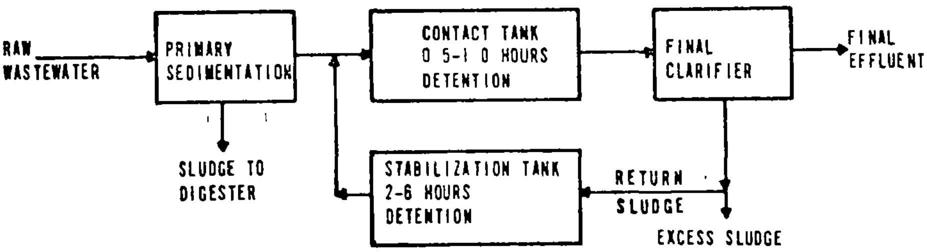
STEP AERATION FLOW DIAGRAM



COMPLETELY-MIXED FLOW DIAGRAM

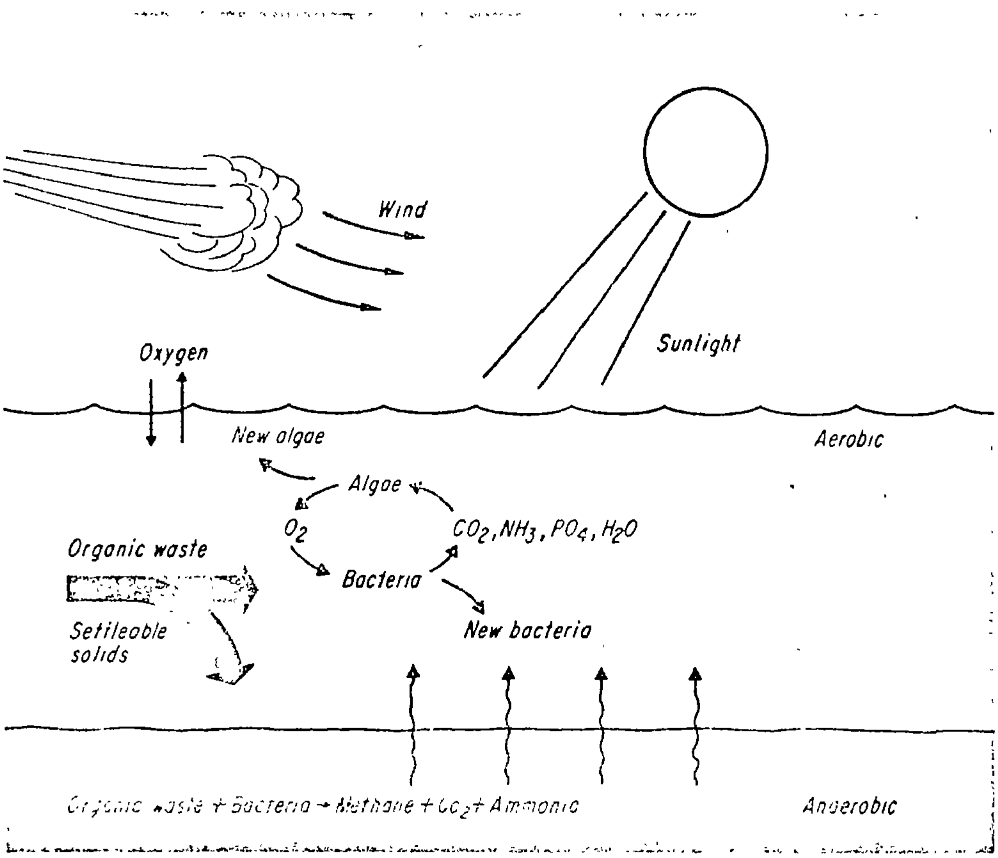


CONTACT STABILIZATION FLOW DIAGRAM



ACTIVATED SLUDGE VARIATIONS

FIGURE 3



Oxidation ponds need sunlight, wind, bacteria and algae

An oxidation pond is a large shallow lagoon or basin with waste water added at one point and stabilized effluent removed at another. Depth is usually 2 to 4 ft although 10 to 20 ft also works well.

Metabolic cycle, left, shows how bacteria aerobically metabolize organic matter to produce more bacteria, CO_2 and water. Algae takes energy from sunlight and grows by consuming CO_2 produced by bacteria, water, inorganic minerals.

Oxygen released as a side reaction is not enough to satisfy bacteria demand unless the waste water contains additional algae nutrients such as carbonates or bicarbonates not connected with the waste metabolism. Needed oxygen also comes from the atmosphere as wind action breaks the pond surface and sets up hydraulic currents that mix the contents and expose fresh surfaces to air.

Oxidation pond, left, is called a facultative type since it has an anaerobic layer at the bottom. If the aerobic layer disappears, methane and other gases will be released. Eventually the pond must be dredged to remove settled inert matter and microorganisms.

ILLUSTRATION OF OXIDATION POND OPERATIONS

FIGURE 4

(FROM POWER SPECIAL REPORT)

(4) Greater reliability

(a) Shock loads

(b) Industrial discharges

(5) Greater reduction of total oxygen demand

(6) Greater flexibility

6. New Water Quality Requirements and Standards

A - Federal Water Pollution Control Act Amendments of 1972

(1) Infiltration/Inflow control

(2) "Best practicable technology" by July 1, 1977
(Effluent limitations based on secondary treatment)

(3) "Best available technology" by July 1, 1983

(4) National goal to eliminate discharge of pollutants

B - Improved effluent quality to meet non-regulatory requirements

(1) Reduction of eutrophication

(2) Improve quality of water supply

(3) Trends toward water re-use

7. General Upgrading Possibilities

A - Addition of secondary treatment components to existing primary plant

B - Common changes to existing secondary treatment facilities

(1) Infiltration/Inflow reduction

(2) Flow equalization

(3) Chemical clarification

C - Modification of basic trickling filter plants

(1) Change from low-rate to high-rate

(2) Change from single stage to two stage

(3) Add activated sludge to high rate system

(4) Add roughing filter to high rate system

D - Modification of basic activated sludge plants

(1) Change from conventional to step-aeration

(2) Change from conventional to contact-stabilization

(3) Change from conventional to complete-mix

(4) Conversion to oxygen aeration

E - Other basic upgrading or polishing methods

(1) Chemical treatment

(2) Tube settlers

(3) Polishing lagoons

(4) Microscreening

(5) Media filtration

(a) Sand

(b) Dual media

(c) Multi-media

(6) Carbon adsorption (conversion to physical-chemical treatment)

(7) Pre- and post-aeration

(a) Diffused

(b) Mechanical

F - Upgrading sludge handling facilities

(1) Thickening

(2) Digestion

(3) Dewatering

G - Operation and maintenance

(1) Instrumentation

(2) Manpower

Treatment Process	Approximate % Reduction			
	BOD_5	Suspended Solids	Coliform Bacteria	COD
Pre-screening	5-10	2-20	10-20	5-10
Plain sedimentation	25-40	40-70	25-75	20-35
Chemical precipitation	50-85	70-90	40-80	40-70
Trickling filtration preceded and followed by plain sedimentation	50-95	50-92	90-95	50-80
Activated sludge preceded and followed by plain sedimentation	55-95	55-95	90-98	50-80
Wet burning (Extended Aeration)	90-95	70-95	90-98	50-80
Stabilization ponds	90-95	80-90	95-98	70-80
Chlorination of effluent of biological treatment plant	-	-	98-99	-

APPROXIMATE EFFICIENCIES OF CONVENTIONAL
TREATMENT PROCESSES

TABLE 1

FLOW EQUALIZATION

FLOW EQUALIZATION

1. Introduction

    a. Flow equalization is the method of dampening or equalizing the diurnal flow variations.

    b. Achieves a constant or nearly constant flow of pollution load to downstream treatment processes.

    c. Interest in flow equalization for municipal treatment has increased recently due to:

        - Strict water quality standards

        - Elimination of plant bypassing

        - Increased removal efficiencies when processes are operated at or near steady-state

2. Advantages of Flow Equalization:

    a. Diurnal flow variations eliminated

    b. Nearly constant flow rate provided to treatment processes

    c. Distribution of shock loads of toxic materials

    d. Increased reliability of treatment efficiencies

    e. Optimization of process operation possible

    f. Savings in Federal and/or State fines for violation of effluent standards

3. Sizing of Equalization Basins

    a. Plot hourly flow variation

    b. Superimpose the inflow mass diagram of hourly fluctuations for the typical daily wastewater flow

        - Accumulate hourly flows

        - Convert to equivalent volumes

    c. Draw a straight line from origin to end point on inflow mass diagram

    d. The slope of line A represents average pumping rate from equalization basin to downstream units (example is 10,000 gal/hour)

e. Draw straight lines B and D parallel to A and tangent to the inflow mass diagram at maximum and minimum points, E and F.

f. Vertical distance between lines B and D is minumum required equalization volume (example is 30,000 gal or approximately 12.5% of average daily flow).

g. Additional sizing of basin should include:

- Anaerobic digester supernatant

- Sludge dewatering filtrate

- Other return flows to head of plant

- These flows can create shock loads and reduce efficiency

  . COD's from 10,000 - 20,000 mg/l
  . Ammonia up to 1,000 mg/l

h. For the example, total equalization volume should be:

Source	% Flow
Flow equalization	12.5
Digester supernatant	0.3 - 1.4
Sludge dewatering filtrate	0.5 - 1.5
Total	13.3 -15.4

i. Maximum volume to equalize typical flows depend on magnitude of infiltration and extraneous surface water entering collection system.

- Examine plant's past flow records

- Evaluate regulatory elimination of bypassing

- Consider economics to equalize extreme peaks of wet-weather flow

j. Successful operation of equalization basins should include:

- Completely mixed basins (prevents deposit)

- Use of diffused air or mechanical surface aerators (prevents septicity)

4. Design and Costs Estimates

a. Capital cost estimates, not including land costs, contingencies, engineering design and bonding are:

Plant Size MGD	Capital Costs $1,000's
1	210
3	450
5	600

ENR Index 1,500

b. Costs were based on typical flow diagram and 15% of treatment plant daily capacity.

c. Basins may be constructed as

- Shallow-lined lagoons
- Conventional circular concrete tanks
- Conventional rectangular tanks

d. Select basin dimensions to avoid interference between aerators and to minimize fluctuations in basin water level

e. Minimum basin size of 15 to 50 feet square and minimum depth of 5 to 8 feet

f. Use compartmented basins to avoid large volumes of dead storage

- Two compartments of a four-compartment basin for diurnal flows
- All four compartments for wet-weather peaks

g. Maintain minimum water level to protect floating surface aerators

- Compartmentalization
- Low-level controls on pump and aerator

h. Suspended solids concentrations of approximately 200 mg/l require 0.02 to 0.04 hp/1,000 gallons of maximum storage volume

i. To prevent septicity, supply oxygen to the equalized flow at approximately 15 mg/l/hr. Mechanical aerators furnish mixing and aeration (3-4 lbs O_2/hp/hr)

j. Design considerations:

- Earthen lagoons when ground conditions and space are satisfactory, reduces cost
- Reinforced concrete basin when lagoons are not feasible
- Anchor floating aerators to periphery of basin and permit fluctuation with water level

- Variable-speed centrifugal pumps

k. Two types of flow equalization basins

- Flow-through
- Side-line

l. Volume requirements are identical

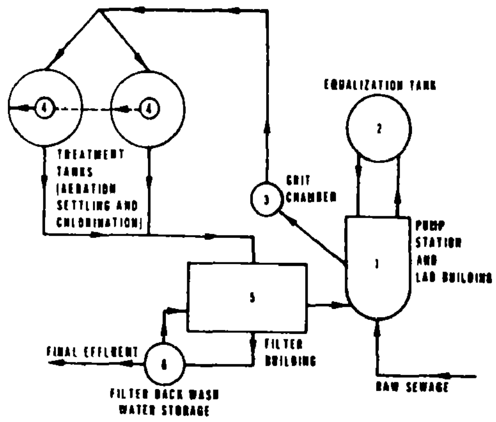
- Flow-through type provides better mixing or mass flow dampening
- Side-line type retains flow in excess of average but minimizes pumping requirements

5. Case History

a. Flow equalization utilizing side-line basin

b. Performance data for a five month period at Walled Lake-Novi plant included

WALLED LAKE NOVI WASTEWATER TREATMENT PLANT 2 1 mgd

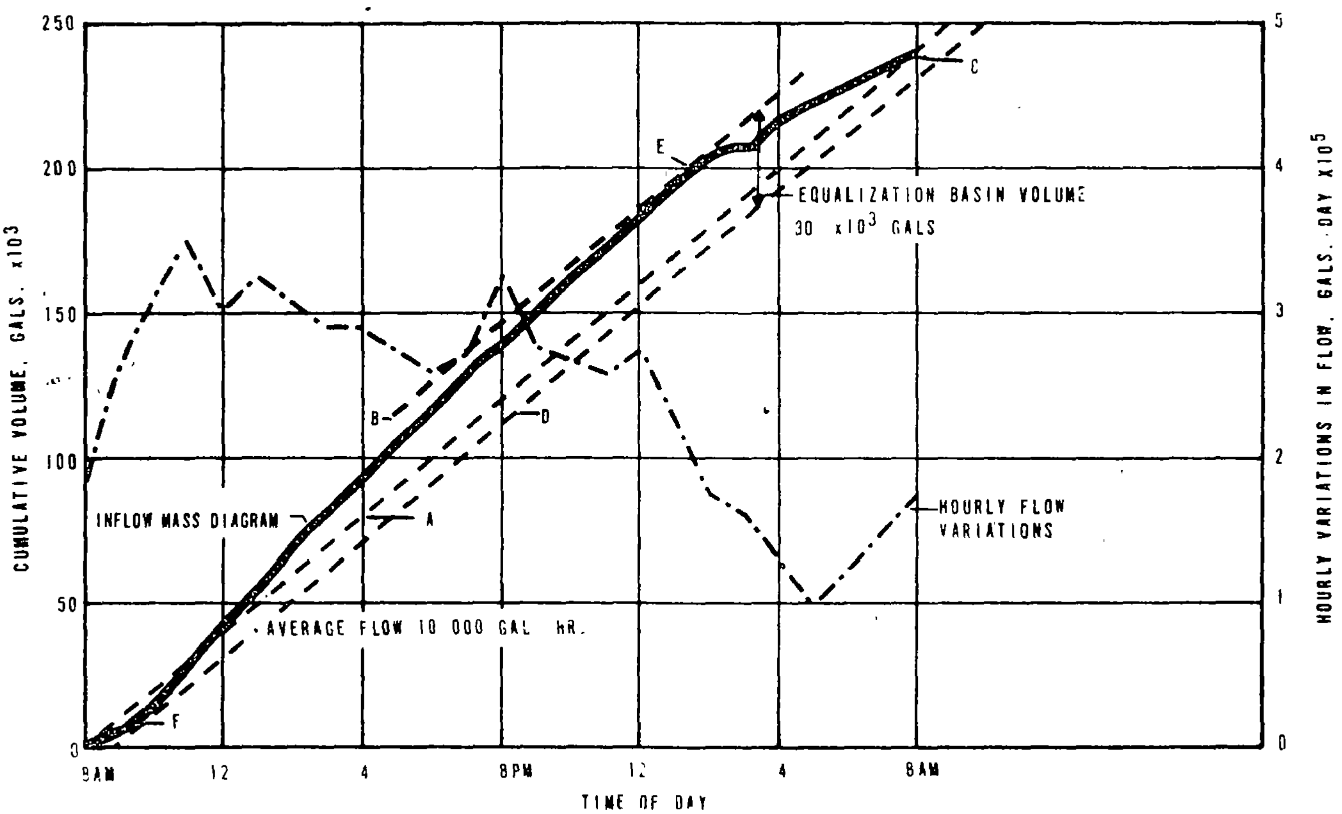


Walled-Lake Novi Wastewater Treatment Plant 2.1 mgd

Performance Data - Walled Lake Novi Plant

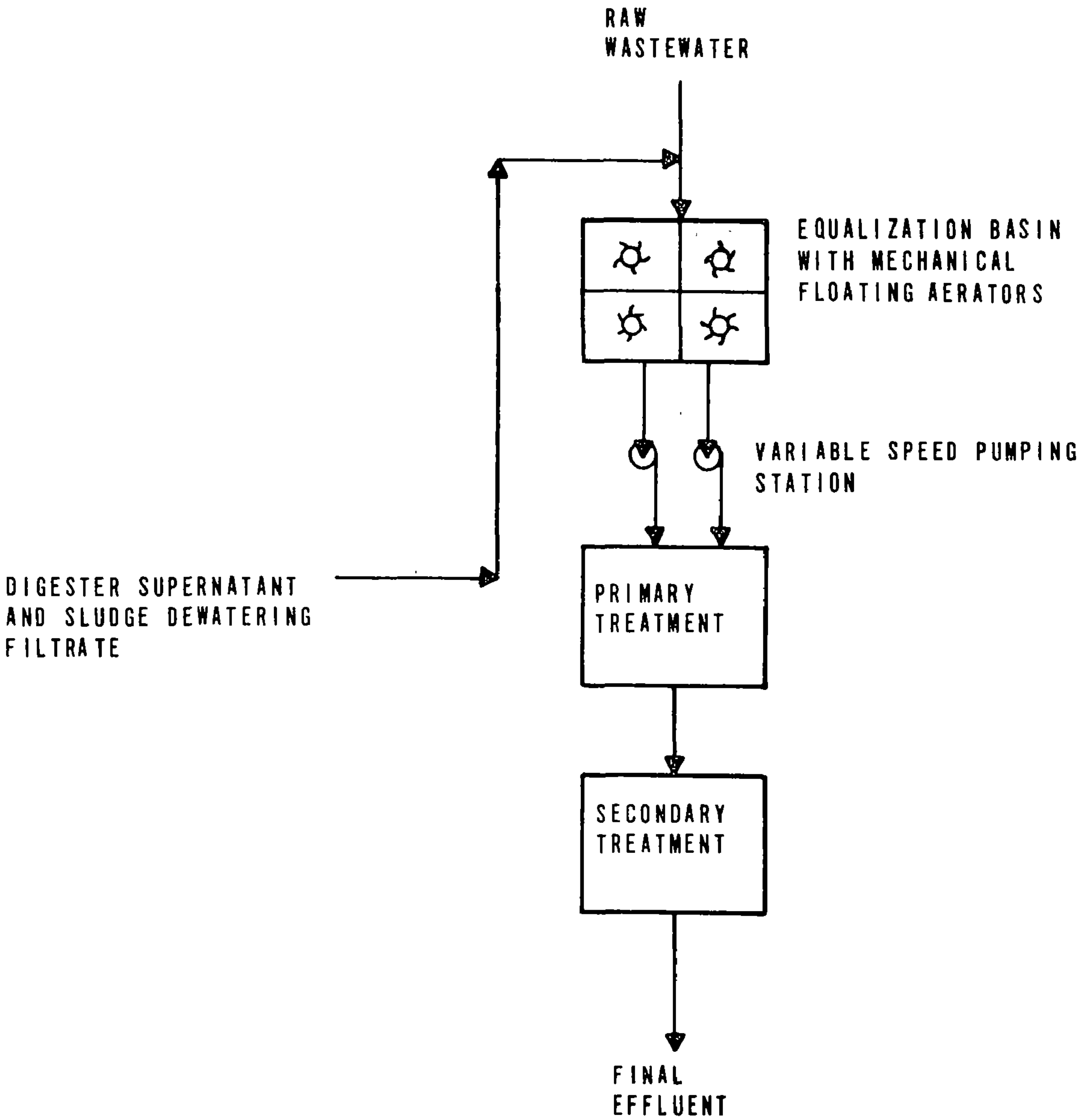
PERFORMANCE DATA
WALLED LAKE-NOVI PLANT

MONTH	REMOVAL %		EFF	
	BOD	SS	BOD	SS
SEPT. 71	91.6	96.5	6	4.1
OCT. 71	98.6	98 2	2	3 4
NOV. 71	98.6	93.7	2 3	18 7
DEC. 71	98.8	92 3	2 3	19.0
JAN. 72	98.2	96.1	3 5	9.0



FIGURE

EQUALIZATION REQUIREMENTS FOR A TYPICAL FLOW



FIGURE

SCHEMATIC FLOW DIAGRAM OF EQUALIZATION FACILITIES

EXPANDING PRIMARY TREATMENT FACILITIES

EXPANDING PRIMARY TREATMENT FACILITIES

1. Introduction

- Primary treatment facilities are rapidly becoming a thing of the past

- The 1972 Water Bill dictates a minimum of secondary treatment for all municipal wastewater treatment operations

- The local decision to make is either:

  . discharge into regional plant

  . expand existing primary facility to meet new effluent standards

  . build new plant

2. Alternates to Consider for Expansion

- The consultant should evaluate various treatment alternatives and select the appropriate one to meet all objectives under consideration

- Treatment alternatives:

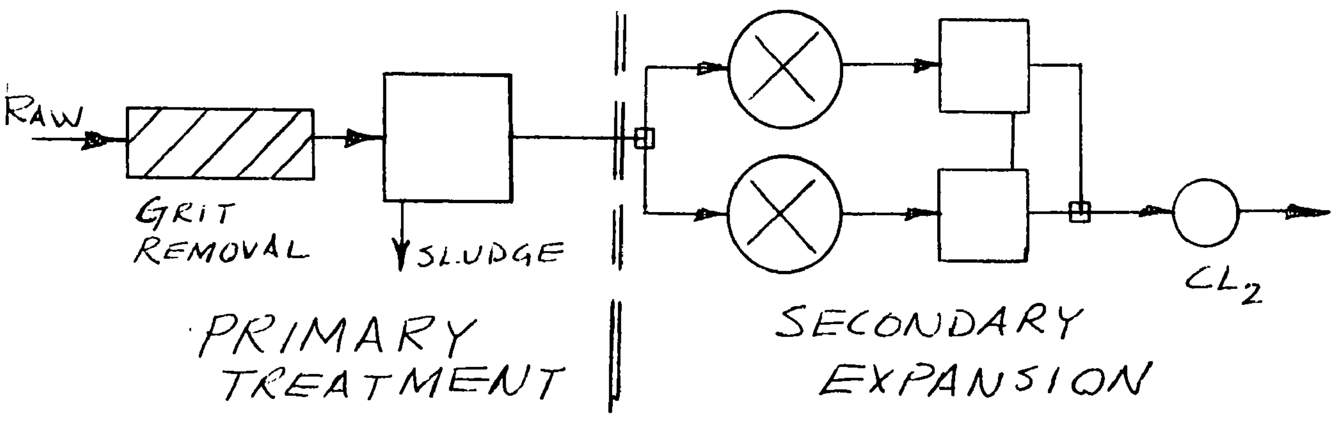
  . trickling filters

  . activated sludge

  . lagoons

3. Trickling Filter

- The addition of trickling filter to a primary plant can increase removal efficiencies up to 85-90% of BOD_5.



- Typical flow scheme
  - . single stage
  - . two-stage
- Advantages
  - . low initial cost
  - . economic operation
- Types

Type	Organic loading 16 BOD/1,000 cu.ft./day	Hydraulic loading million gal/acre/day
low-rate	10 - 20	2 - 4
intermediate	15 - 30 *	4 - 10
high-rate	up to 90 *	10 - 30
	* includes recirculation	

  - . Super-rate trickling filter using synthetic media can accommodate hydraulic loading of 150 mgad.
- Performance factors
  - . Wastewater characteristics - vary
  - . Filter media - rock or synthetic
  - . Filter depth - low-rate 5-7 ft.
- high-rate 3-6 ft.
  - . Recirculation - 0.5 to 4.0
  - . Hydraulic and organic loading
  - . Ventilation
  - . Temperature of wastewater

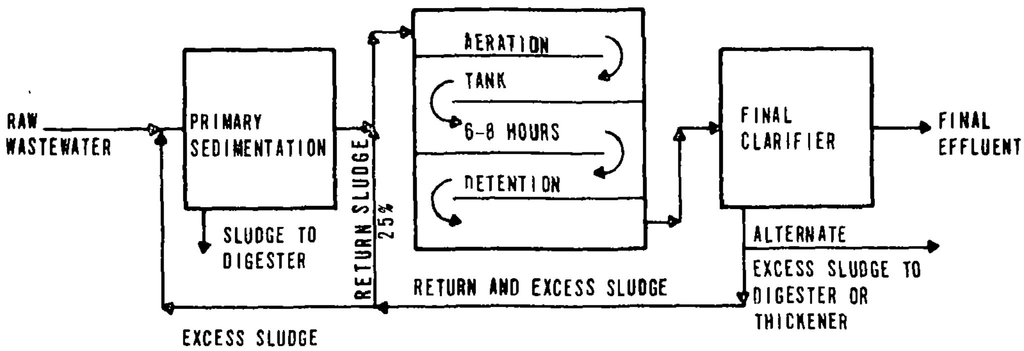
4. Activated Sludge

- The addition of activated sludge to an existing primary treatment plant can increase removal efficiencies to 90-95% BOD_5.

- Advantage . most versatile and efficient biological treatment process

- Types

Conventional



- Aeration time 6 - 8 hrs.

- Return sludge 25% - min. 15% max. 75%

- BOD leadings approximately 35#/1000 ft^3/day

- Air requirements 700-1000 ft^3/#BOD removal

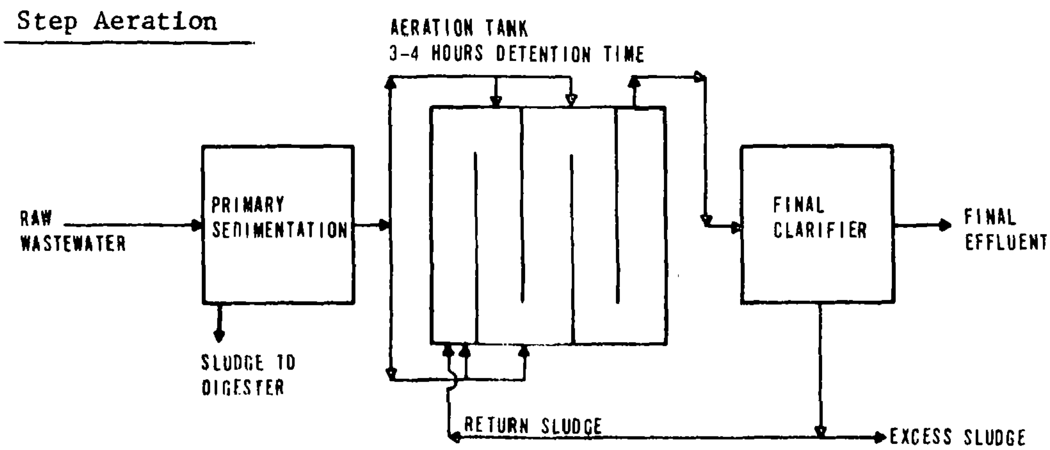
- High initial oxygen demand in head of aeration tank

- Final clarifier subjected to high solids loading

- Increase recirculation with increased BOD loading

- Lack of operational stability with variations in hydraulic and organic loadings.

. Step Aeration



- Aeration time 3-4 hrs.

- Return sludge 50% min. 20% max. 75%

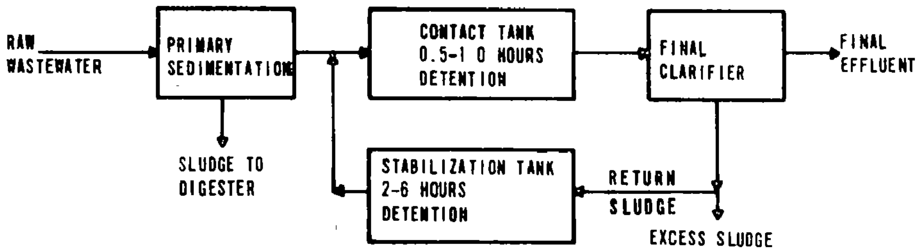
- BOD loading - approximately 50 #/1000 ft^3/day

- Distributes organic loading more uniformly over length of aeration tank

- Lower solids loading to final clarifiers

- Air requirements - 500-700 ft^3/#BOD removed

. <u>Contact **Stabilization**</u>



- Aeration time:
  - contact tank 0.5 - 1.0 hrs.
  - stabilization tank 2-6 hrs.

- Return sludge approximately 40%

- BOD loadings approximately 100 #/1000 ft^3/day

- BOD removed in short contact time by biological flocculation, adsorption and enzyme-complexing

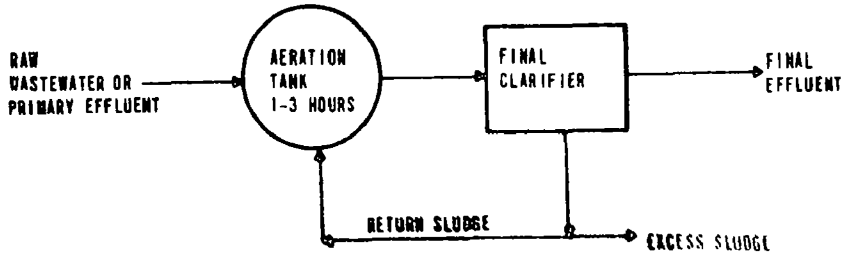
- Air requirements - 750 ft^3/#BOD Removed

- Concentrated sludge is stabilized in another aeration tank

- Stabilization tank offers biological buffering capacity to handle greater shock and toxic loadings

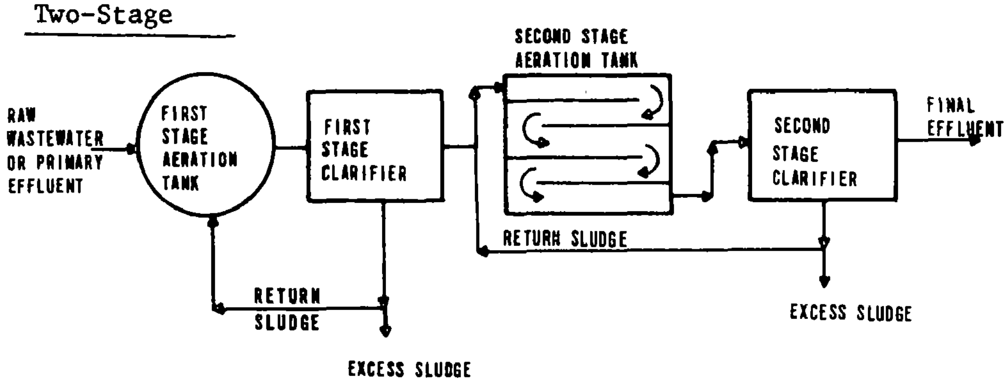
- Stabilization time is function of contact time, temperature and strength of waste

. Complete Mixed



- Aeration time 1-3 hrs.
- BOD loading approximately 80#/1000 ft^3/day
- Air requirements - 600 ft^3/#BOD removed
- Influent waste and recycled sludge are introduced uniformly throughout aeration tank
- Operational stability for slug loads of industrial waste

. Two-Stage



- Two separate activated sludge processes operating in series
- Develops two specialized microbial populations
- Competitive only when nitrification is required.

. Oxygen Aeration

- Utilizes pure oxygen instead of air in the activated sludge process

5. Lagoons

- The addition of lagoons or oxidation ponds to an existing primary plant can meet secondary treatment requirements in certain cases
- 80-95% waste organic matter is converted to algae
- Economical treatment alternative when land is available
- Types
  - High rate aerobic ponds
    - shallow depth 12-18 inches
    - intermittently mixed
    - aerobic bacterial oxidation and algal photosynthesis
    - organic loading range

      60 - 200 lbs BOD_5/acre/day
    - BOD_5 removal 80-95%
  - Facultative Ponds
    - deeper ponds 3-8 feet
    - two zones
      - aerobic surface zone
      - anaerobic bottom layer
    - organic loading range 15-80 lbs BOD_5/acre/day
    - BOD_5 removals 70-95%
  - Anaerobic Ponds
    - high organic loadings 200-1000 lbs BOD_5/acre/day
    - anaerobic condition prevails
    - BOD_5 removals 50-80%
    - follow with aerobic or facultative ponds

- Tertiary Ponds

    - polishing pond after secondary treatment (trickling filter or activated sludge)

    - reduces settleable solids, BOD_5, fecal organisms and ammonia

    - organic loadings usually less than 15 lbs BOD_5/acre/day

- Aerated Lagoons

    - aerobic stabilization by air diffusion or mechanical aeration

    - BOD_5 removals 90-95%

NEW TECHNOLOGY IN WASTEWATER TREATMENT

NEW TECHNOLOGY IN WASTEWATER TREATMENT

1. Conventional Methods of Wastewater Treatment Usually Considered As Biological Treatment

   A - Activated Sludge

   B - Trickling Filters

   C - Oxidation Ponds

2. Major New Advances in Municipal Wastewater Treatment

   A - Pure oxygen activated sludge (UNOX system developed by Union Carbide with EPA - Other companies now marketing variations

   (1) First successful full-scale demonstration at Batavia, N. Y.

   (2) Characteristics of system

   (a) Utilizes covered and staged oxygenation for contact of oxygen gas and mixed liquor

   (b) High purity oxygen (over 90%) enters first stage and flows co-currently with wastewater

   (c) Slight pressure (2-4 inches water column) to maintain control and prevent back mixing

   (d) Low power requirements

   (e) Mass transfer and mixing within each stage

   1) Surface aerators

   2) Submerged turbine rotating sparge system

   (f) Good sludge settling characteristics

   (g) Dissolved oxygen concentration maintained at approximately 5-8 mg/l

(3) Design criteria and considerations

(a) "Food" to biomass ratio (lbs BOD/lbs MLVSS) normally .5 to .8

(b) 1.3 - 1.8 lbs oxygen per pound of BOD removed

(c) Mixed liquor suspended solids 6,000 - 8,000

(d) 160 - 200 lbs BOD_5/1000 cu. ft.

(4) Oxygen generation

(a) On site liquid oxygen storage

(b) On site generation

1) Pressure swing adsorption (PSA)

2) Cryogenic generation

(5) Advantages of oxygen activated sludge

(a) High MLSS concentrations

(b) Low detention periods

(c) Low quantities of excess biological sludge

(d) Improved sludge settling characteristics

(e) Reduced power requirements

(f) High dissolved oxygen levels all stages

(g) Low waste gas volume

(6) Middlesex County, N. J. Oxygen-activated sludge design

(a) 120 mgd average flow; high strength (382 mg/1 BOD_5); 88% total BOD_5 removal

(b) Total cost oxygen: $83.58 million
Annual cost: 7.39 million
Comparable Air: $104. million (comp. mix.)
Annual cost: 8.29 million

(7) Westgate Plant, Fairfax County, Va.

OXYGEN PROCESS FLOW SHEET

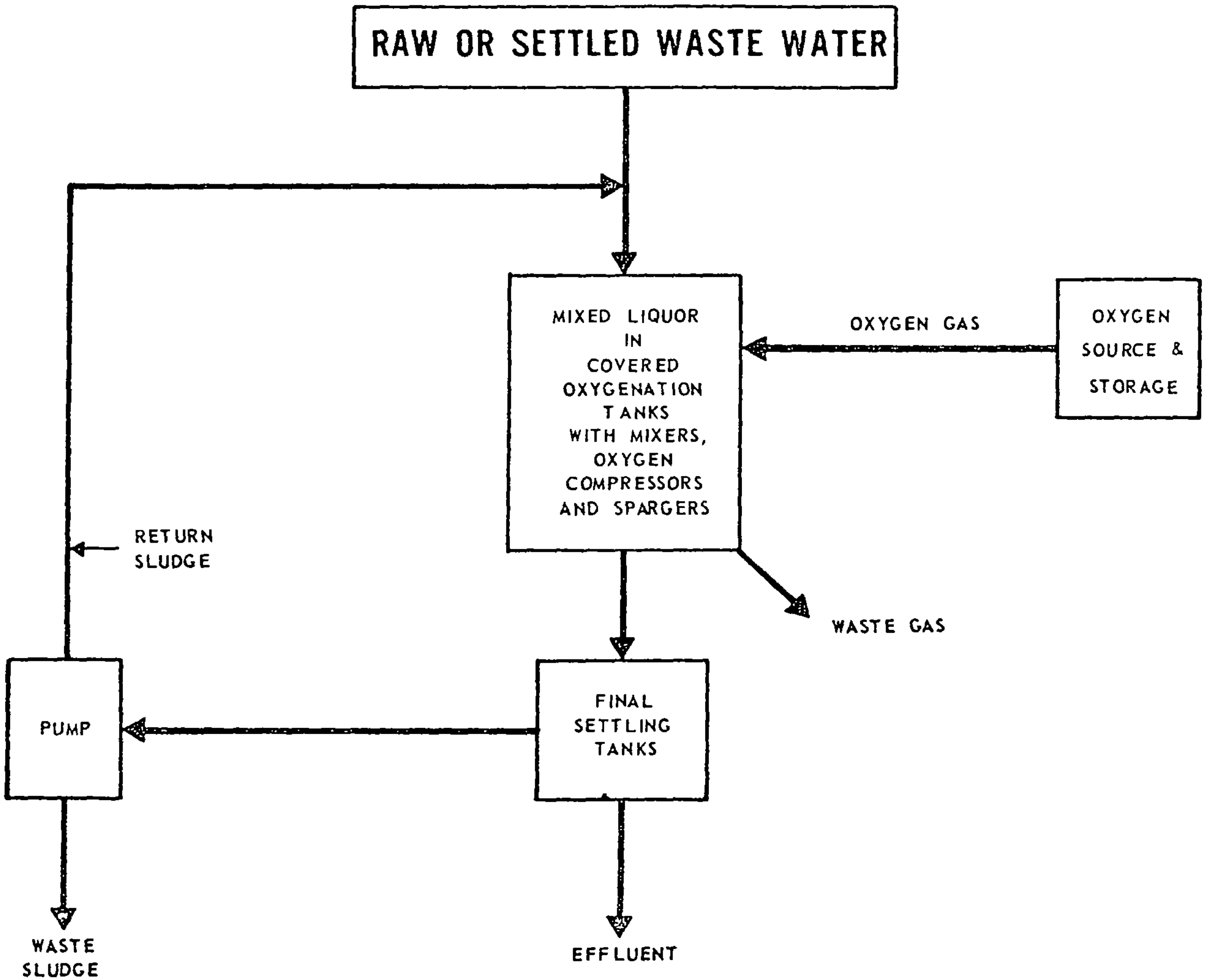
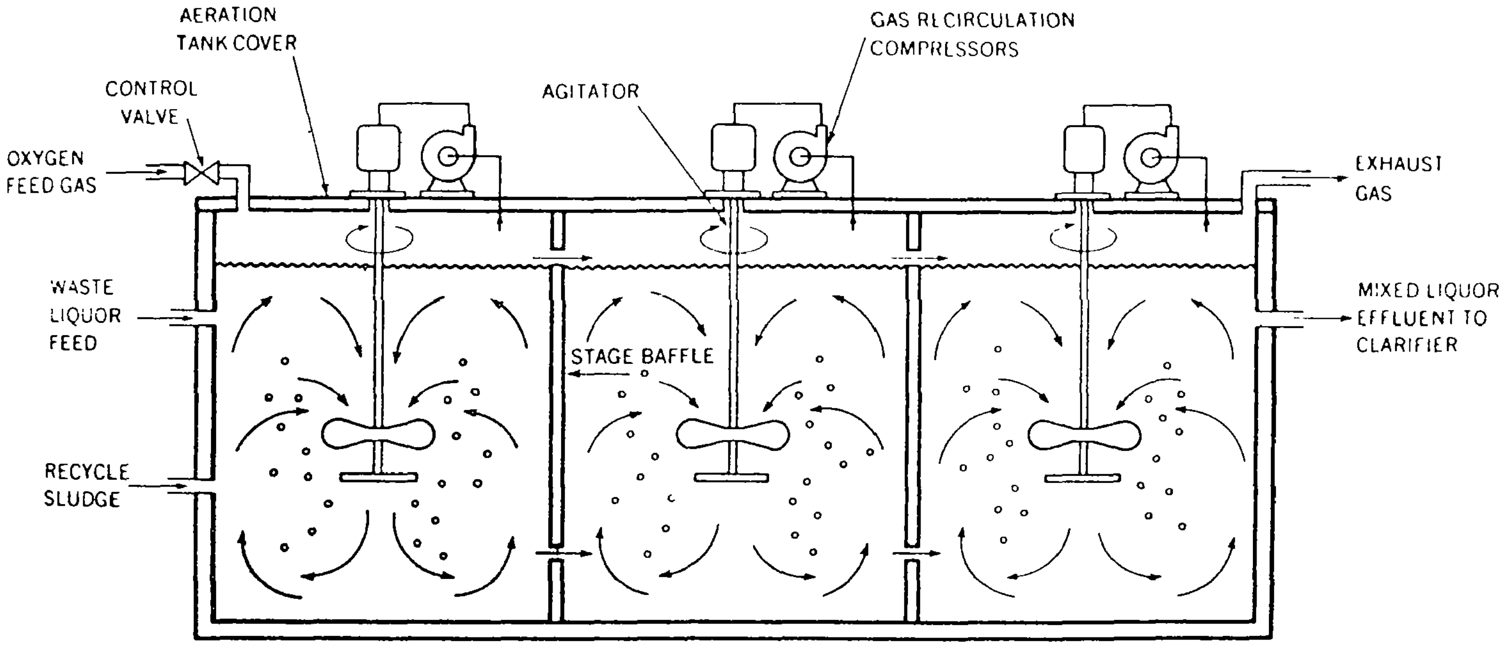
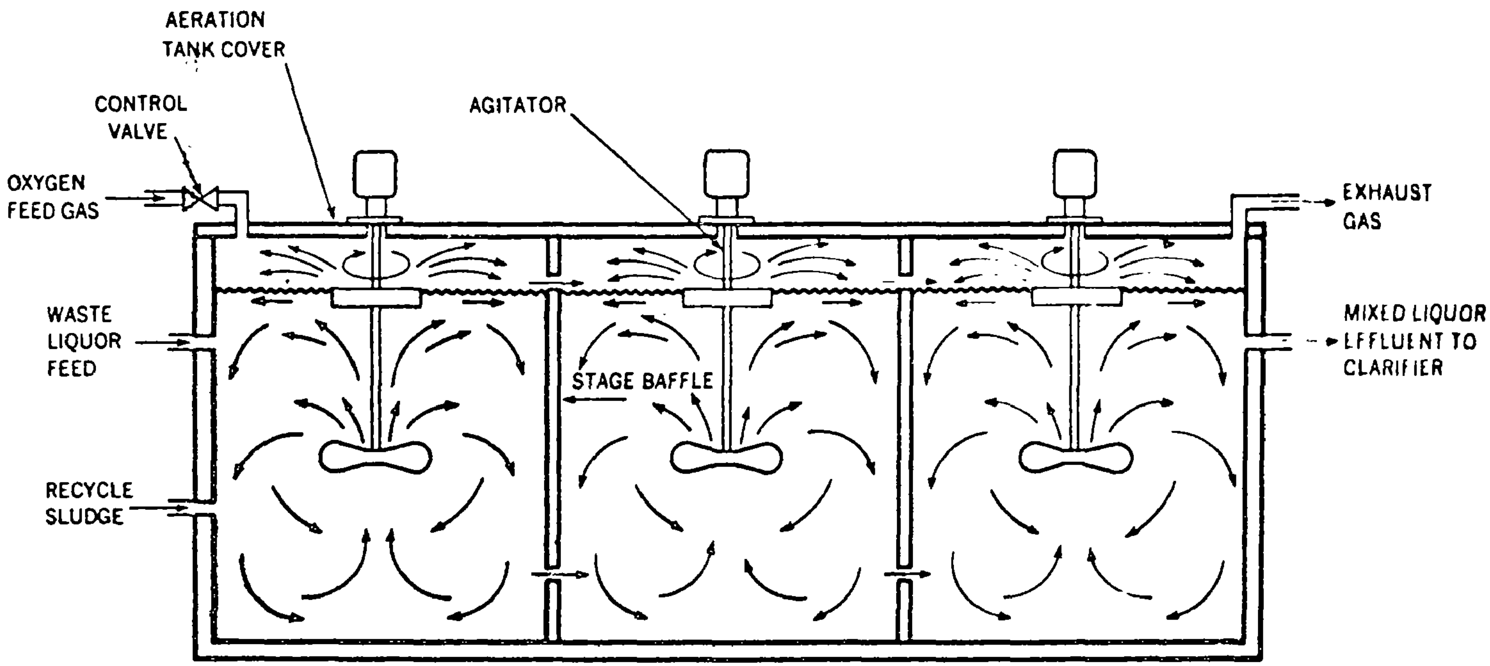


FIGURE 1



SCHEMATIC DIAGRAM OF OXYGEN SYSTEM WITH ROTATING SPARGER

FIGURE 2



SCHEMATIC DIAGRAM OF OXYGEN SYSTEM WITH
SURFACE AERATOR

FIGURE 3

SETTLING CHARACTERISTICS FOR
AIR AND OXYGEN BIOMASS
(ISR VS CONCENTRATION)

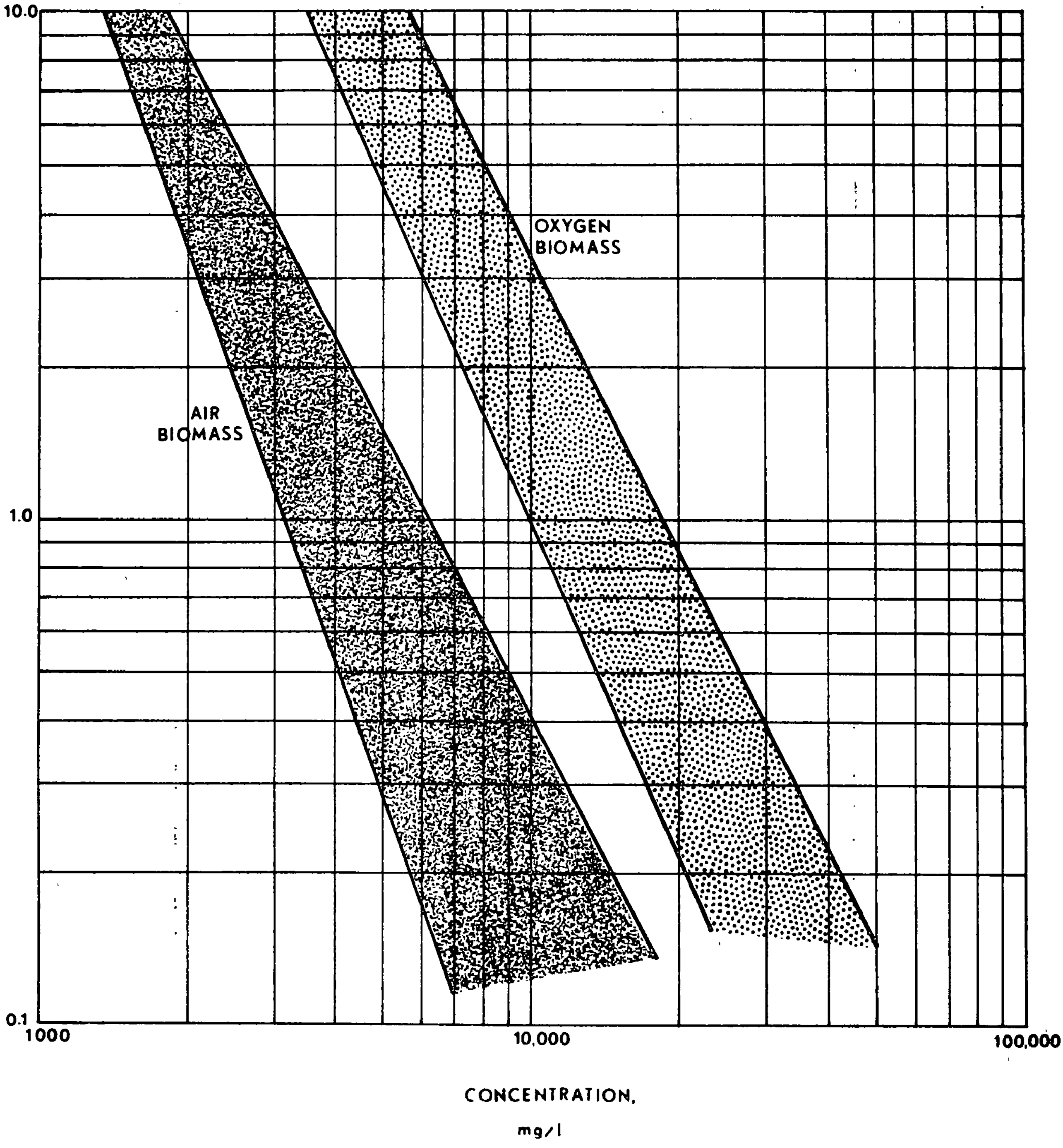
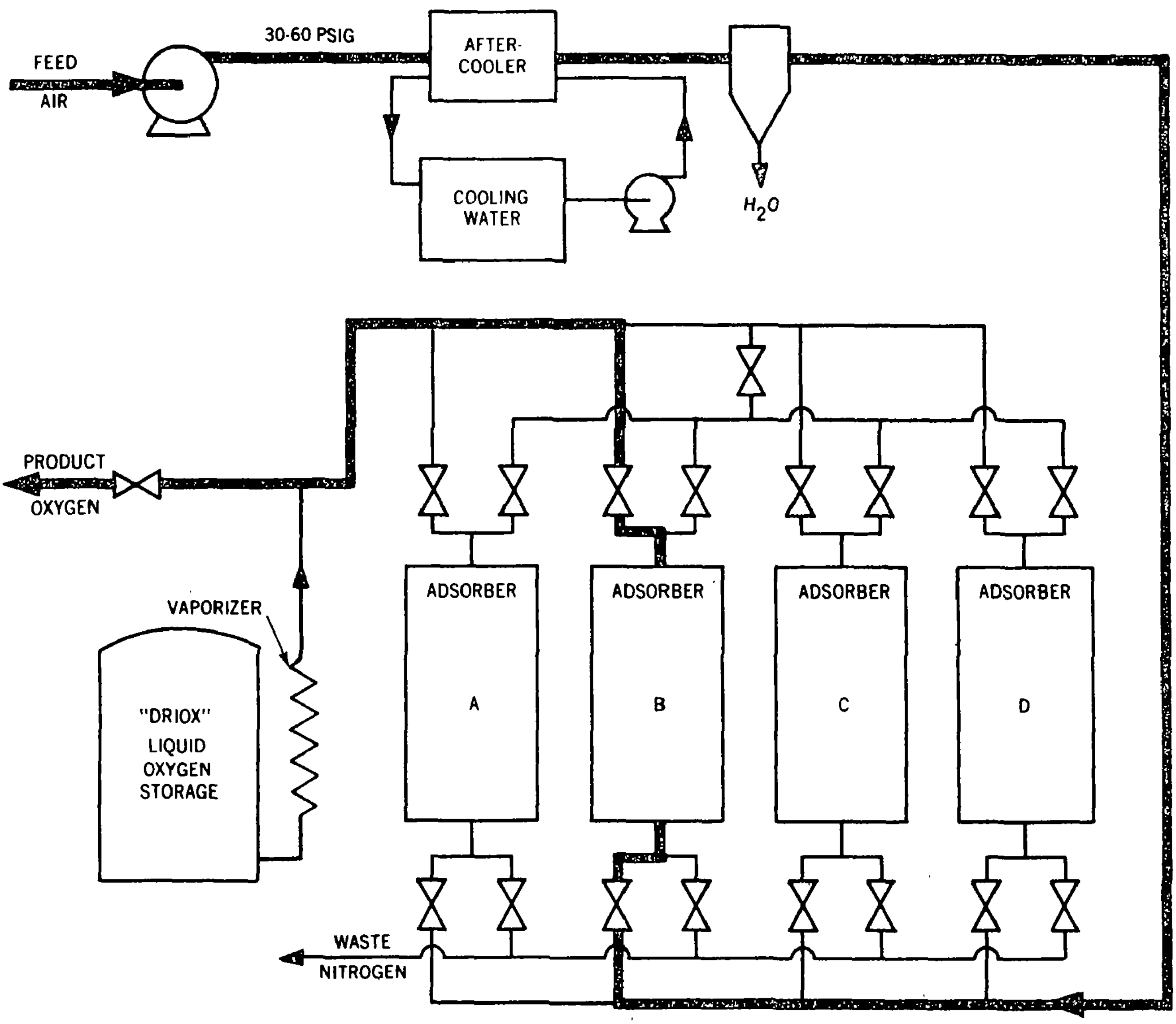


FIGURE 4

FLOW DIAGRAM OF A PSA OXYGEN GENERATING SYSTEM



PRESSURE SWING ADSORPTION UNIT

FIGURE 5

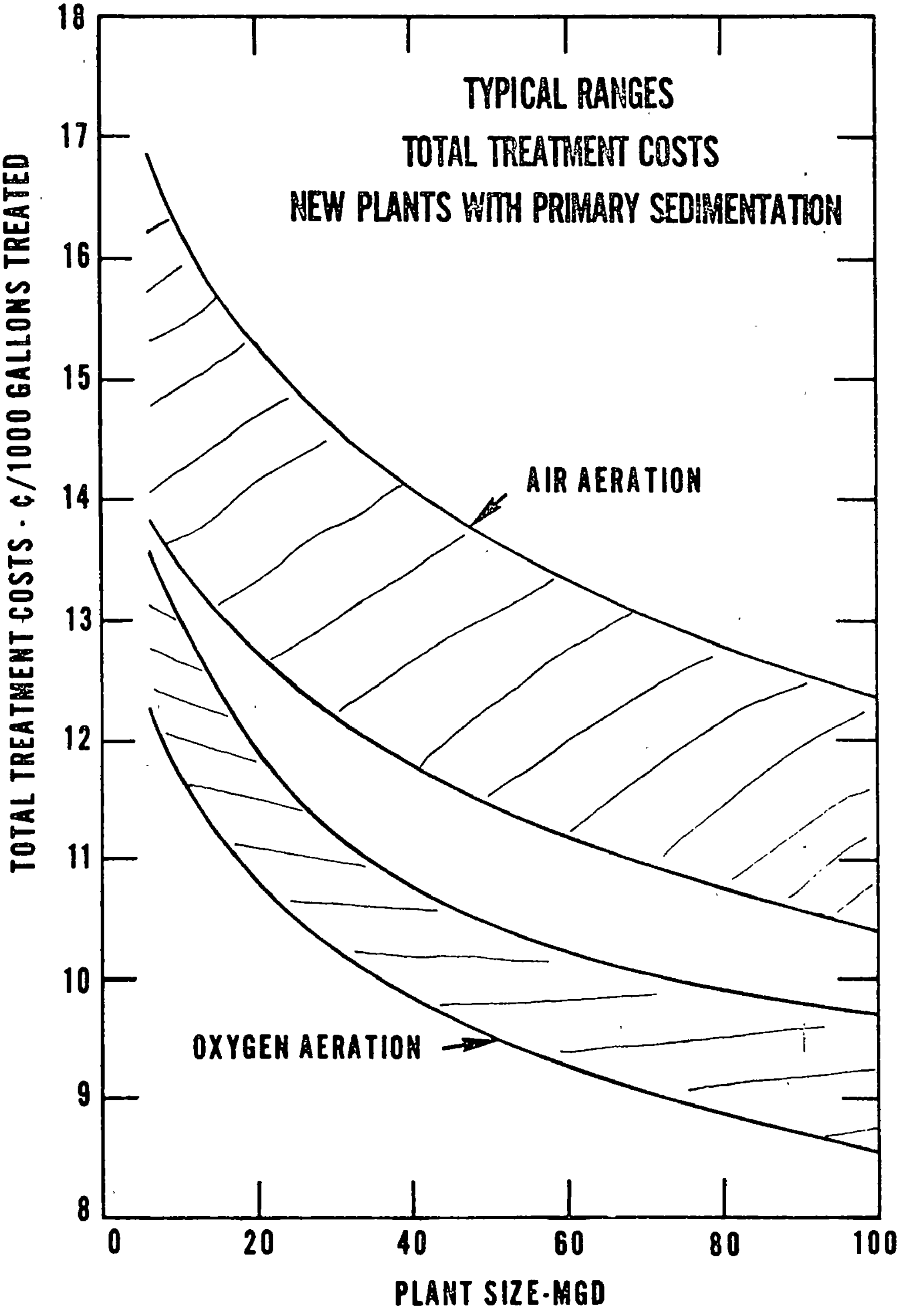

TYPICAL RANGES
TOTAL TREATMENT COSTS
NEW PLANTS WITH PRIMARY SEDIMENTATION
AIR AERATION
OXYGEN AERATION
TOTAL TREATMENT COSTS - ¢/1000 GALLONS TREATED
18
17
16
15
14
13
12
11
10
9
8
0
20
40
60
80
100
PLANT SIZE-MGD

FIGURE 6

WASTEWATER TREATMENT FACILITIES, USING OXYGEN AERATION, UNDER DESIGN, CONSTRUCTION OR OPERATION (PARTIAL LIST)

LOCATION	DESIGN FLOW (MGD)
Detroit, Mich.	300
Newtown Creek, N. Y. City	20
Speedway, Ind.	8
Louisville, Ky.	105
Wyandotte, Mich.	100
Decatur, Ill.	18
Morganton, N. C.	8
New Rochelle, N. Y.	14
Middlesex County, N. J.	120
Euclid, Ohio	22
Deer Park, Texas	6
Danville, Va.	24
Miami, Fla.	55
East Bay MUD, Calif.	120
Fayetteville, N. C.	16
Hollywood, Fla.	36
Salem, Ore.	16
Jacksonville, Fla.	10
Baltimore, Md.	5
Fairfax County, Va.	12
New Orleans, La.	122
Denver, Colo.	73
Tampa, Fla.	36

FIGURE 7

(a) Interim requirement from 50 percent to 80 percent

(b) Act removals over 90 percent

(c) Equivalent to conventional aeration with 3 times tank volume

(8) Municipalities with oxygen systems under design, construction or operation in figure.

B - Phosphorus Removal

(1) Technology now well established in areas with eutrophication problems

(2) Phosphorus removal in conventional biological systems is poor (20 - 30%)

(3) Phosphorus removal technically and economically feasible by chemical precipitation

(a) Salts of aluminum

(b) Salts of iron

(c) Lime

(4) Chemical dosage to achieve specified degree of removal by jar tests

(5) Chemical precipitation also upgrades performance of plant

(a) Coagulation of suspended solids

(b) Colloidal solids

(6) Chemicals for phosphorus removal can be added:

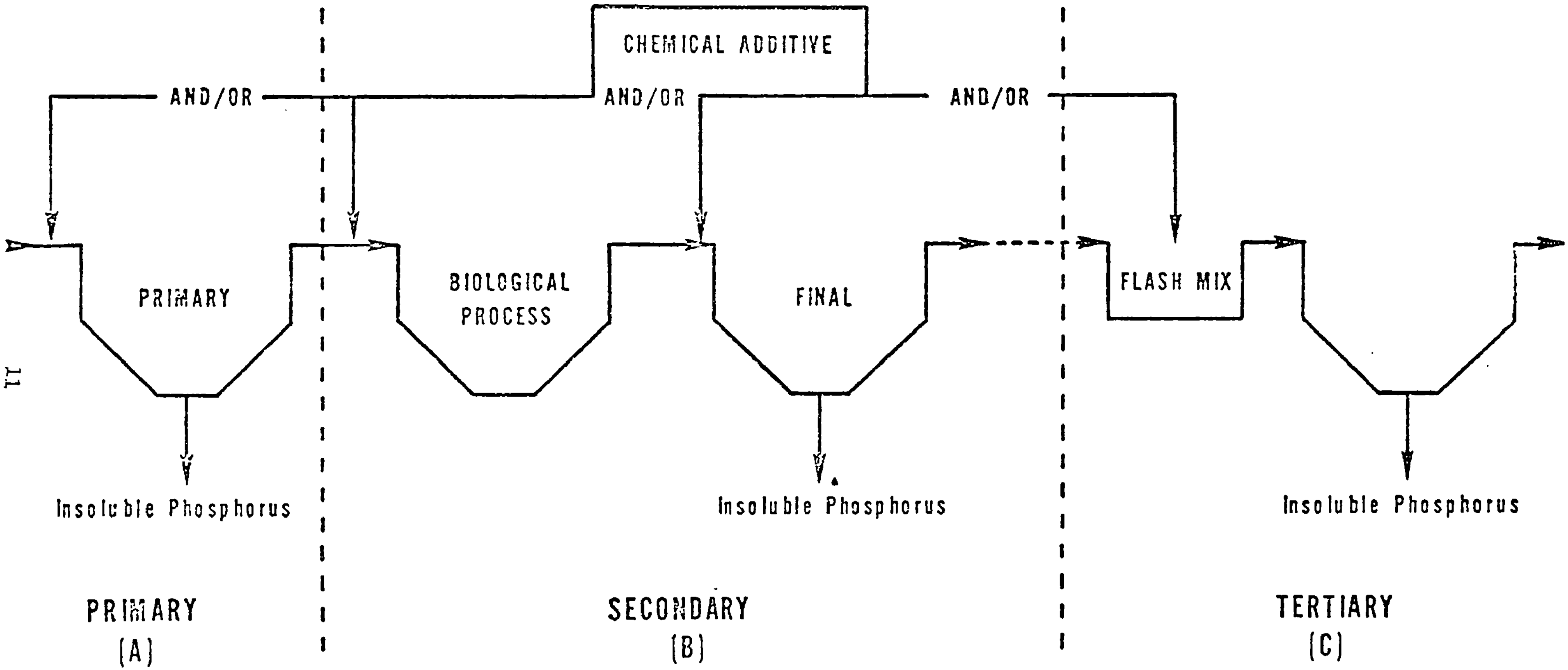
(a) Just before primary tank

(b) In secondary section (biological) with removal in secondary clarifier

(c) In tertiary stage

(7) Advantages and disadvantages of Phorphorus removal in various treatment plant components shown in figure.

(8) Lowest costs for addition in secondary - removals below 1 mg/l are difficult



LOCATIONS FOR CHEMICAL CONTROL OF PHOSPHORUS

FIGURE 8

CHEMICALS FOR PHOSPHORUS REMOVAL

Ferric Chloride	$FeCl_3$
Ferric Sulfate	$Fe_2(SO_4)_3$
Ferrous Chloride	$FeCl_2$
Ferrous Sulfate	$FeSO_4$
Alum	$Al_2(SO_4)_3$
Sodium Aluminate	$NaAlO_2$
Steel Mill Pickling Liquor	$FeCl_2 + FeSO_4$
Lime	$Ca(OH)_2$

FACTORS AFFECTING CHOICE OF CHEMICAL FOR PHOSPHORUS REMOVAL

Influent Phosphorus Level

Wastewater Suspended Solids and Alkalinity

Chemical Cost Including Transportation

Reliability of Chemical Supply

Sludge Handling Facilities

Ultimate Sludge Disposal Methods

Compatibility with Other Treatment Processes in Plant

FIGURE 9

WASTEWATER TREATMENT FACILITIES, WITH PHOSPHORUS REMOVAL, UNDER DESIGN, CONSTRUCTION OR OPERATION
(PARTIAL LIST)

MORE THAN 100 MUNICIPALITIES INCLUDING:

- Milwaukee, Wisc.
- South Bend, Ind.
- Petersburg, Mich.
- Green Bay Metro, Wisc.
- Saginaw, Mich.
- Cleveland, Ohio
- Decatur, Ill.
- Bowie, Md.
- Marborough, Mass.
- Deerfield, Mich.
- Rockwood, Mich.
- Ann Arbor, Mich.
- East Canton, Ohio
- Mentor, Ohio
- Upper Sandusky, Ohio
- Pontiac, Mich.
- Bay City, Mich.
- Holland, Mich.
- Seattle, Wash.
- San Antonio, Tex.
- Xenia, Ohio
- Rochester, N. Y.
- Tampa, Fla.
- Arlington, Va.
- Hatfield Twp., Penna.
- Flint, Mich.
- Fairfax Cty., Va.
- Alexandria, Va.
- Waukegan, Ill.
- Detroit Metro, Mich.
- Greater Chicago Metro, Ill.
- Lancaster, Calif.
- Sparta, Mich.
- Lorain, Ohio
- Defiance, Ohio
- Ashtabula, Ohio
- Ypsilanti, Mich.
- Kalamazoo, Mich.
- Piscataway, Md.
- Owosso, Mich.
- Manassas, Va.
- El Lago, Tex.
- Michigan City, Ind.
- Racine, Wisc.

FIGURE 10

(9) Highest cost in tertiary - excellent quality low in P, BOD, and suspended solids

(10) Basic equipment required primarily chemical and polymer storage tanks, chemical pumps and feed lines

(11) Cost $.03 to $.06 per 1000 gallons for 80 to 95 percent removal at normally loaded and functioning plants.

C - <u>Nitrogen Control and Removal</u>

(1) Nitrogen controlling nutrient in some eutorphication areas

(2) Nitrogen in sewage primarily organic-N and ammonia-N

(3) Nitrogen control prevents depletion of dissolved oxygen by biological oxidation of ammonia-N to nitrate-N (Nitrification)

(a) Nitrogenous Oxygen Demand (NOD) can be more than one-fourth of total oxygen demand (TOD)

(b) Ammonia-N exerts chlorine demand which reduces disinfection efficiency

(c) Toxic to some forms of aquatic life

(4) Nitrification by altering conventional activated sludge: increase aeration rate; contact time; sludge age; and control pH.

(5) Stable nitrification possible by two-stage system

(a) First stage for organic carbon oxidation

(b) Second stage for nitrification

(c) Separate sedimentation and recycle in each stage

(6) Nitrification alone may not be adequate

(a) Nutrient value of nitrogen

(b) Nitrate limit on potable water supply

(7) Nitrogen can be removed from wastewater by biological and physical-chemical methods

(a) Biological denitrification

1) Uses methyl alcohol (methanol CH_3OH) as carbon source

2) Results in release of nitrogen gas

3) Three-stage biological system developed by EPA research program

a) First stage: high rate, short aeration (2 hour) for organic carbon oxidation and conversion organic nitrogen to ammonia

b) Second stage for nitrification (about 3 hours)

c) Third stage for denitrification (methanol added)

d) Theoretical need 1.9 mg methanol per mg of nitrate-N; actual about 3 mg methanol per mg of nitrate-N

e) Alternate denitrification systems shown in figure

(b) Breakpoint chlorination

1) Chlorine addition to wastewater produce chloramines; additional chlorine to breakpoint results in conversion and release of nitrogen gas

2) Dosages of breakpoint approximately 8 to 10 parts of chlorine per part of ammonia-N

3) High chlorine in effluent can be prevented by carbon column

4) Chlorides will be added to receiving stream

(c) Ammonia stripping

1) pH raised above 11 with lime with ammonia stripped out with air in tower

2) Classic application at Lake Tahoe

a) About 90% ammonia removal in warm weather

b) About 400 cu. ft. of air per gallon of sewage; lower temperature much higher volumes

3) Tower ices and becomes inoperable in freezing weather - use limited to warmer climates or seasons

4) Some difficulty with calcium carbonate scaling

(d) Selective Ion Exchange

1) Use naturally occurring zeolite (clinoptilolite)

2) Clino favors exchange of ammonium ion.

3) Columns may be operated 24 to 30 hours before regeneration

4) Regeneration by solution of lime and sodium chloride

5) Approximately 0.1 to 1.0 lbs of ammonia-N per cu.ft. of resin

6) Removals to less than 0.5 mg/l of ammonia-N technically feasible

7) Clino being designed for 22.5 mgd plant in Fairfax County, Virginia

D - <u>Physical-Chemical Treatment</u>

(1) Major viable alternative to conventional biological treatment

(2) P-C processes include:

(a) Chemical clarification

(b) Filtration

(c) Granular activated carbon adsorption

(3) May follow biological treatment (as Tahoe) or be "independent" P-C without biological

(4) Typical schematic flow diagram shown in figure

(5) Chemical clarification of raw sewage

IMPORTANCE OF NITROGEN

NH_3 IN EFFLUENTS CAN CAUSE DO SAG IN RECEIVING WATER

NH_3 IS CORROSIVE TO COPPER FITTINGS

1 NH_3 REQUIRES 7 PLUS $C\ell_2$ FOR BREAKPOINT

NO_2 CAUSES HIGH $C\ell_2$ DEMAND

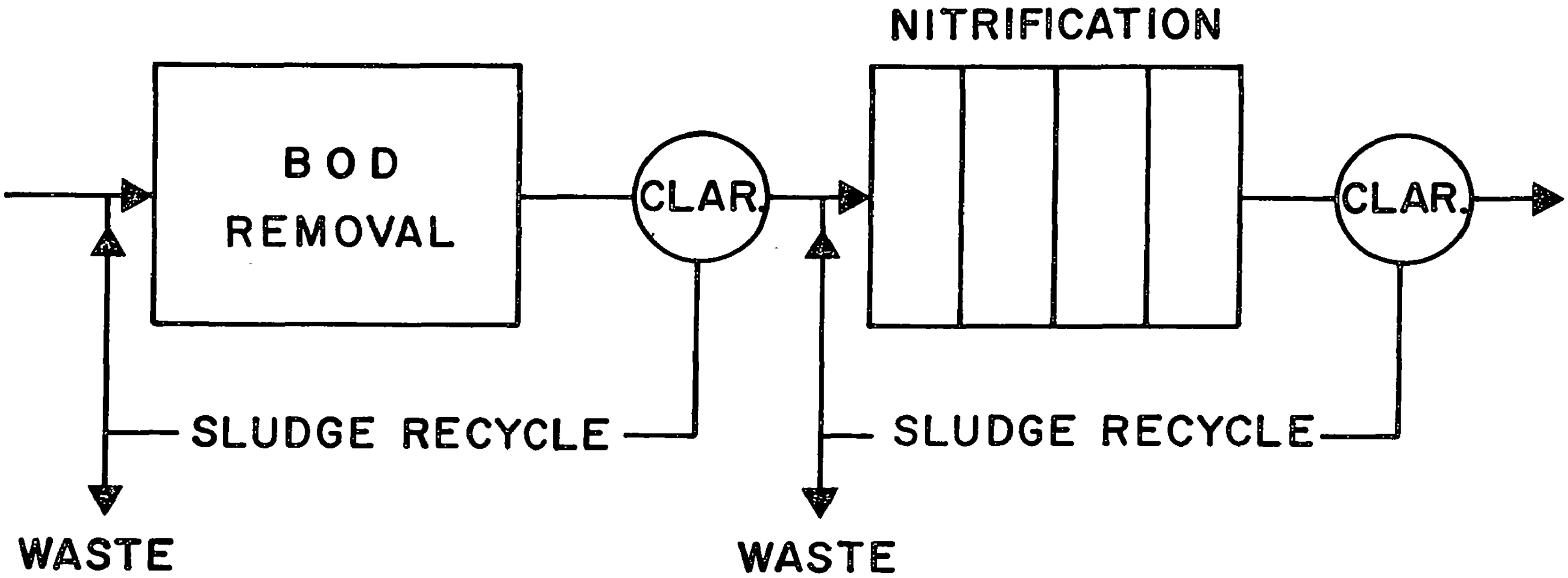
NH_3 INFLUENCES $C\ell_2$ CONTACT TIME

NITROGEN COMPOUNDS ARE NUTRIENTS

NO_3 CAN BE HEALTH HAZARD

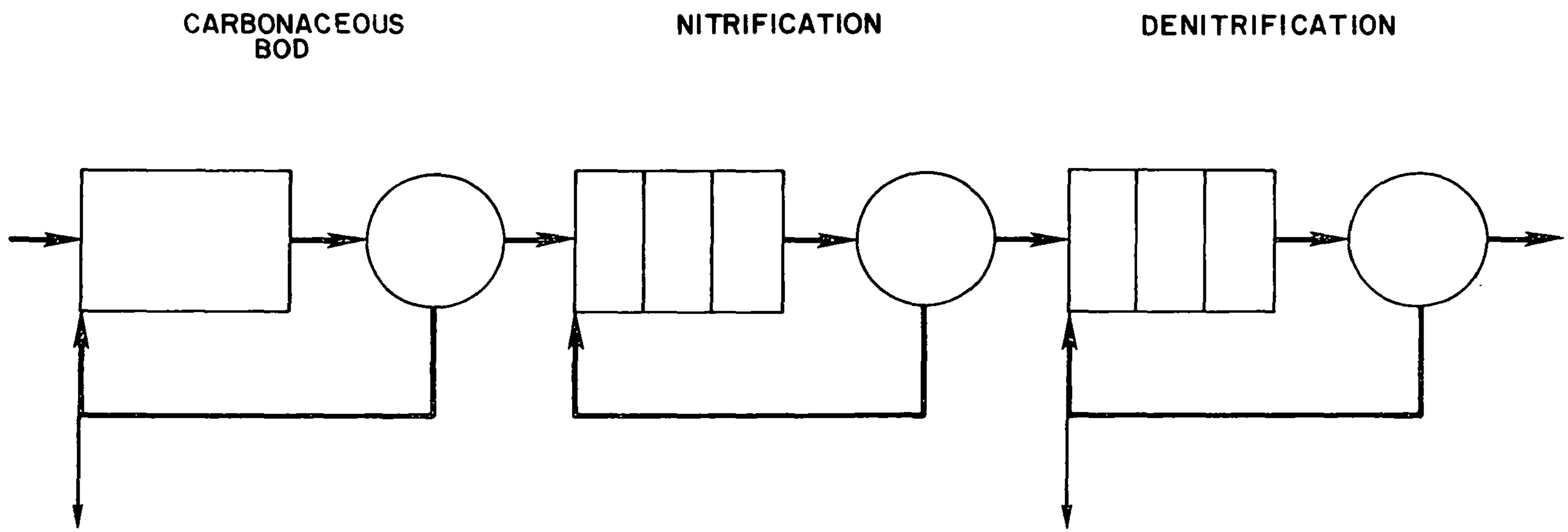
NH_3 CAN BE TOXIC TO FISH

FIGURE 11



TWO STAGE BIOLOGICAL SYSTEM REQUIRED TO GUARANTEE COMPLETE NITRIFICATION

FIGURE 12



MODEL SYSTEM FOR NITRIFICATION AND DENITRIFICATION

FIGURE 13

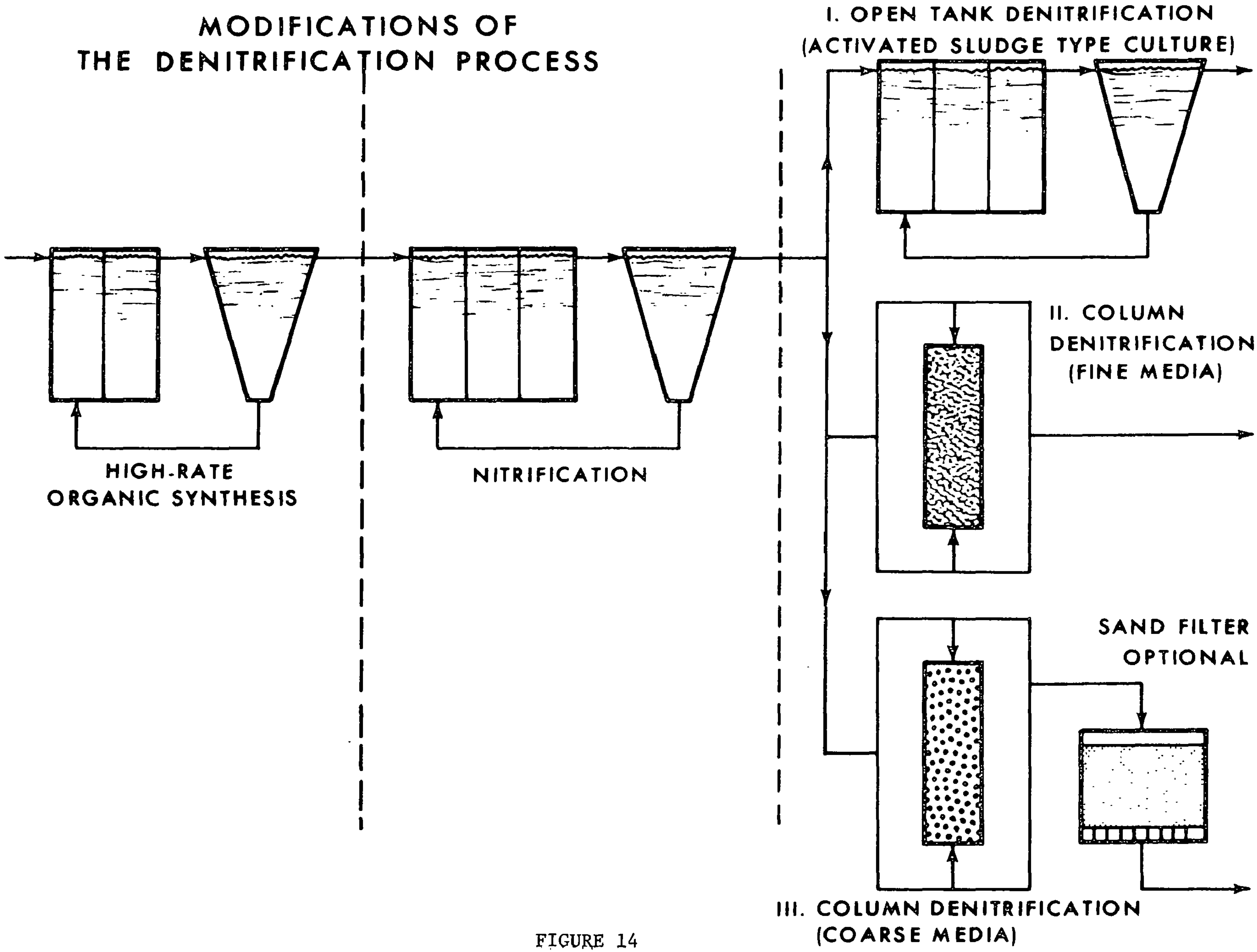

MODIFICATIONS OF
THE DENITRIFICATION PROCESS
I. OPEN TANK DENITRIFICATION
(ACTIVATED SLUDGE TYPE CULTURE)
II. COLUMN
DENITRIFICATION
(FINE MEDIA)
HIGH-RATE
ORGANIC SYNTHESIS
NITRIFICATION
SAND FILTER
OPTIONAL
III. COLUMN DENITRIFICATION
(COARSE MEDIA)

FIGURE 14

WASTEWATER TREATMENT FACILITIES WITH NITRIFICATION AND/OR DENITRIFICATION UNDER DESIGN, CONSTRUCTION OR OPERATION

(PARTIAL LIST)

LOCATION	DESIGN FLOW (MGD)
HOBBS, N. M.	5
TAMPA, FLA.	60
WASHINGTON, D. C.	300
SALT CREEK (CHICAGO), ILL.	50
EL LAGO, TEX.	.5
WAUKEGAN, ILL.	30
FLINT, MICH.	20
CENTRAL CONTRA COSTA SAN. DIST.	1
JACKSON, MICH.	16
BENTON-ST. JOSEPH, MICH.	13
FAIRFAX CTY., VA.	22.5
DENVER, COLO.	10
ARLINGTON, VA.	30
WELLSVILLE, N. Y.	1.5
PRINCETON, N. J.	10
ORANGE COUNTY, CALIF.	15
ALEXANDRIA, VA.	54
NO. SHORE SAN. DIST., ILL.	60
MADISON, WISC.	30

FIGURE 15

(a) Remove 65 to 75 percent of organic material

(b) Alum, lime, or iron salts will also remove phosphorus

(c) Includes mixing, flocculation, sedimentation

(6) Granular carbon adsorption is major new process

(a) Removes colloidal and dissolved organics

(b) Wastewater passes through carbon columns

1) Downflow columns at flow rates of 2 to 8 gpm/ft^2 better flow distribution

2) Upflow at 2-7gpm/sq.ft. - allow periodic removal of carbon at base

3) Packed bed operation provides some filtration but requires more frequent backwash

4) Columns can be insseries or parallel

5) Commercial granular carbon sizes 8 X 30 and 12 X 40 mesh

6) Carbon requires regeneration for reuse

a) Waste carbon hydraulically transported in water slurry

b) Regenerated in multiple hearth furnace at 1500°F - 1700°F

c) Regeneration losses 5 to 10 percent per cycle

(7) Filtration as component inPP-C treatment

(a) Usually mixed media type

(b) Filtration before carbon column enables use of packed beds

(c) More efficient removal of solids

(d) Filtration after upflow expanded bed columns to remove floc flushed from carbon

(e) Polymers may be added as coagulant aids

(8) Advantages of Physical-Chemical treatment

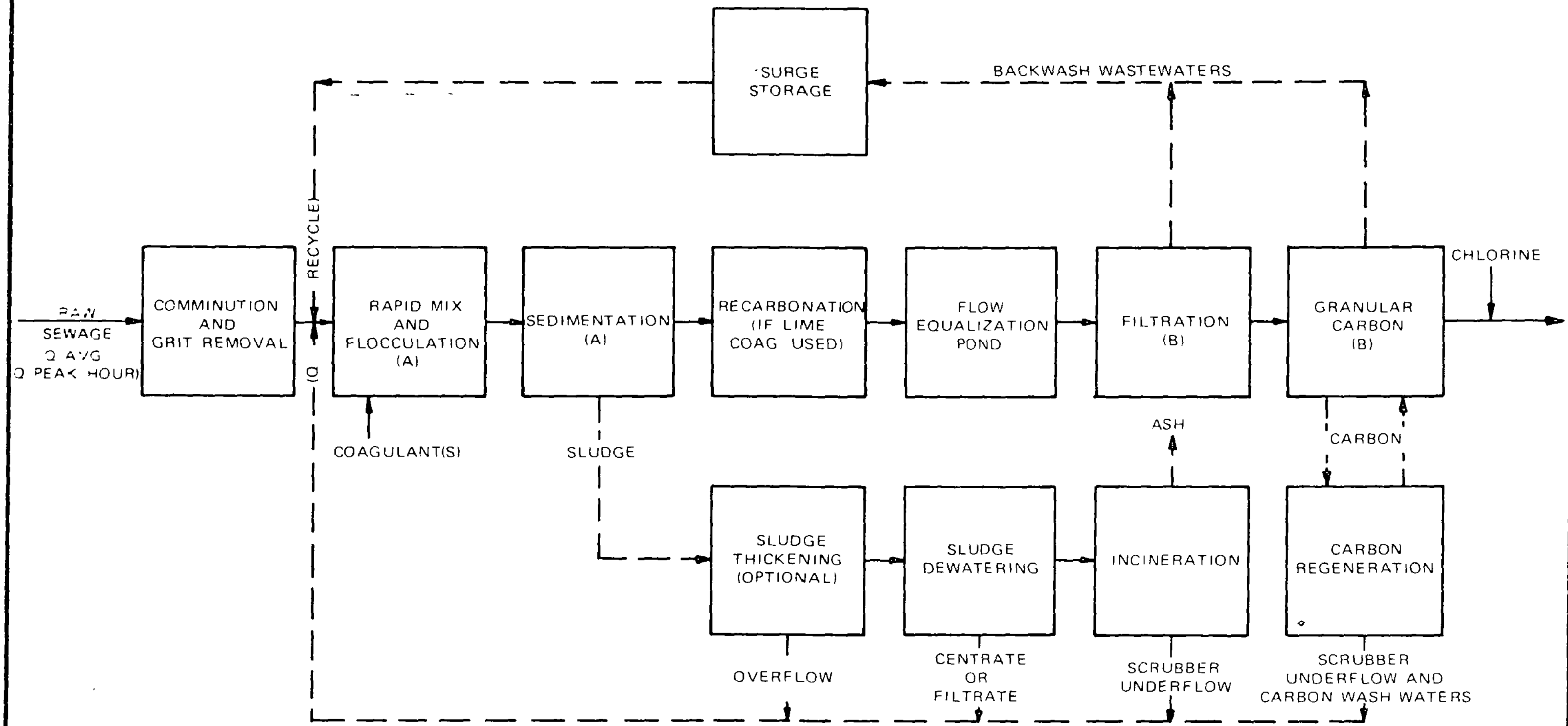
(a) Less land area (1/2 to 1/4)

TREATMENT COSTS FOR PHYSICAL TREATMENT (10 MGD)

STEP	TOTAL COST* CENTS PER 1000 GALS.	PERCENT OF TOTAL PLANT COST
PRELIMINARY TREATMENT	0.8	2
LIME COAGULATION & RECALCINATION	10.1	36
FILTRATION	3.6	13
ACTIVATED CARBON ADSORPTION	12.9	46
DISINFECTION	0.9	3
TOTAL PLANT COST	28.3	100

*NOTE: TOTAL COST INCLUDES CAPITAL COSTS, OPERATING AND MAINTENANCE COSTS, & AMORTIZATION

FIGURE 16

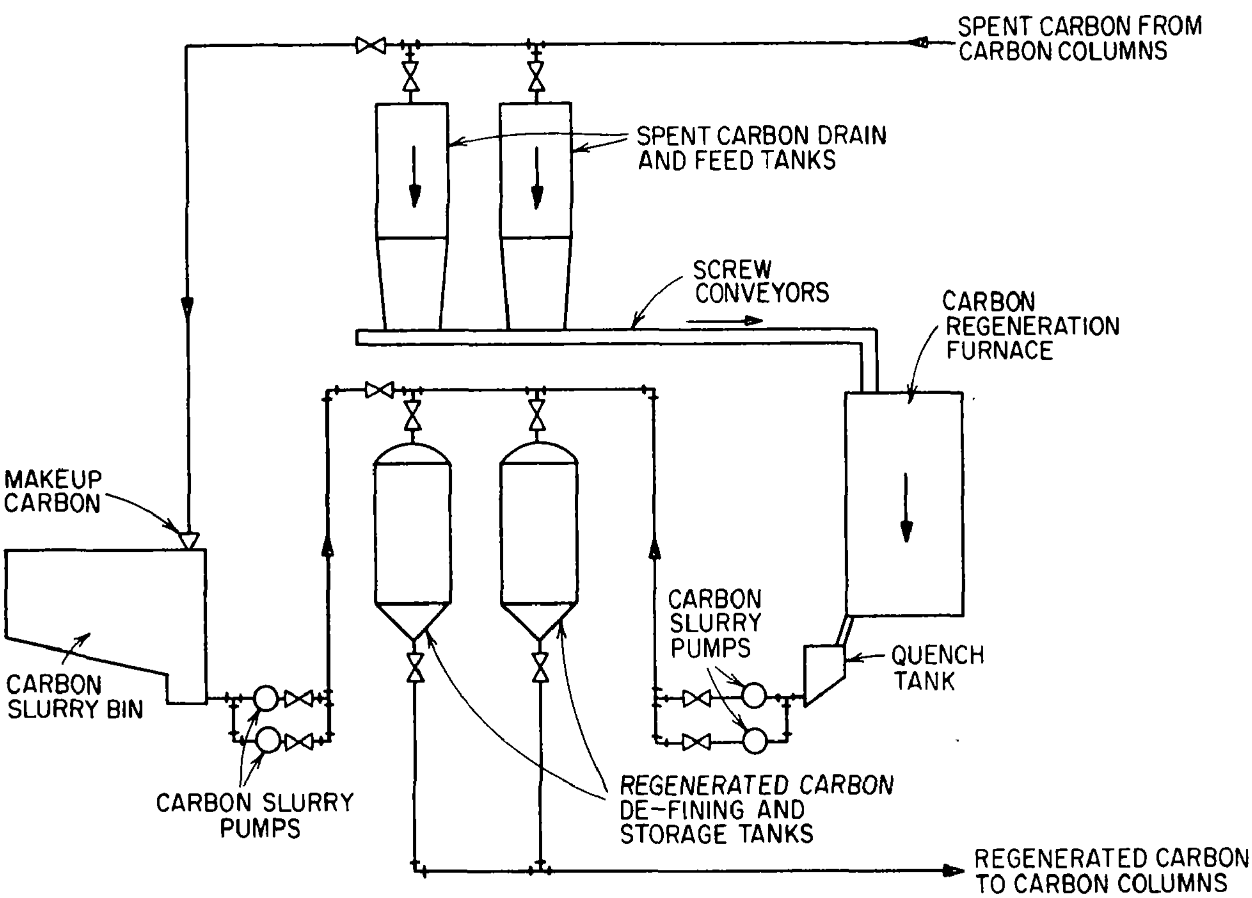


(A) DESIGN FLOW BASED ON Q PEAK HOUR PLUS Q RECYCLE

(B) DESIGN FLOW BASED ON Q AVERAGE PLUS Q RECYCLE

ILLUSTRATIVE SCHEMATIC OF
A PHYSICAL – CHEMICAL TREATMENT PLANT

FIGURE 17



ILLUSTRATIVE CARBON REGENERATION SYSTEM
(FROM CULP & CULP)

FIGURE 18

PHYSICAL-CHEMICAL TREATMENT PROJECTS CURRENTLY UNDER DESIGN, CONSTRUCTION OR OPERATION (PARTIAL LIST)

LOCATION	DESIGN FLOW(MGD)
NIAGARA FALLS, N. Y.	60
SOUTH LAKE TAHOE, CALIF.	7.5
ROCKY RIVER, OHIO	10
GARLAND, TEXAS	30
ROSEMONT, MINN.	.6
NASSAU COUNTY, N. Y.	.5
CORTLAND, N. Y.	10
ORANGE COUNTY, CALIF.	15
CLEVELAND, OHIO	50
FITCHBURG, MASS.	15
UPPER MONTGOMERY COUNTY, MD.	20
OWOSSO, MICH.	6
ALEXANDRIA, VA.	54
PORT JEFFERSON, N. Y.	5
OCCOQUAN, FAIRFAX COUNTY, VA.	22.5
COLORADO SPRINGS, COLO.	2.0
PISCATAWAY, MD.	5
LEROY, N. Y.	1.5
LEETSDALE, PENNA.	5
ARLINGTON, VA.	30

FIGURE 19

(b) Lower sensitivity to diurnal variations

(c) Not affected by toxic substances

(d) Potential for heavy metal removal

(e) Flexibility in design and operation

(f) Superior organic removal

(9) New concept of centralized regeneration for smaller communities

E - Suspended Solids Removal

(1) Gravity sedimentation no longer adequate in many

(2) Microscreens

(a) Surface filtration devices

(b) Polish effluent for secondary biological treatment plants

(c) Rotating drums with specially woven corrosion-resistant fabric on periphery

(d) Influent enter along axis of drum and flows radially outward through fabric

(e) Available with variable speed drums

(f) Nashed continuously (5 percent of throughput)

(g) Removal of 50 to 80 percent removal of biological solids in secondary effluent

(h) Screen sizes 23 to 35 microns

(3) Deep Bed Filtration

(a) Dual or mixed media filters

(b) Tri-media (e.g. Tahoe) usually anthracite, sand and garnet

(c) Flow rates 5 to 10 gpm/sq.ft.

(d) Provides quality control by removal of virtually all suspended solids and high degree removals of turbidity and phosphorus

(4) Chemical clarification (see phosphorus removal above)

(a) Now becoming standard practice inmmany areas

(b) Provides additional BOD and suspended solids removal

WASTEWATER TREATMENT FACILITIES, USING TERTIARY MULTI-MEDIA FILTRATION, UNDER DESIGN, CONSTRUCTION OR OPERATION (PARTIAL LIST)

LOCATION	DESIGN FLOW (MGD)
Spring Creek, Penna.	6.5
Aurora, Colo.	1.3
Louisville, Ky.	5.4
Bensenville, Ill.	1.1
Walled Lake, Mich.	2.8
Bedford Hts., Ohio	9.0
Beaverton, Ore.	1.6
Warren, Mich.	50.0
Barrington, Ill.	2.0
Hatfield Twp., Penna.	3.6
Midland, Mich.	6.5
Winslow, N. J.	1.0
Upper Gwynedd, Penna.	2.7
Hammond, Ind.	1.0
So. Lake Tahoe, Calif.	7.5
San Buena Ventura, Calif.	17.4
East Lansing	20
Denver, Colo.	10
Hatfield, Penna.	3.6
Arlington, Va.	30
Stony Brook, Princeton, N. J.	10
Alexandria Sew. Auth., Va.	54

FIGURE 20

TYPICAL MICROSTRAINER UNIT

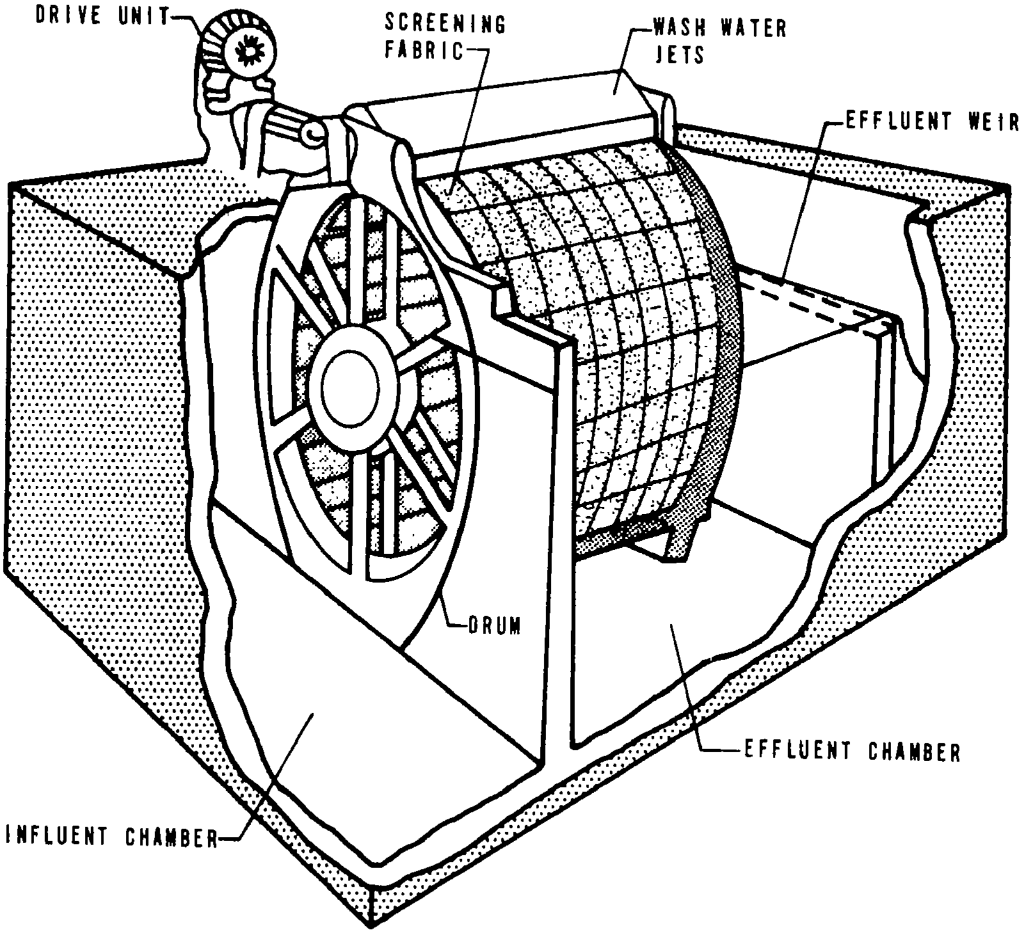


FIGURE 21

SLUDGE HANDLING & DISPOSAL

SLUDGE HANDLING & DISPOSAL

1. Importance
2. Current and Previous Methodology
3. Nature and Handling Characteristics of Sludges
4. Sludge Stabilization Processes
5. Sludge Thickening and Blending
6. Sludge Dewatering
7. Thermal Processing of Sludges
8. Final Disposal

SECTION 1 - IMPORTANCE OF SLUDGE PROCESSING AND DISPOSAL CURRENT EPA PROGRAMS

1. Introduction

   - Solids removed in the processing of waters for human consumption, industrial usage, or in the case of wastewaters, for discharge to a receiving stream, present a disposal problem.

   - Disposal of sludges from wastewater treatment will today account for up to 50 percent of the total treatment cost.

   - Sludge is the settleable solids that are naturally present in water and wastewater or that are found during treatment.

   - Tighter effluent criteria, increasing land scarcity and population pressure combine to make sludge disposal more difficult and expensive.

2. Quantities and Characteristics of Sludge to be Handled

   - Approximate amounts of sludge produced in the treatment of waste-water by simple clarification, chemical treatment and biological processes are shown in Table.

   - Activated sludge process contributes large quantities of sludge for disposal.

   - Sludge is a semi-liquid waste and the water content of all sludges is high, as shown in Table.

   - Typical sludge masses to be handled are shown in Table.

   - The quantity of sludge can be calculated from wastewater analysis and efficiency of the treatment units.

   - Physical-chemical treatment means new kinds of sludges, more mass and sometimes more volume.

   - The sludge produced when lime is added to wastewater in the primary or as a tertiary can be calculated from water and wastewater analysis

3. Sludge Management Alternatives

   - Sludge can be ultimately disposed of in dry, dewatered filter cake, liquid or in the form of ash and combusion gases.

   - Steps to be followed in solving a sludge handling and disposal problem are indicated in Figure.

4. Costs of Sludge Processing and Disposal

- Costs of sludge processing are a function of:

  . Treatment sequence

  . The raw sewage

  . Location (the surrounding neighborhood)

  . Climate

  . Scale of operation

  . Regulations, etc.

- Costs are sensitive to all of the above and individual author's assumptions. If possible, get all comparisons from the same unbiased source.

  . The cost of some sludge handling and disposal processes is given in Table.

  . The cost of some sludge handling and disposal combinations is given in Figure.

TABLE

TYPICAL QUANTITIES OF SLUDGE PRODUCED IN WASTEWATER TREATMENT PROCESSES

Treatment	
Plain Sedimentation	2,440 - 3,530
Trickling Filter Humus	530 - 750
Chem. Precipitation	5,250
Activated Sludge	14,600 - 19,400

TABLE

WATER CONTENT OF SLUDGES

Treatment	Percent Moisture	Pounds of Water/ Pound Sludge Solids
Primary Sedimentation	95	19
Chem. Precipitation	93	13.3
Trickling Filters		
Humus-Low Rate	93	13.3
Humus-High Rate	97	32.4
Activated Sludge	98 - 99	~ 65.6
Well Digested Sludge		
Primary Treatment	85 - 90	~ 7.0
Activated Sludge	90 - 94	~ 11.5

TABLE

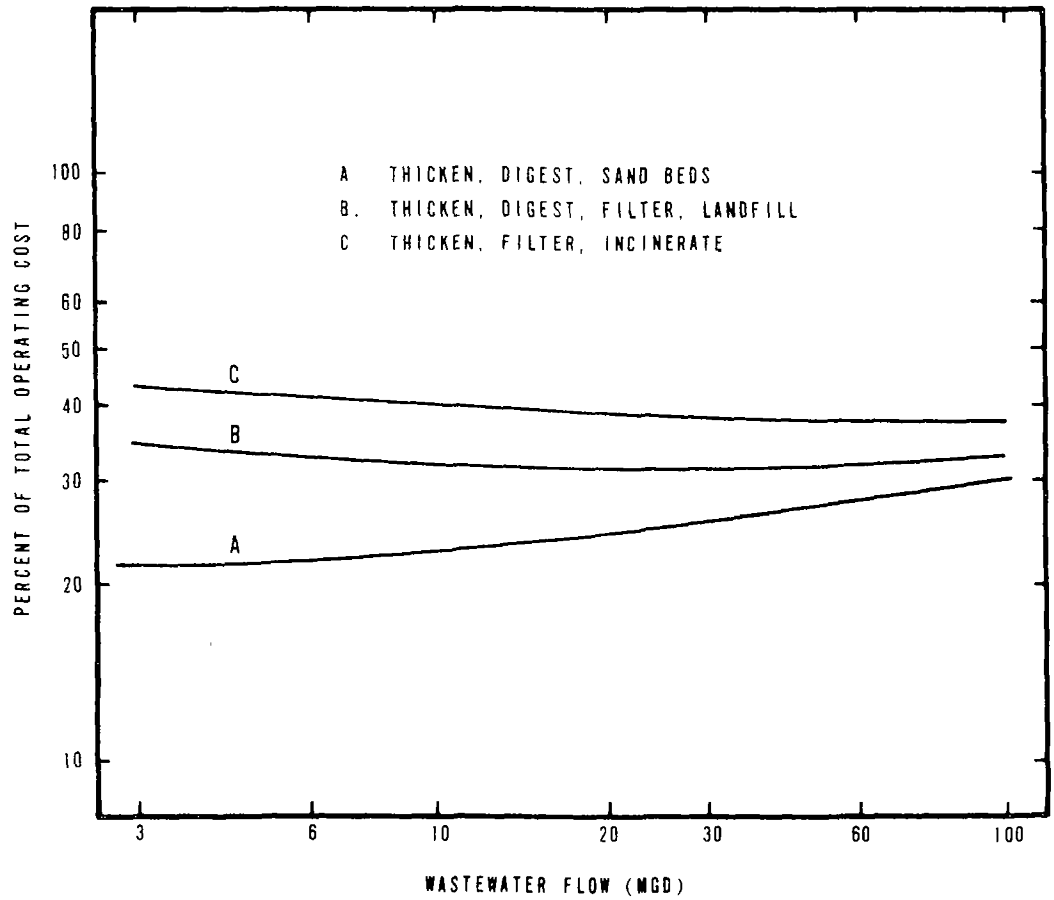
SLUDGE MASSES

Treatment	Percent Suspended Solids Removal	lb/day/mg Removed	Percentage of Volatile Materials Removed	Specific Gravity Suspended Solids
Plain Sedimentation	60	1,020	65	1.33
Tricklimg Filter Humus	30	510	45	1.52
Activated Sludge (excess)	92	1,563	65	1.33
Imhoff Tank Dig.	60	1,020	50	1.47

TABLE

TOTAL COST IN CENTS PER 1,000 GALLONS OF WASTEWATER PROCESSED FOR INDICATED SLUDGE HANDLING PROCESSES

Process	Plant Size		
	1 mgd	10 mgd	100 mgd
Gravity thickening of primary and waste activated sludge	1.61	0.31	0.13
Gravity thickening of primary sludge above	1.47	0.22	0.08
Air flotation thickening of waste activated sludge above	2.28	1.01	0.75
Anaerobic digestion of combined primary and waste activated sludge	6.09	2.09	1.89
Dewatering of digested sludge on sandbeds	2.20	1.64	NA
Dewatering thickened raw sludges on rotary vacuum filters	8.39	5.15	3.70
Multiple hearth incineration of filter cake	13.53	5.02	1.16



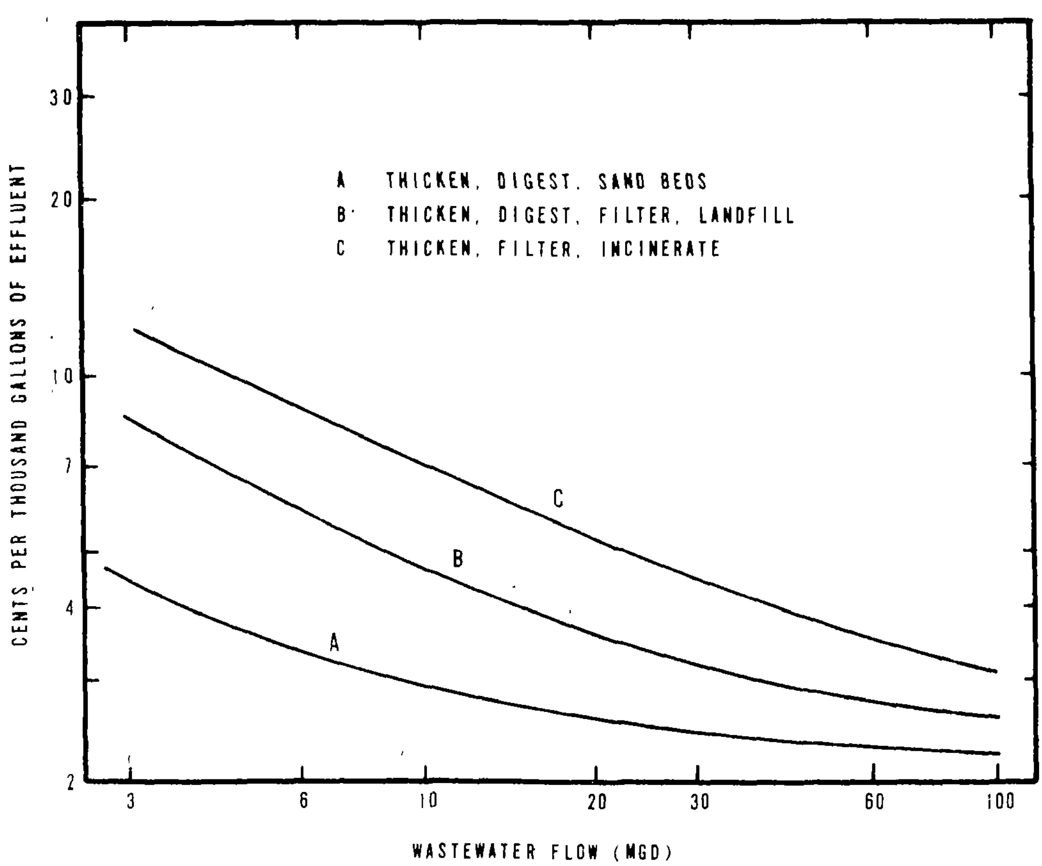
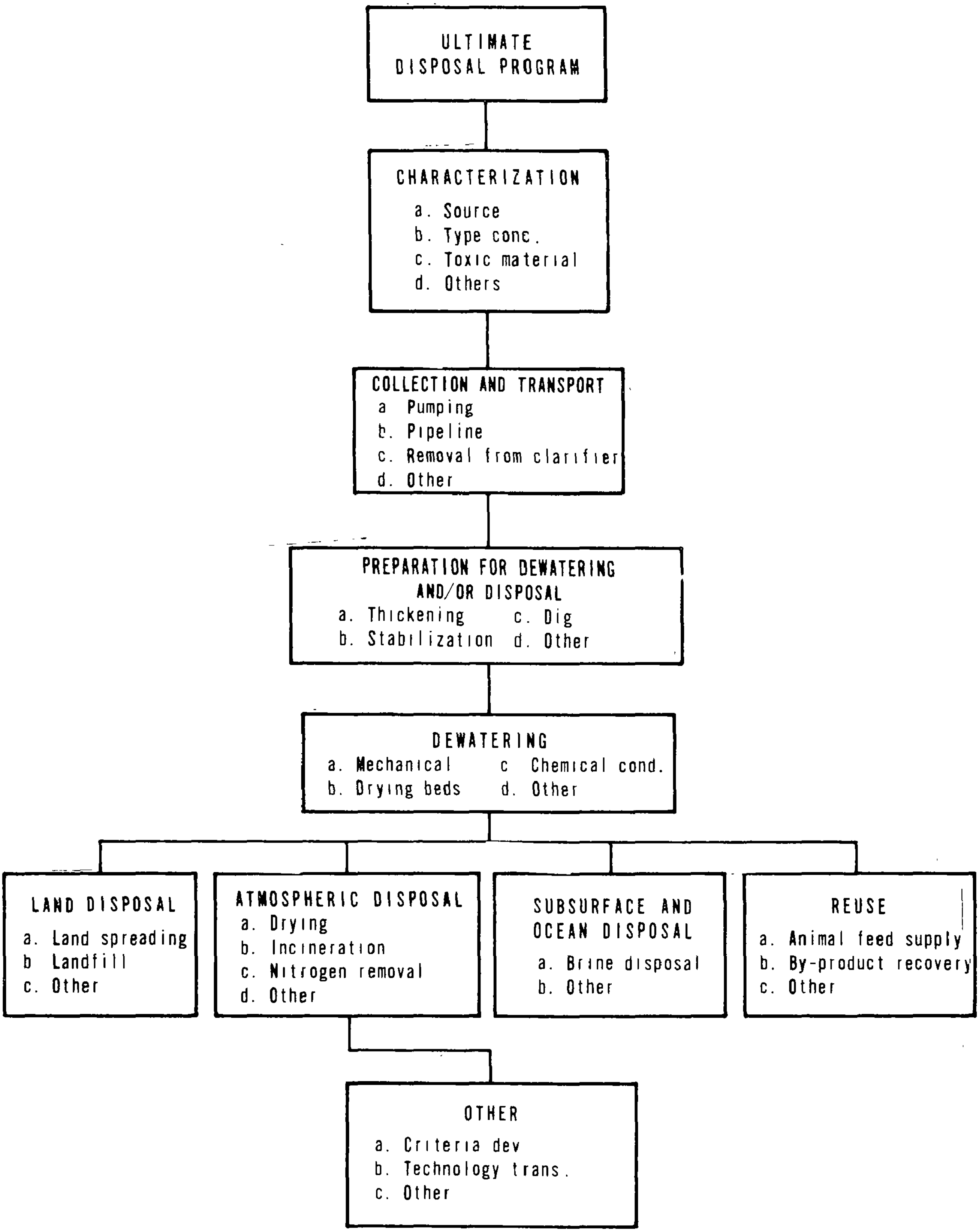


FIGURE 7 TYPICAL COSTS OF SLUDGE PROCESSING AND DISPOSAL - INCLUDING AMORTIZATION

CONSIDERATIONS IN THE HANDLING AND DISPOSAL OF SLUDGE



FIGURE

SECTION 2 - CURRENT AND PREVIOUS METHODOLOGY

1. Project Objectives - Wastewater Treatment Plants

   - The way it used to be - The old climate surrounding design and startup of wastewater treatment plants.

     . Partial funding for and somewhat limited role of the A/E firm.

     . Divided responsibility for design of sub-systems.

     . Emphasis on liquid handling.

     . Elastic enforcement policies (habit forming).

     . Problems with sludge handling systems.

   - The way it is now - The new climate. The objectives have always been there but the new climate now makes them obtainable.

     . Effective, reliable processing of wastewater (both liquid and solid fractions).

     . At lowest practical cost.

     . Concurrent non-polluting effluent streams (liquid, solid and gaseous).

     Plants must function properly, both initially and continually.

     . Both liquid and solids fractions must be processed satisfactorily.

     . Effluent standards are going to be enforced.

     . Capital, operating and maintenance costs must be essentially on forecast.

2. Essential Ingredients (for a successful project)

   - Optimum Conceptual and Detailed Designs

     . New standards require new processes.

     . New processes mean text books are a questionable source.

     . The importance of being contemporary in process engineering disciplines.

- Construction as Designed
  - Increased A/E involvement, new C.M. methods.
- Proper Operation and Maintenance
  - Following the Doctor's orders or he is not responsible for the results.
- Continuing Plant Service and Development
  - Nobody's perfect; even naval vessels still have a shakedown cruise.
  - A vital source of process improvement and future design information.

3. Sources - Conceptual Design Information

- Textbooks and Literature
  - Must be reviewed but rarely give all the answers.
- Laboratory and Pilot Studies
  - Practically always necessary.
- Supplier's Recommendations
  - Equipment and product firms, their own R&D engineering work.
- Previous Experiences
  - All too seldom available.
- Visitation to Other Plants
  - Helpful but sometimes misleading.
- Client's Wishes (existing plant results)
  - Depends on the client's experience and capability.

4. Special Considerations - Design Rationale

- Adequacy of Available Literature
  - Self serving publications.
  - Strategic omissions.

- Supplier's Recommendations
  - . Essential but must be sifted carefully.
  - . The importance of follow-up.
- Plant Data - Fact vs. Folklore
  - . Reliability, a function of adequacy of O&M.
  - . Defending an untenable position - mistakes die hard.
- Process Engineering
  - . Unit operations technology.
  - . Biological process technology.
  - . Putting the whole thing together.
  - . Experience in other industries and in plant operations.

SECTION 3 - NATURE AND HANDLING CHARACTERISTICS OF SLUDGES

1. Fundamental Point

Need - Knowledge/Insight
Nature of Sludges/Handling Characteristics

Potential Pitfall

"All generalities are inherently false, including this one."

2. Raw Primary Sludge

- Almost universally settles, thickens, dewaters and incinerates relatively easily.
- Is usually coarse and relatively fibrous.
- Vacuum filtration and centrifugation work well at low cost.
- Costs are low and efficiences good.

VACUUM FILTRATION - RAW PRIMARY SLUDGE

% Sludge Solids	Conditioner Used	Cost ($/Ton)	Yield $lb/ft^2/hr$	Cake Solid (%)	Solids Capture (%)
10	Cationic Polymer	1.67	10	32	90-95

3. Effect of Digestion (Primary Sludge)

- Anaerobic digestion, contrary to some information in the literature, makes sludges somewhat more difficult to thicken and dewater.
- But results are still good and costs low.
- Shear effects on particle size and increased hydration of solids.

% Sludge Solids	Conditioner Cost ($/Ton)	Yield $\#/hr/ft^2$	Cake Solids (%)	Solids Capture (%)
12.7	2.64	7.4	28	90+

4. Activated Sludges (Conventional)

- Inherently more variable
- Principal source of variation
  - Configuration and mode of operation of activated sludge system involved.
- Also, Domestic/Industrial waste ratio and type, Nature of Collection System can have real effect.
- Structure
  - Generally finer in particle size.
  - 60-90 percent cellular organic matter.
  - Bioflocculated to some degree, by excretion of natural polymeric material by the micro-organisms.
  - Density close to density of water.
- Water Content
  - Biomass from conventional air systems has much associated water.
  - Theoretically, if the loosely held and bound surface water disengaged, up to 29 percent solids obtained.

5. Summary - Activated Sludges

- Conventional Air Aeration Systems Excess Activated Sludge requires very careful operation to give settleable sludge.
- Activated sludge is sensitive to further processing. Hydration easily and tends to float.

6. Handling Combined Primary and Activated Sludges

- Existing plants, many cases designed one of two ways.
- A. Recirculate E.A.S. to head of plant - Primaries
  - Results Primary Solids Capture goes to pot.
  - Greater BOD load on secondary system.
  - More E.A.S. created than necessary.

. Combined Mixed Sludge

Settles poorly in digester, another recirculation load.

When elutriated (without flocculants) sludge fractionates - another low efficiency process and recirculation load.

- B. E.A.S. mixed with Primary Sludge prior to gravity thickening

. Results: Better than recirculation to primaries but:

Dirty thickener overflow.

Activated portion will not settle in digesters or elutriation basins, so still poor.

. Remedy

Combine and thicken sludges just before dewatering.

Not early in process.

7. Oxygen Activated Sludges

- Biomass from oxygen process has better settling characteristics.
- Clarifier performance, based on overflow rate is better with oxygen process sludge (Watch bottom loading rates).
- Recycle sludge solids are higher with oxygen activated sludge.
- Sludge volume indices are improved over air aeration sludge.
- Gravity thickening.

  Summation - oxygen activated sludge appears to gravity thicken more readily.
- Flotation thickening
- Vacuum Filtration
- Centrifugation

8. Alum Use - Primary Plant - Mixed Chemical Organic Sludge

- West Windsor
- With no chemical addition to primaries, ferric/lime conditioning, high yield and low cost.

- With alum, primary solids level drops, amount of sludge increases, yield decreases and costs go up.

- Ferric and lime may not be best conditioning system for alum/organic sludge.

9. Lime Use - Conventional Sludge Plant - Mixed Lime/Organic Sludge (Raw)

    - Newmarket

    - 2.0 mgd, lime added just ahead of primaries.

    - Sludge volume almost triples, but centrifugation looks easy and inexpensive.

    - Low polymer dose to clean up centrate.

10. Alum and Lime Sludges - Conventional Activated Sludge Plant

    - Windsor Little River

    - Normal, untreated sludge conditioning costs are abnormally high, particularly for a sludge feed to filters.

    - Lime usage gave a mixed sludge (with small amount of activated sludge content?) which dewatered well at a lower cost.

    - Alum lowered sludge solids concentration, decreased yield and increased conditioner costs. Cake solids were only 16 percent with alum use.

11. Ferric Chloride/Organic Sludge - Conventional Activated Sludge Plant

    - North Toronto

    - Use of ferric chloride for phosphorus removal.

    - Tested for many months.

    - First applied at primary basins.

    - Current application point = at end of aeration basin.

    - Chemical conditioning costs about $8/ton.

    - Reasonable production rate and cake solids content realized.

12. Lake Tahoe Solids Handling

- Two sludges handled separately in this tertiary plant.

  . Organic sludges (from a system which recirculates activated sludge to head of plant).

  . Lime sludges from tertiary type treatment.

13. Aerobically Digested Activated Sludges

- Aerobic digestion is an inherently "cleaner" means of reducing the volume of activated sludge to be dewatered and to stabilize same for land disposal.

- Plant scale work current at several locations.

- Atlanta

  . New 6 mgd Flint River Plant tests.

  . Digestion process works well.

  . Sludge compacts to 2-3 percent and can be dewatered via vacuum filtration using ferric chloride.

  . Yield is on the lean side.

  . If aerobically digested sludge were mixed with thickened primary sludge, dewatering and incineration would be more efficient.

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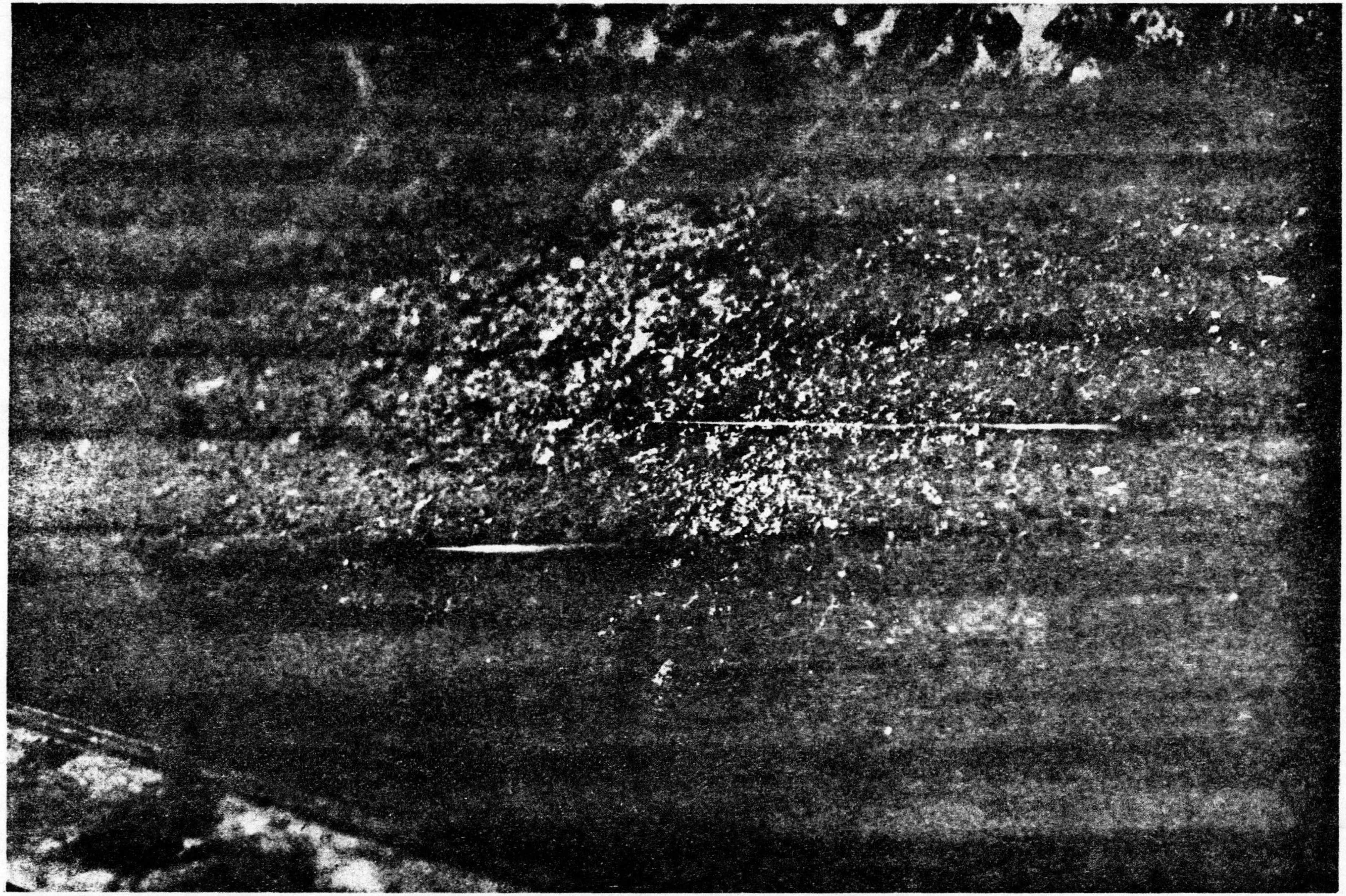


FIGURE CLOSE–UP RAW PRIMARY SLUDGE FILTER CAKE

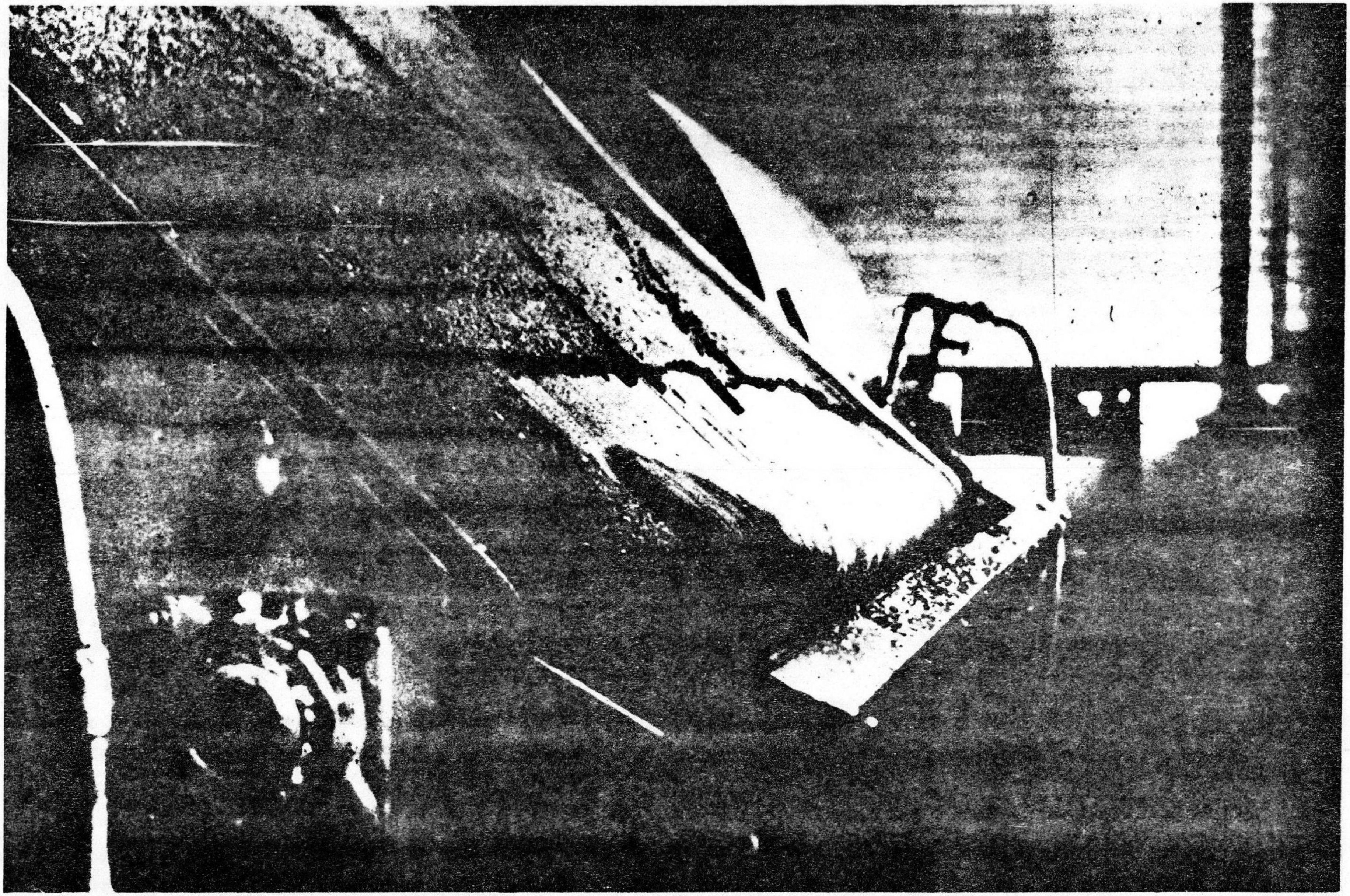


FIGURE RELEASE CHARACTERISTICS – RAW PRIMARY SLUDGE FILTERS

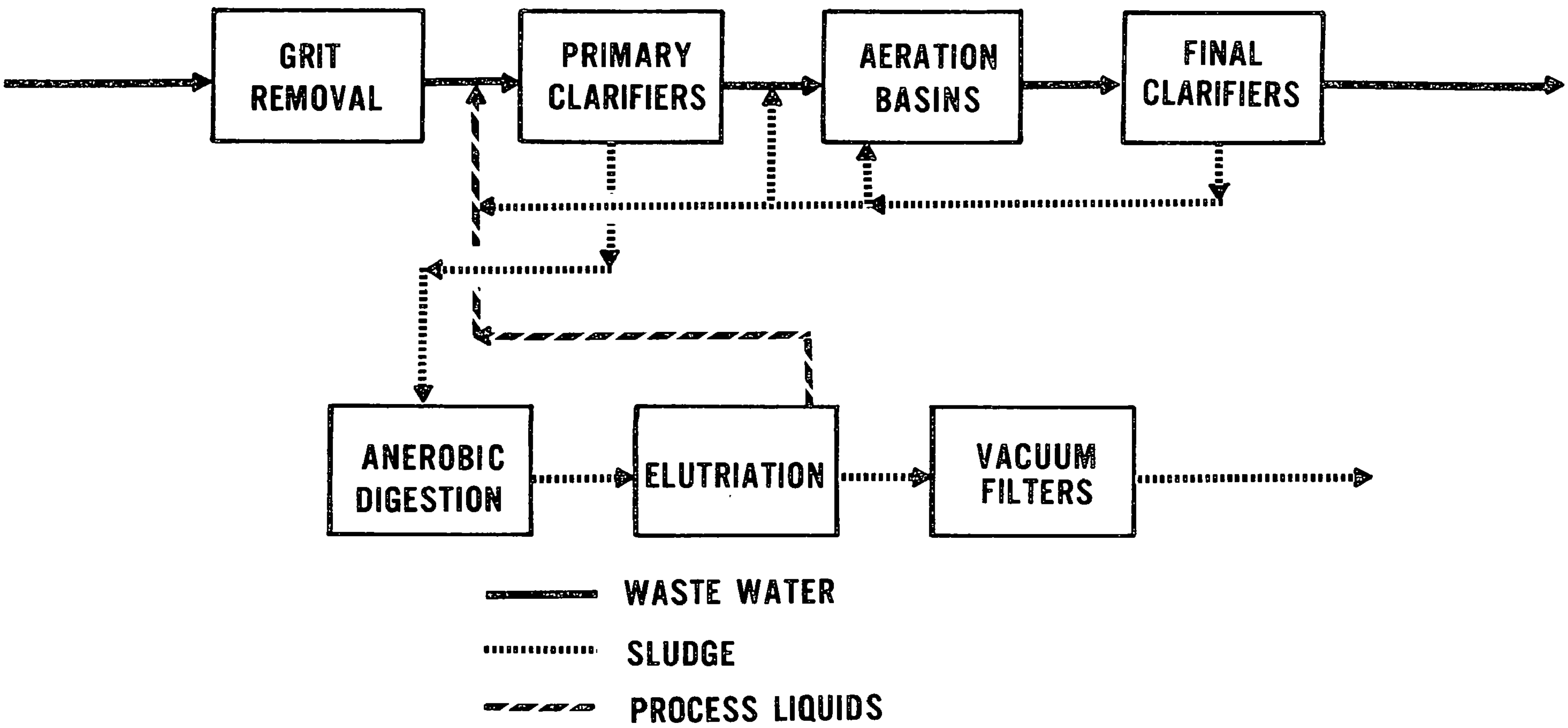


FIGURE SECONDARY PLANT WITH SURPLUS ACTIVATED SLUDGE TO HEAD OF WORKS

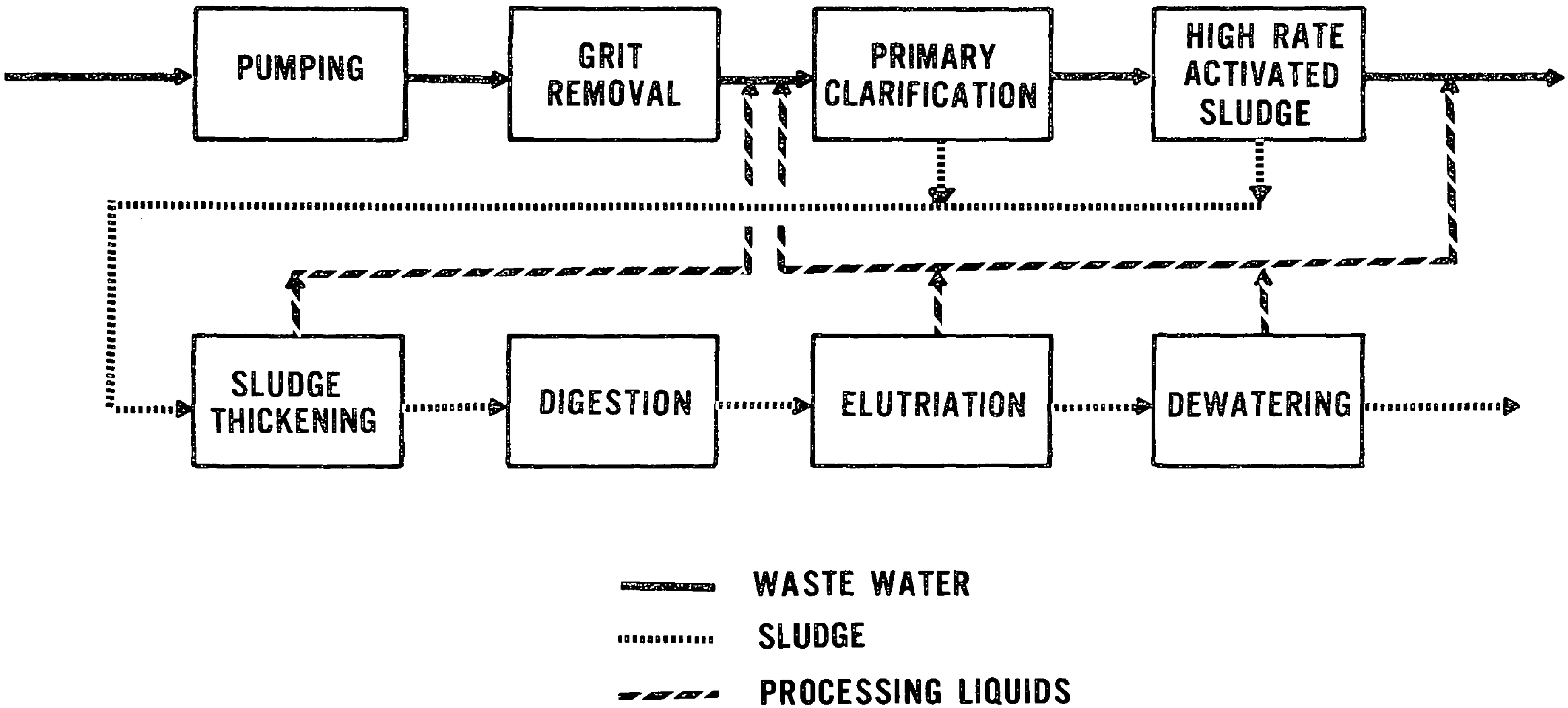
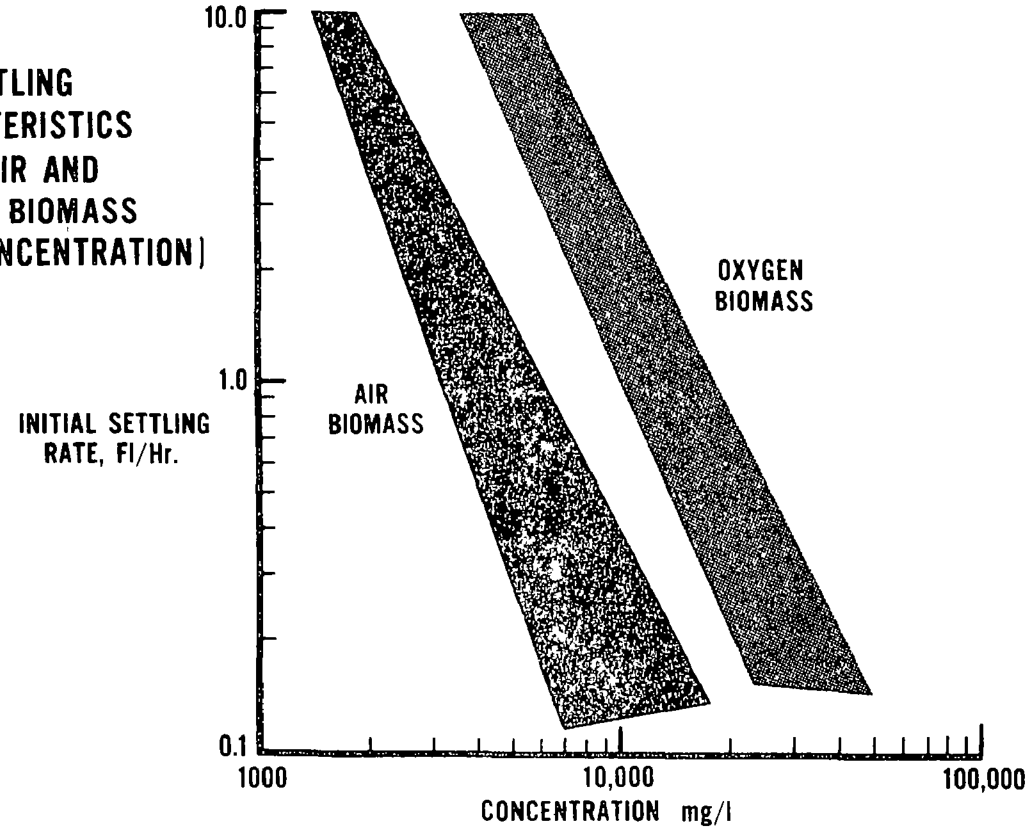


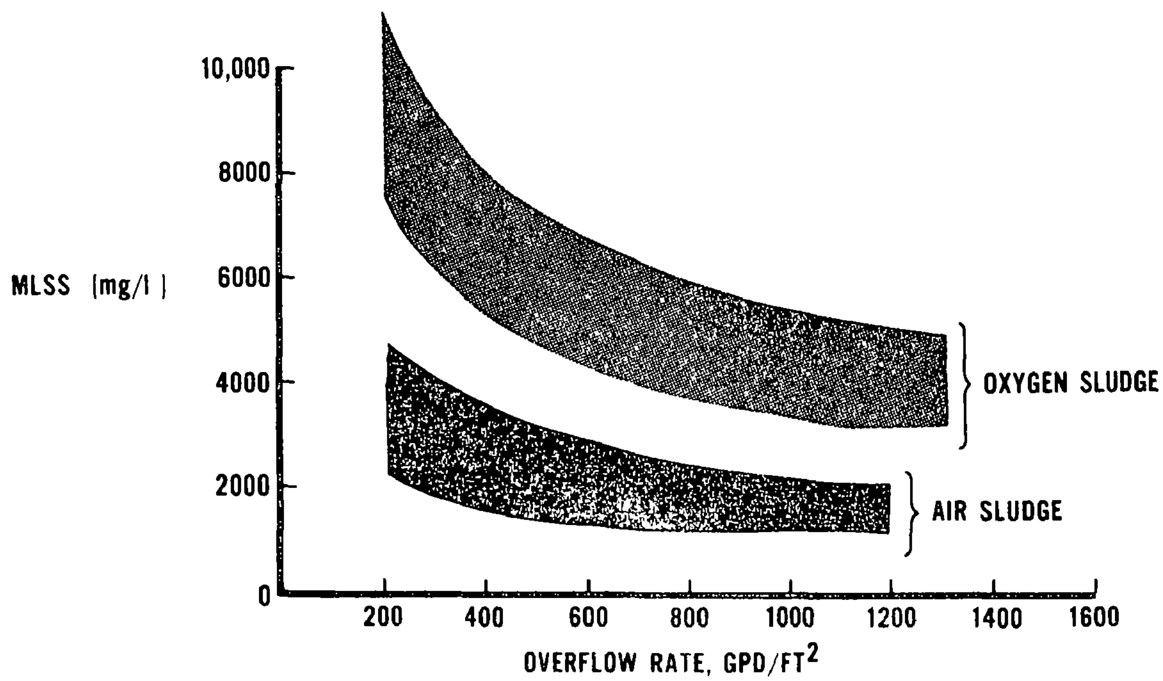
FIGURE SECONDARY PLANT WITH SURPLUS ACTIVATED SLUDGE MIXED WITH PRIMARY SLUDGE PRIOR TO THICKENING AND DIGESTION

SETTLING CHARACTERISTICS FOR AIR AND OXYGEN BIOMASS (ISR VS. CONCENTRATION)



FIGURE

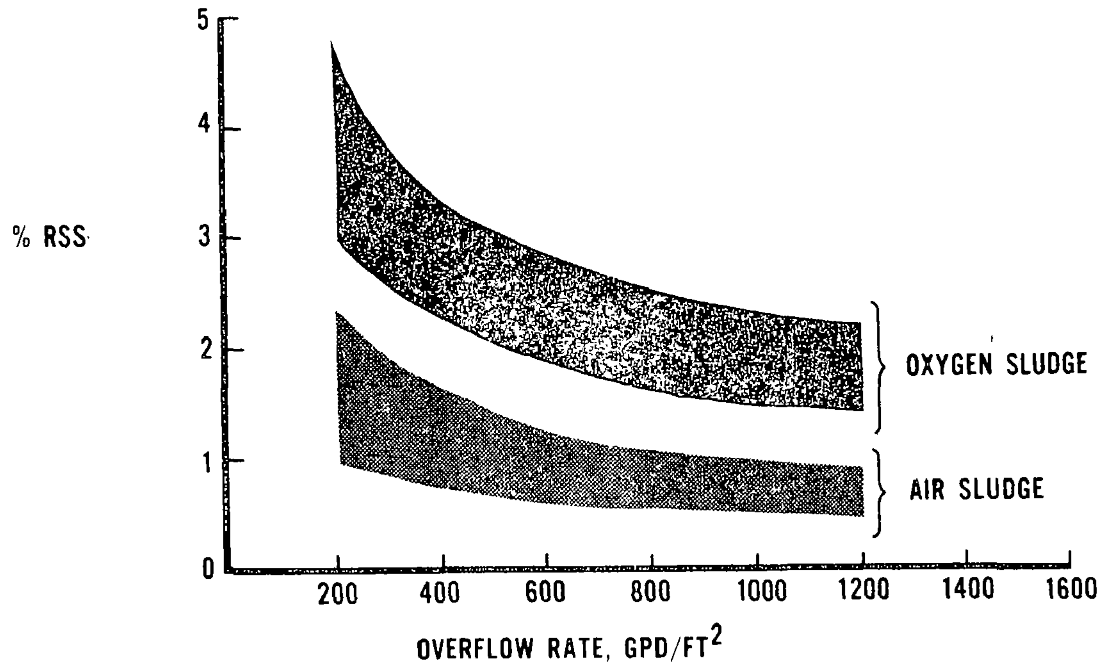
TYPICAL CLARIFIER PERFORMANCE FOR AIR AND OXYGEN SLUDGES (AT 30 % RECYCLE)



FIGURE

TYPICAL CLARIFIER PERFORMANCE FOR AIR AND OXYGEN SLUDGES

(AT 30 % RECYCLE)



FIGURE

GRAVITY THICKENING

FEED SLUDGE		SOLIDS LOADING	UNDERFLOW CONC.	
TYPE	% SOLIDS	#/Ft.^{2}/DAY	% SOLIDS	LOCATION
OXYGEN W.A.S.	1.7	10	4.8	LOUISVILLE
AIR W.A.S.	0.9	20	1.4–2.8	CHICAGO
OXYGEN MIXED	2.3	—	5.6	MIDDLESEX
AIR MIXED	1.1	20	3.3(4.4)	CHICAGO

FIGURE

SECTION 4 - SLUDGE STABILIZATION PROCESSES

1. Anaerobic Digestion

- Describes the biological conversion of organic matter in the absence of molecular oxygen to simple compounds. Gas products are chiefly methane and carbon dioxide.

- Process advantages include:

  . Anaerobic digestion is the most frequently employed process for sludge stabilization. When digestion operates properly, it converts raw sludge to a stable material which is inoffensive to the senses, and which has a greatly reduced pathogen content.

  . Methane generated can be used for heating and to run generators.

  . Can usually obtain a 50 percent reduction in volatile solids.

  . Do not have to or want to maintain a high dissolved oxygen level.

- Process disadvantages include:

  . Control is difficult because of sensitivity of micro-organisms to toxicity, especially from industrial effluents.

  . Capital costs for facility construction and heating provision are high.

  . Supernatant is usually high in BOD, solids, and nutrients requiring further treatment.

  . Anaerobic digestion produces changes in sludge which, on the average, reduce the filter yield. If ferric chloride and lime are used, chemical demand is increased. If sludge density is increased, yield can be increased.

- Design criteria for anaerobic digesters

  . Volume - allow 3 to 6 cubic feet per capita.

  . Organic loading - allow from 0.02 to 0.15 pounds of applied solids per day per cubic foot.

- Reported costs

  . For anaerobic digestion followed by sand bed dewatering is approximately $25/ton dry sludge solids.

. For anaerobic digestion of activated sludge followed by reclamation of farm land or a strip mine is approximately \$15 to \$16/ton dry solids.

Some recommended techniques for treating supernatants are:

Processes for the Removal of Constituents of Anaerobic Supernatant

Constituent	Means of Removal
Suspended material	Coagulation, filtration, microstraining
Phosphorus	Removal with suspended material, chemical precipitation, ion exchange
Nitrogen	Removal with suspended material, stripping, ion exchange
CO_2	Lime addition, stripping, ion exchange
BOD	Removal with suspended material, stripping of volatile acids, biological treatment, adsorption on activated carbon

2. Aerobic Digestion

- Describes the separate aeration of:

  . Waste primary sludge

  . Waste biological sludge, or

  . A combination of waste primary and biological sludges.

  . Aerobic stabilization is usually used to stabilize waste activated sludges or the waste sludges from smaller plants which do not have separate primary clarification.

- Usually designed for a 15-20 day retention.

- Biological steps include:

  . Oxidation of biodegradable material.

  . Oxidation of microbial cellular material.

- Process advantages include:
  - Relatively simple to operate.
  - Requires small capital expenditure compared to anaerobic digester.
  - Does not generate significant odors.
  - Reduces pathogenic organisms to low level.
  - Reduces grease or hexane solubles.
  - Produces a supernatant if clarified that is low in BOD, solids, and total P.
  - Reduces sludge volatile solids.
  - Reduces sludge respiration rate.
  - Production of a highly nitrified sludge which could be denitrified if sludge is to be placed on land.
- Process disadvantages include:
  - High operating cost.
  - Unclear design parameters at present.
  - Aerobically stabilized sludge has poor dewatering characteristics on vacuum filters although a recent publication claims otherwise. Ordinarily, this sludge is dewatered on sand beds or applied in liquid form to cropland.
- Important process parameters are:
  - Air requirements.
  - Time of aeration.
  - Sludge age.
  - Proposed method of ultimate disposal.
  - Temperature and heat dissipation.
- Some designs have been
  - To allow for a 5-day retention, a sludge concentration of 12,000 mg/l and to size at 1.4 cubic feet per capita, or
  - To load at a rate of 0.1 to 0.2 lb VSS/lb solids/day.

3. Chlorine Oxidation

- The Purifax process oxidizes sludge with heavy doses of chlorine. Sludge dewaters well on sandbeds. Stability is excellent.

- Purifaxed sludges present some difficulties when they must be dewatered on vacuum filters. Chemical (or polymer) conditioning is needed, but the low pH interferes with the action of conditioning agents. Pilot plant tests indicate that pH must be increased to greater than 4 to get good conditioning.

- Supernatant and filtrate contain high concentrations of chloramines. They should not be carelessly discharged.

4. Lime Treatment

- Lime treatment of sludge stabilizes the sludge as long as the pH stays high (11.0 - 11.5). Kill of pathogenic bacteria is excellent. Sludge dewaters well on sandbeds without odor.

- Sludge filtrability is improved. Caution is advised on disposal of sludge cake to landfills to avoid thick layers. The pH could fall to near 7 before the sludge dries out, permitting regrowth and noxious conditions.

- A key factor is the maintenance of a pH of 11.0 for a sufficiently long time (24 hours).

SECTION 5 - SLUDGE THICKENING AND BLENDING

1. Sludge Particles

- Heterogeneous mixture of various materials ranging from the size of colloids to the size of flocculated particles.

- Type of matter can be animal, vegetable or mineral and can be fibrous, granular or amorphous in shape.

- Particles can be hydrophobic (non-water loving) or hydrophilic (water loving). Hydrophilic particles, due to presence of polar groups such as hydroxyl, carboxyl, or amino, have a strong affinity for the water solvent and retain a sheath of water around the particles which tend to resist compaction.

- Surface charge of most particles such as paper fibers, bacterial cells, clays, sands, hydrated metal oxides, and the usual material found in wastewater is negative as shown in Figure.

- Behavior of the particles is dependent on their size, surface charge, solvation, and the temperature, pH, and ionic type and concentration of the water. But particles can have capability of adsorbing positive or negative charge as is also shown in Figure.

2. Sludge Blending

- Varieties of sludges are numerous: primary, conventional activated, high rate activated, oxygen activated, trickling filter humus; with or without chemical addition in any of the above; then any of the foregoing may be raw, anaerobically digested, chlorinated or heat treated. Just from the kinds above mentioned results in so many possible combinations as to boggle even a sanitary engineer's mind.

- Purpose of blending is to mix any two or three sludges that result from the various kinds of wastewater treatment to eliminate or minimize variation, eliminate duplication of facilities, and produce a decreased volume of sludge with a higher solids concentration.

- Important considerations:

  . All of the factors previously discussed under sludge particles are obviously important in sludge blending and thickening.

  . It is possible that blending will result in compaction as a result of particles interacting with each other just like particles and chemicals as shown in Figure.

- On the other hand, it is possible that blending will result in only a minimum of compaction such as the case of the plant that blended primary sludge, waste activated final effluent, and centrate from the heat treated sludge. The resultant sludge thickened to a concentration of only 1 percent.

- The question appears to be whether sludges should be blended to result in thickening; or thickened and then blended for further processing. The latter is called for in the design of the expansion at Washington, D. C., where activated sludge will be thickened separately by flotation and primary sludge will be thickened in gravity thickeners, and the two sludges will be blended enroute to vacuum filtration.

3. Gravity Thickening (Sedimentation)

- Gravity thickening has produced results that range from good to fair to mediocre. Sludge concentrations usually increase in primary settling tanks using polymer for raw sewage flocculation. Although polymer improves the efficiency of suspended solids removal, the polymer **usually** increases sludge concentration.

- Gravity thickening was formerly accomplished in anaerobic digesters which produced thickened solids from the bottom and relatively low suspended solids in the straw-colored supernatant. However, the present mode of operation blends sludges in the digester not only physically but mechanically. This produces sludge that does not settle completely in the secondary digester and thus produces a supernatant that is usually a sludge of only slightly lower solids concentration than the digester underflow.

4. Flotation Thickening

- Flotation is the opposite of gravity thickening - the solids are caused to float due to attachment and entrapment of fine air bubbles. Usually one volume of water saturated with air at 40 psig will provide sufficient air bubbles to float the solids in an equal volume of sludge containing suspended solids at a concentration of 5,000 mg/l.

- It should be noted that flotation with chemicals effects only marginal increase in thickened sludge concentration, but use of chemicals does permit a 100 percent to 300 percent increase in solids loading and about a 10 percent incremental increase in solids capture. The latter may be or may not be an important consideration in a given plant regarding recycle of solids.

- It should also be noted that the usual chemical used in flotation was a cationic polymer. However, anionic polymer is also sometimes effective and should not be overlooked. This was recently demonstrated at one plant when a metal salt addition to the activated sludge was implemented for operation improvement purposes. This changed the sludge characteristics which required use of an anionic polymer to condition the sludge for flotation, but it appears that there was also a decrease from 8 percent to 6 percent in the floated sludge concentration. In another plant the sludge responded equally to either cationic or anionic polymer conditioning, so that choice could depend in such cases on the relative costs of the two chemicals.

5. Centrifugal Thickening

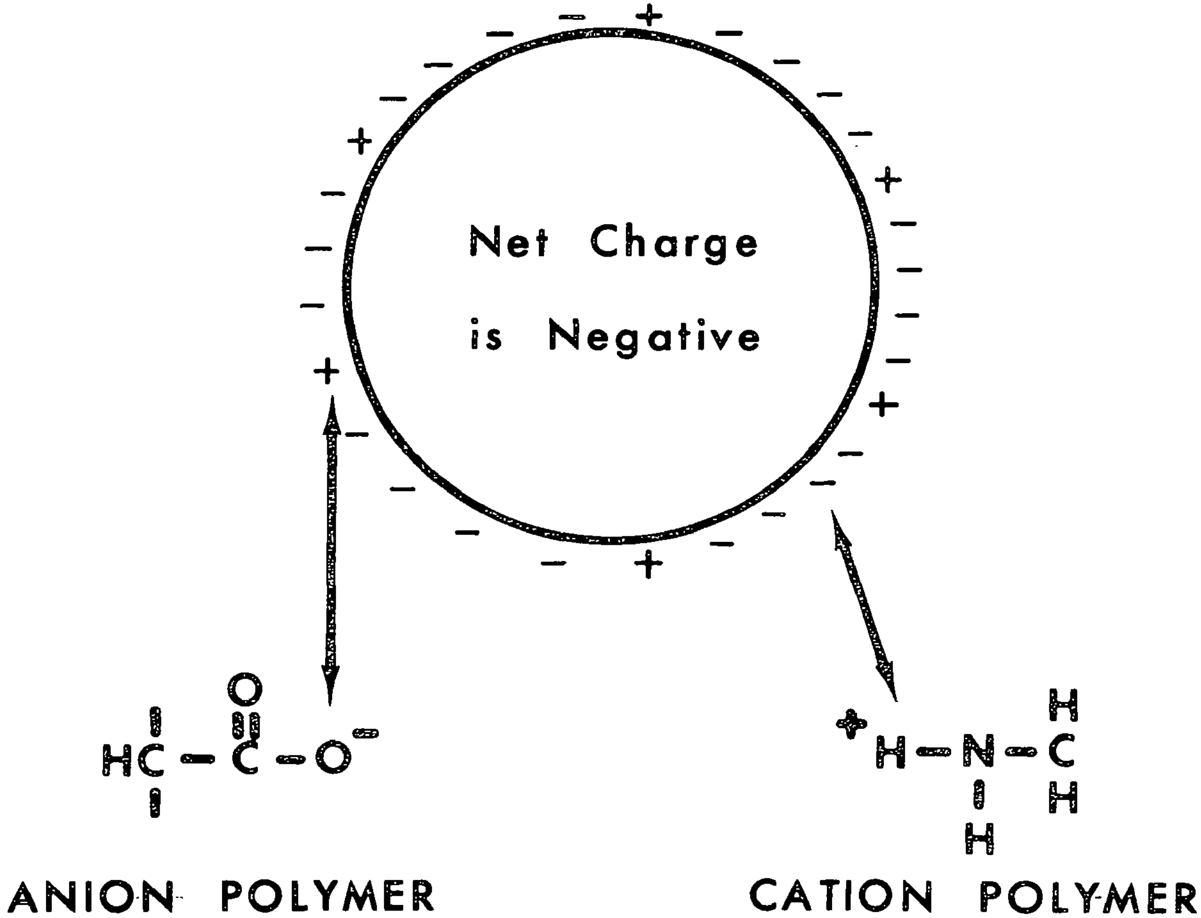
- Centrifugal thickening is accomplished by utilizing centrifugal force which can be developed in a centrifuge to exert the equivalent of 2,000 times the force of gravity that was utilized in gravity thickening previously discussed.

6. Considerations in Design for Thickening

- Provide variable speed sludge pumps so that blending and thickening can be continuous.

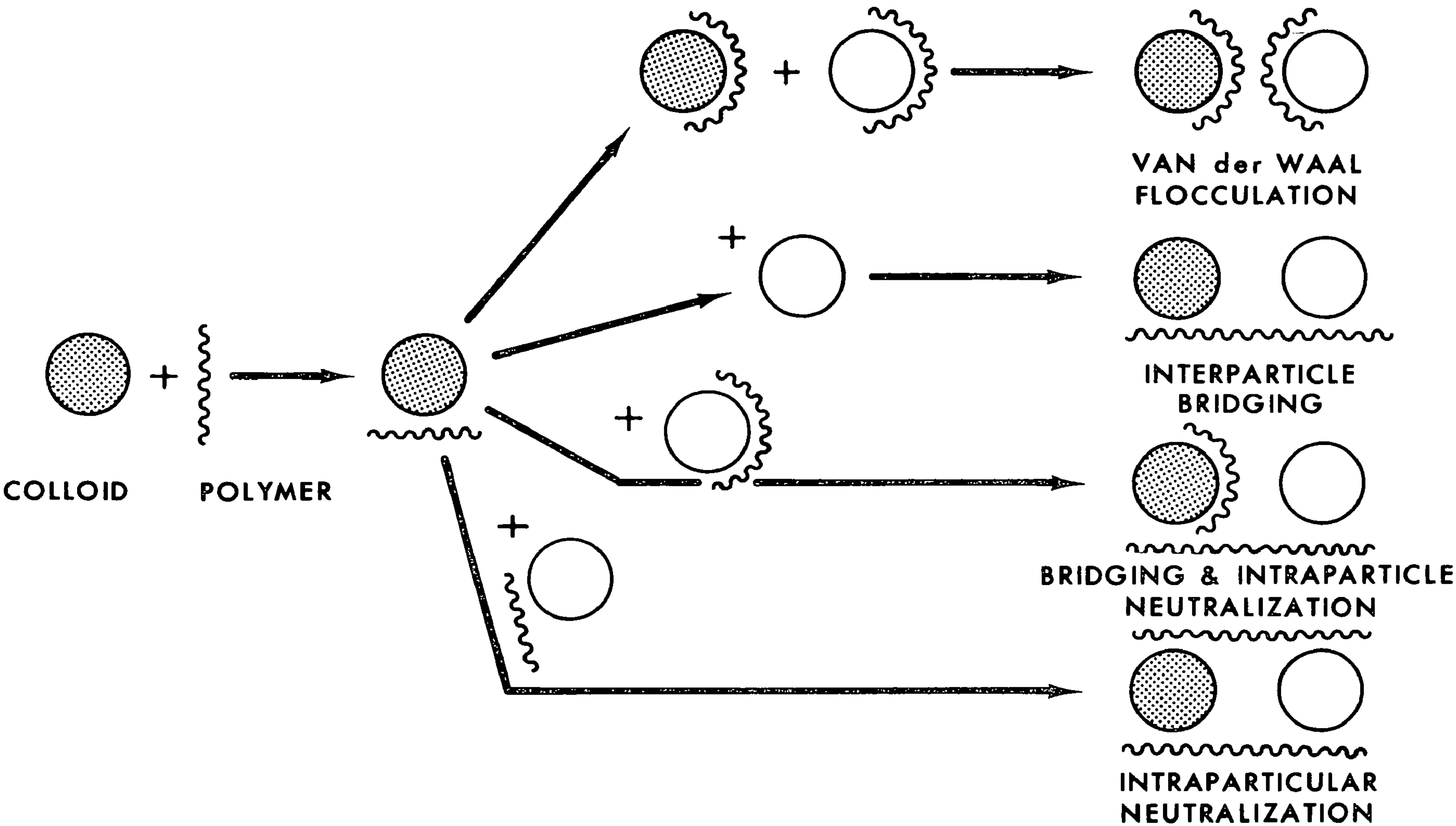
- Provide for possible use of chemicals. Install chemical injection taps into pipelines at points where sludges meet, or water and sludge meet, and also into dilution water line upstream of where water meets the sludge. Install tap for chemical injection immediately downstream of the pressure reducing valve or the water line in the case of dissolved air flotation. Piping design should provide for good mixing of water, sludge and polymer, and then minimum of turbulence and shear to prevent deflocculation.

CHARGED PARTICLE



FIGURE

POLYMER AND PARTICLE INTERACTIONS



FIGURE

SECTION 6 - SLUDGE DEWATERING

1. Definition

- Sludge dewatering in this discussion means further dewatering of slurries to change the physical form of the sludge from a slurry of liquid to a cake which should be a solid. However, some sludge filter cakes are not quite solid enough to keep from splashing when the cakes drop from the filter media onto a conveyor belt.

2. Purpose

- Reduce volume occupied by the solids in case of disposal of sludge cake.
- Reduce water associated with the solids in case of disposal by incineration.
- Change the physical form from liquid to solid for handling purposes.

3. Chemical Sludge Conditioning

- Very few wastewater sludges will dewater without any treatment.
- Inorganic chemicals have been used for many years. The most notable have been iron chloride, calcium oxide, iron sulfate, alum, aluminum chloride. These chemicals are effective in most cases, but history tells us that there have been many failures in the past and we even see them performing poorly in certain plants today.
- The need for something better than the inorganic chemicals led to the development of water soluble polymers for sludge conditioning. Polymers are water soluble, high molecular weight organic chemicals that are available in nonionic (no formal electrical charge), anionic (negatively charged), or cationic (positively charged). These polymers can be made in a variety of charge densities and a variety of molecular weights.
- Other additives that are sometimes used in sludge filtration are fly ash, furnace ash, and diatomaceous earth. Even rice hulls have been used as a sludge filtration aid as well as paper pulp.
- Considerations for design of sludge conditioning process and equipment should include laboratory and pilot plant studies; provide flexibility in the equipment so that a variety of

of conditioning materials could be used; provide variable speed agitators and conditioning tanks where plug flow can be observed and conditioning agents can be added easily in a variety of points along with the conditioning tank for observation; provide for gentle open trough handling of conditioned sludges rather than through pipelines; avoid high shear of conditioned sludge; provide ratio control of conditioning chemical to sludge and also ratio control of water to sludge where polymers may be used.

4. Dewatering Equipment and Results

- Vacuum Filters:
  Coil filter, drum filter, and belt filter are three basic types. Coil filter and belt filter have continuous washing of the media, but usually not found on a drum filter. Drum and belt filters offer opportunity to change type of media but this is not easily done with a coil filter.

  All three types have been used with sludges conditioned with polymers as well as inorganic chemicals.

  Considerations in design of vacuum filtration should take into account the following: the conditioned sludge to the filter pan should be distributed in more than one or two points - this is especially important with regard to low solids concentration sludges; the under-filter agitator should have a variable speed drive - How can a designer possibly know in advance the optimum speed? - make it variable and give the operator some leeway for adjustments and compensations; the eccentric which determines the length of the swing of the under-filter agitator should have provision for variability. Some filters provide no variability; others provide limited variability; proper level control of sludge in the filter pan should be provided so as to maintain continuous sludge conditioning and filtration; filtrate pumps should be of adequate capacity to accommodate as mush as a 40 percent dilution factor when water is used with polymers; vacuum pump capacity should be adequate enough to maintain good vacuum even with more porous cakes which can result with some sludges with polymer or inorganic chemical conditioning; filter valve bridge blocks should be provided for adjustment as necessary in the field.

  Centrifuges: There are three basic types - horizontal solid bowl with scroll, disc type with nozzles, and basket type.

  The horizontal solid bowl is the most widely used in wastewater sludge dewatering. This type of centrifuge can be put on the line and left to operate with only occasional attention. The efficiency of this type of centrifuge can be greatly increased by use of polymers. Internal feed of polymer has been found to reduce polymer dose and appears to be very beneficial.

The disc type centrifuge is like the old farm cream separator. It is used for thickening of activated sludge but has the disadvantage of nozzles which seem to get plugged easily. Screening of the sludge has been tried with some success and at least one installation uses a disc type for thickening to 4 percent solids in series with a horizontal bowl type which dewaters to about 20 percent solids. No polymers are used with the disc type.

The basket type has recently been evaluated and reported to be in contention. Polymers may or may not be used with this type machine which can be automated even though it operates on a batch cycle.

- Sandbeds have been used for sludge dewatering for many years. The more sophisticated type sludges of today, no doubt, have not been dewatering as well as the digested sludges of yesteryears. But that is because present day digested sludges are not very dewaterable without conditioning.

- Press filters, moving bed filters, rotating cylindrical screens and capillary type dewatering devices are marketed in this country, but no large installations are in operation as yet.

5. Polymer Preparation Equipment

- Since polymers are useful and sometimes necessary for sludge conditioning, perhaps a discussion of polymer preparation equipment is in order.

  Polymers are available as dry flakes or powders and also as liquids.

  Preparation of liquid polymers presents no problem because they mix with water very readily.

  Preparation of dry polymers is not difficult but care must be taken when contacting the dry polymers with water. Unless each polymer particle is quickly and thoroughly wetted, the particles stick together to form aggregates of particles from the size and appearance of fish eyes to slubs as large as golf balls or even larger.

  To provide means for preparing solutions of dry polymers, polymer manufacturers have developed manual devices and automatic equipment. Also chemical feed equipment manufacturers have developed their own lines of automatic equipment to meet the needs of the field.

Several manufacturers of automatic equipment for handling and preparing solutions of dry polymers are listed below:

Acrison, Inc., Carlstadt, New Jersey
BIF Corporation, Providence, Rhode Island
Chemix Corporation, Troy, Michigan
Wallace & Tiernan, Belleville, New Jersey

Several polymer manufacturers also market automatic equipment for preparing solutions of dry polymers and these are listed below:

Calgon Corporation, Pittsburgh, Pennsylvania
The Dow Chemical Company, Midland, Michigan
Hercules, Inc., Wilmington, Delaware

SECTION 7 - THERMAL PROCESSING OF SLUDGE

1. High Temperature and High Pressure Sludge Treatment

   - Two basic types - wet air oxidation and thermal conditioning

WET AIR OXIDATION

2. Process Description

   - Flameless combustion, burning of sludge at 450° - 550° F. and high pressures (1,200 psig) with air injection.
   - Equipment - sludge grinder, heating tank, heat exchangers, high pressure reactors, separators, expansion engine and auxiliaries.
   - End products - ash and sludge liquor.
   - Insoluble organics converted to soluble organics CO_2, H_2O, ammonia, sulfates, acetates.
   - At 250° C. and 83.4 percent COD reduction of sludge the oxidized liquor shows a COD of 10,000 mg/l + BOD is only 54 percent of COD.
   - The pH of the oxidized liquor is 4.8.
   - Summation, W.A.O. does reduce sludge volumes and produce a stable solid residue, but the nature of the oxidized acidic liquor and the costs of the process are of some concern.
   - Few installations in operation and very few in design.

THERMAL SLUDGE CONDITIONING

3. Two Similar Processes

   - Porteous steam injection, batch process.
   - Sludge storage - grinding - pre/heater - high pressure and temperature (365° F. and 250 psi) - decanter/thickener - dewatering - auxiliary liquor treatment - off gas deodorizer - steam boiler.
   - Zimpro LPO same as Porteous except adds air via compressors.
   - Farrer same as Zimpro but claims continuous operation mode.

8. Installations

- Porteous - U.S. 1 operating and 2/3 planned (10 in U.K.)
- Zimpro - 14 built and 12 under construction.
- Farrer - No U.S. installations, to my knowledge.

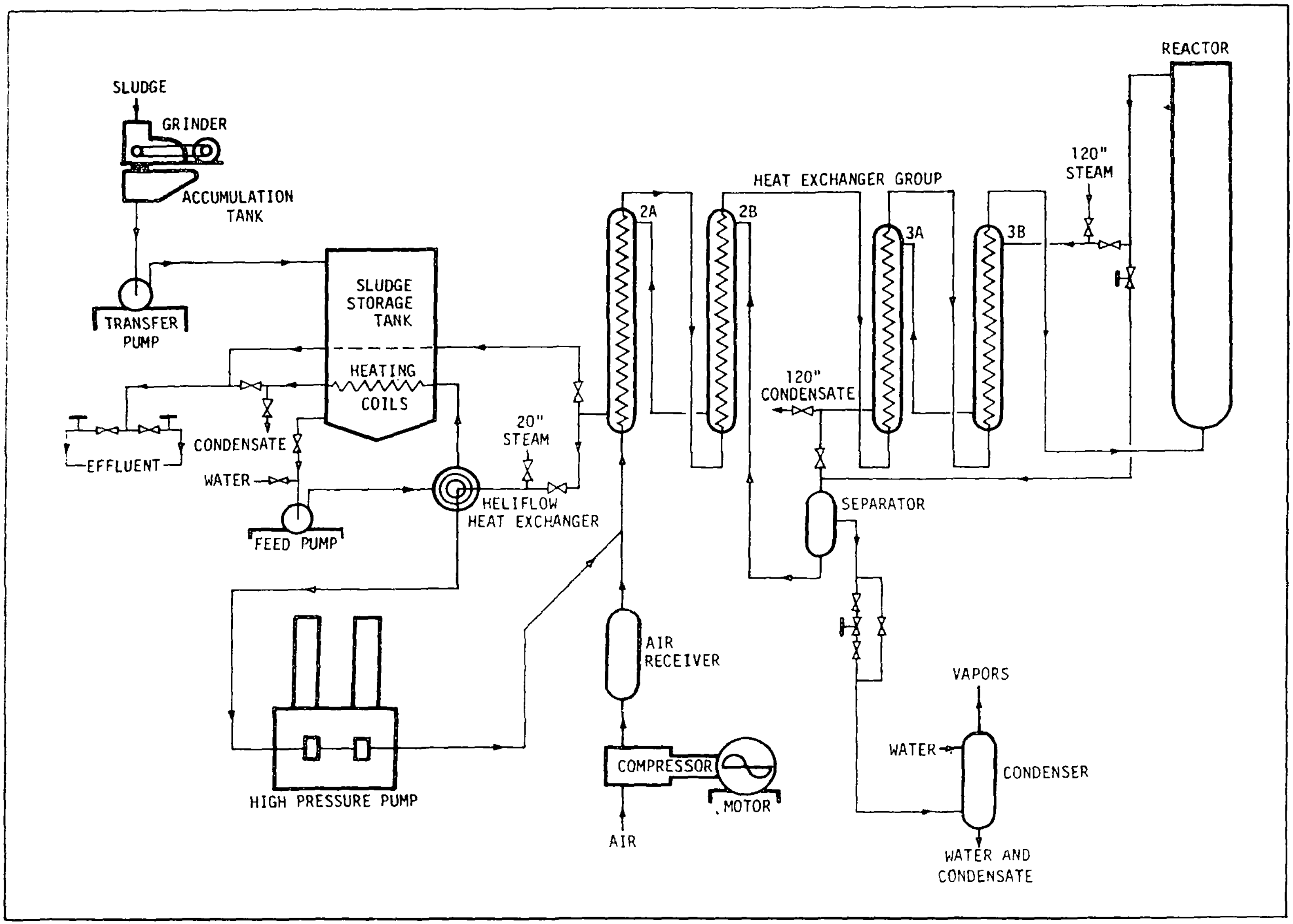


FIGURE WET AIR OXIDATION SYSTEM – WHEELING, WEST VIRGINIA

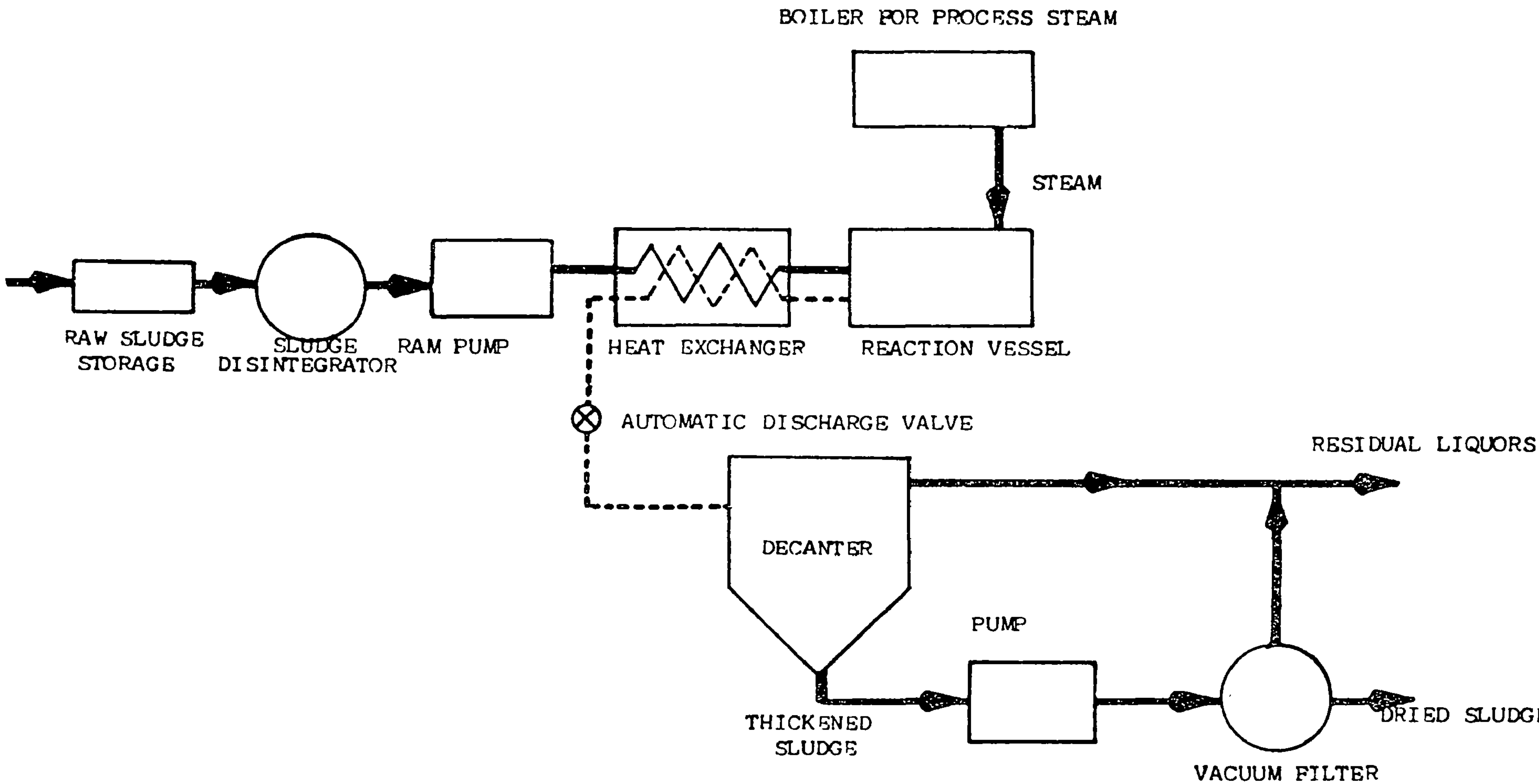


FIGURE **FLOW DIAGRAM OF THE PORTEOUS PROCESS**

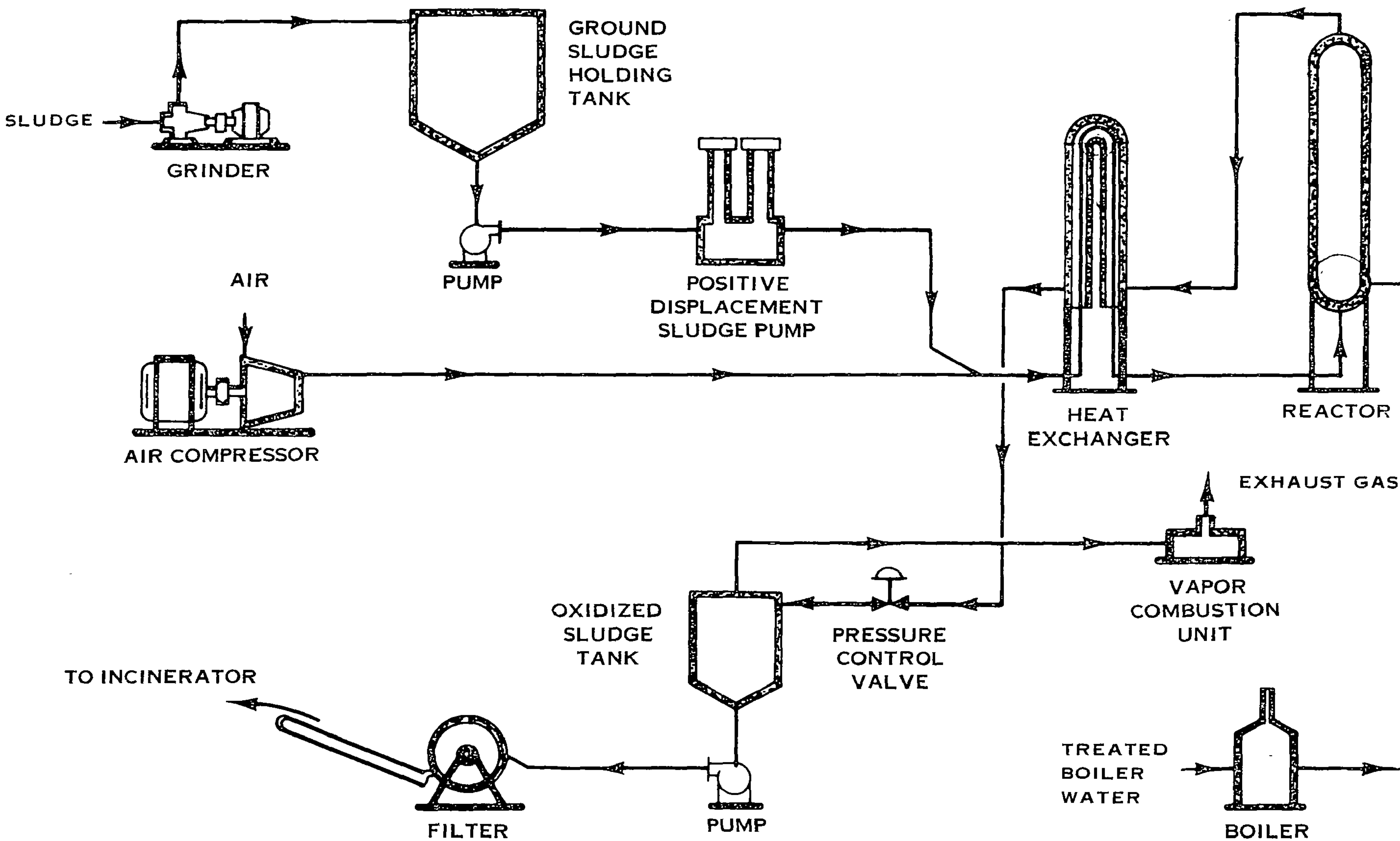


FIGURE THERMAL SLUDGE CONDITIONING AND DEWATERING
ZIMPRO LPO

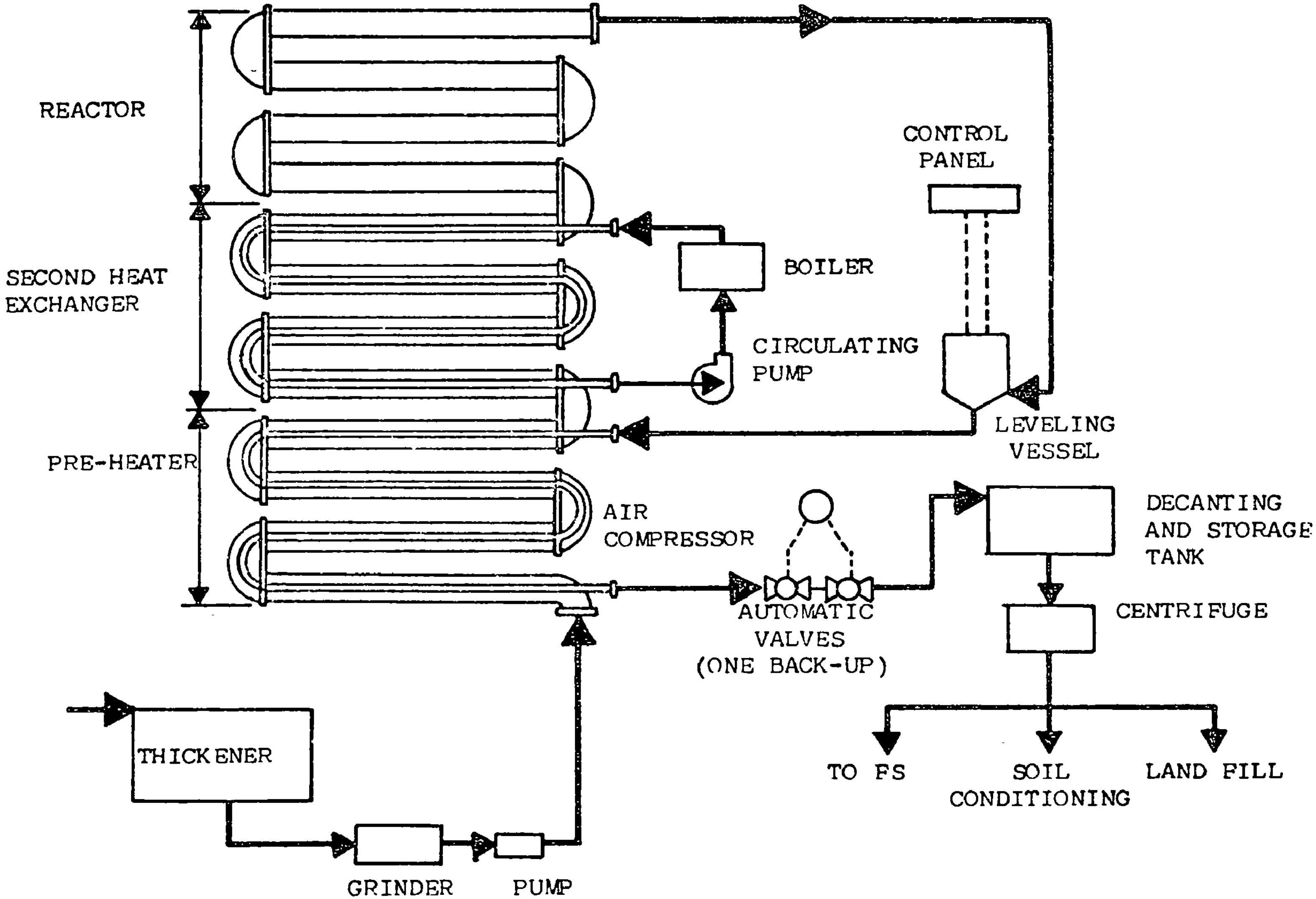


FIGURE FLOW SHEET FOR THE DORR-OLIVER FARRER SYSTEM

SECTION 8 - FINAL DISPOSAL PROCESSES

Ultimate Disposal

- Criteria to follow in selection of method.

  - Should be in accordance with interstate, state, and Federal Quality Office requirements.

  - Should not result in any significant degradation of surface or groundwater, air, or land surfaces.

  - No sludge residues, grit, ash, or other solids should be discharged into the receiving waters or plant effluent.

  - Sludge disposal to ocean waters is not recommended if toxic materials may be transmitted to the aquatic food chain. Present indications are that ocean disposal will be banned.

  - Stabilization of sludge should be considered prior to spreading on land.

- Utlimate disposal is the final treatment process. This transforms the sludge in some instances and places it at its final site.

- Incineration

  - Sludge is burned and reduced to combustion gases or ash.

  - Multiple hearth furnaces range in capacity from 200 to 8,000 lb/hr of dried sludge and operate at 1,700° F.

    a. Furnace consists of refractory lined circular steel shell with refractory hearths, which lie one above the other.

    b. Sludge enters through flopgate and proceeds with the help of rabble arms to move down from hearth until ash discharges at bottom.

    c. Reported total annual cost for incineration varies between $10 and about $30/ton dry solids depending on the need for supplemental fuel, pollution control, etc.

    d. Typical section of multiple hearth incinerator is shown in Figure.

  In a fluidized bed furnace, the dewatered sludge is fed into a fluidized sanbed that is supported by air at 3.5 to 5.0 psi.

a. The sludge solids are normally first degritted.

b. Fluid bed reactor is a single chamber unit where moisture evaporates and combustion of organics occurs at 1,400 to 1,500° F.

c. Reported total operating costs vary between about $26 to $35/ton dry solids depending on the supplemental fuel requirement.

d. Typical section of a fluid bed reactor is shown in Figure.

- Use of Sludge in Agriculture

  - Stabilized, either biologically or by some other mode, sludge may be used as a fertilizer or soil supplement. Raw sludge presents health and nuisance problems.

  - Transportation costs must be considered.

  - Fertilizer value is normally measured by the nitrogen, phosphorus, and potash content.

    Fertilizer Value of Undigested Biological Sludge

Nitrogen	1 - 5%
Phosphate	1 - 3%
Potash	0.1 - 0.3%

  - The nitrogen and phosphorus contents are generally reduced 40-50 percent by digestion.

  - Transportation costs can make this mode of disposal uneconomical.

  - Advantages of land spreading are:

    a. economy.

    b. it is the final treatment process.

    c. it utilizes the water, nutrients, and organic material.

    d. it is nuisance-free if done right.

  - Disadvantages are:

    a. creation of health hazards and nuisance conditions when done wrong.

    b. possible accumulation of toxic metals.

c. possible nitrate contamination of groundwater.

. Quantity of sludge to be spread is determined by:

a. soil characteristics.

b. climate.

c. land use or intended crop.

d. type and solids content of the sludge.

. Typical application rates:

a. for a corn field - 10-30 tons of solids/acre/yr.

b. for a strip mine - 1,000 tons of solids/acre/yr.

- Composting

. Received attention because of its applicability to organic, industrial, agricultural as well as domestic sludges.

. Degree of interest in this country as well as abroad is dwindling for economic reasons.

. Difficulty exists in finding a market for the product.

- Lagooning and Landfill

. Lagoons may be used for:

a. anaerobic digesters but aesthetics may rule this out.

b. as evaporation ponds.

d. as permanent lagoons or landfills - if dewatering is incomplete a full permanent lagoon remains as a permanent liability.

. Area requirement and management are important.

- Drying of Sludge Filter Cake

. Sell as soil conditioner.

. Sell for manufacture of commerical fertilizer.

. Reported to be safe hygienically.

. Process is used in Houston, Milwaukee, and Chicago.

- Reported cost is approximately $45/ton dry solids, net for Chicago.
- Figure shows equipment used in flash drying.

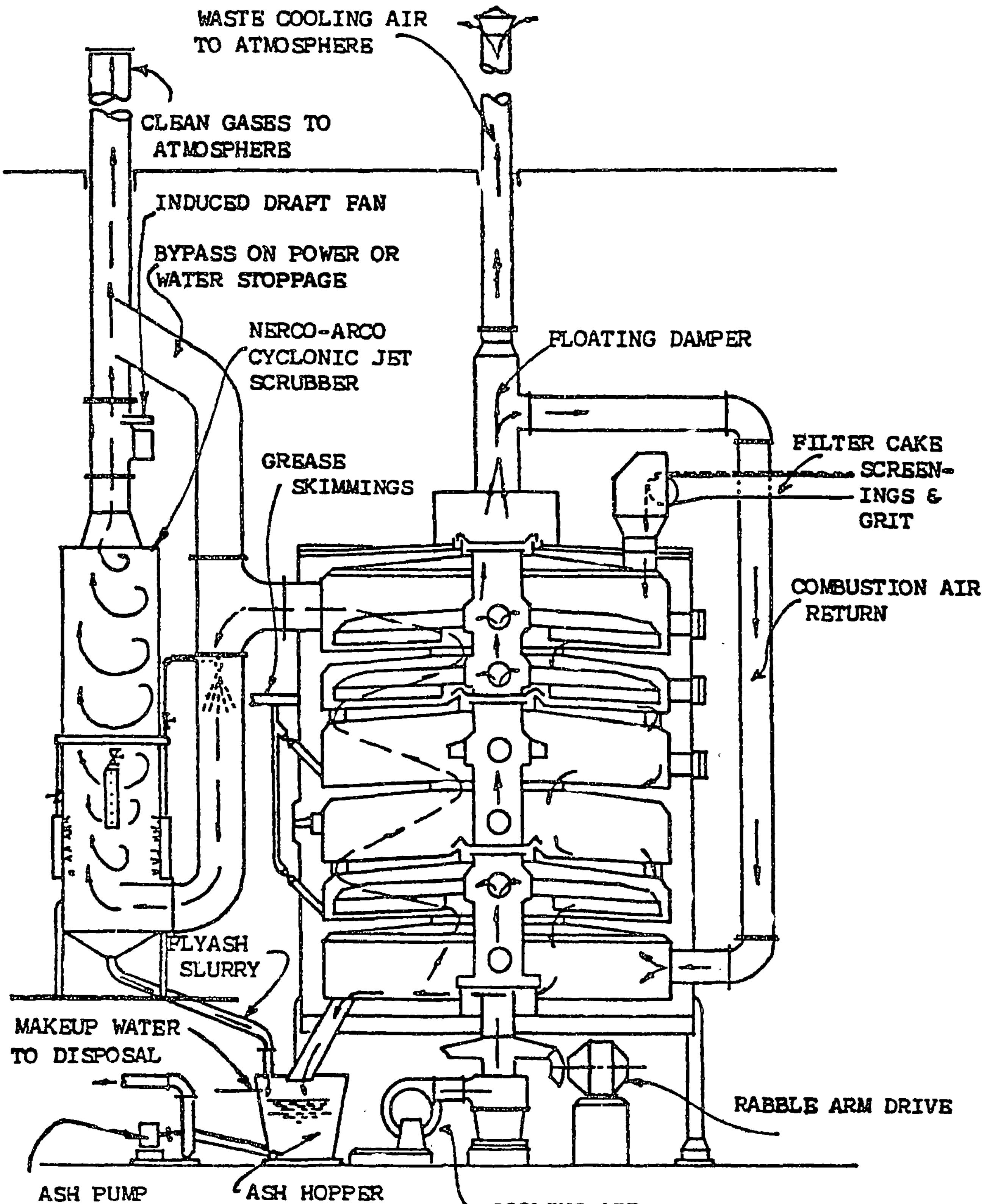


FIGURE TYPICAL SECTION OF MULTIPLE HEARTH INCINERATOR

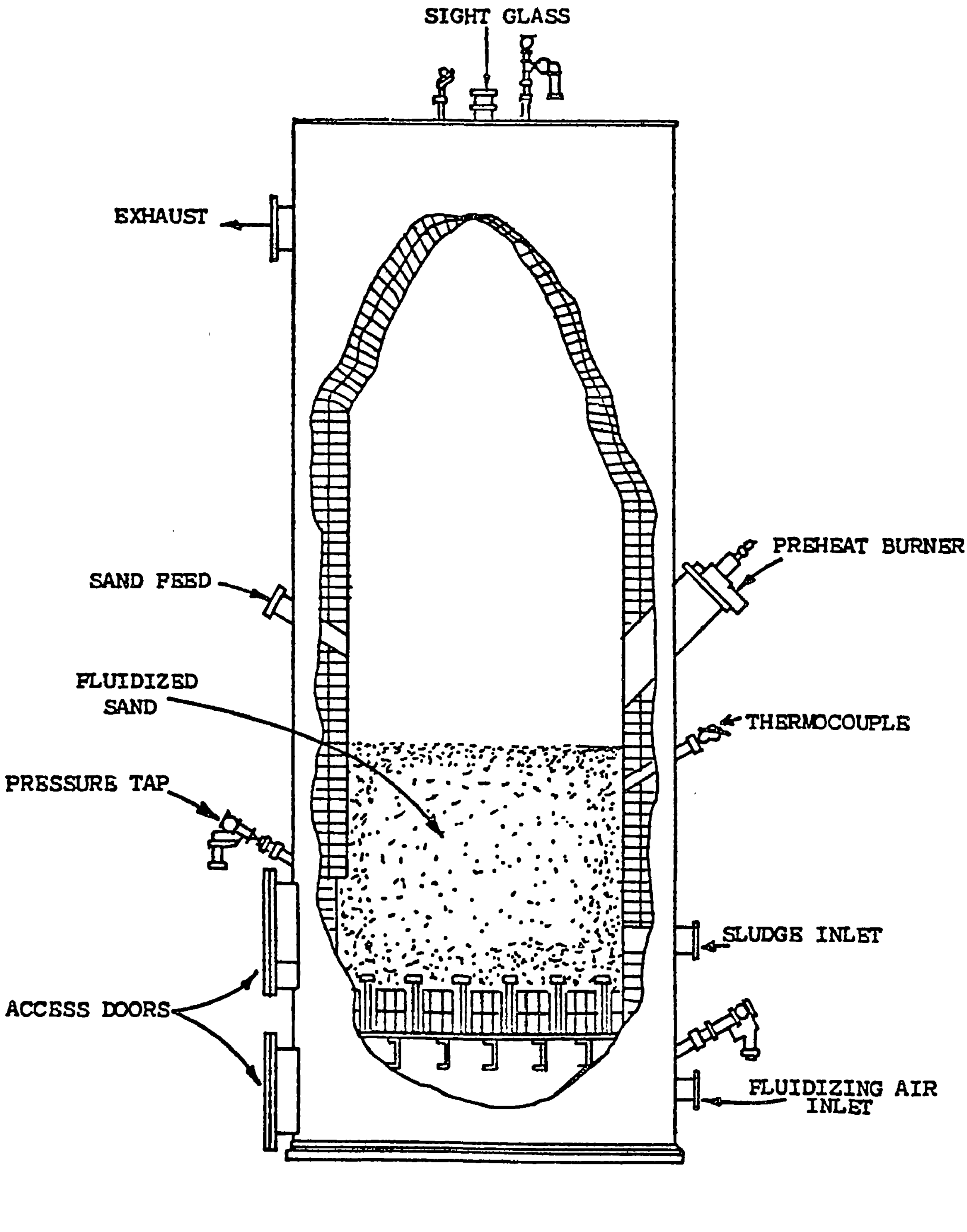
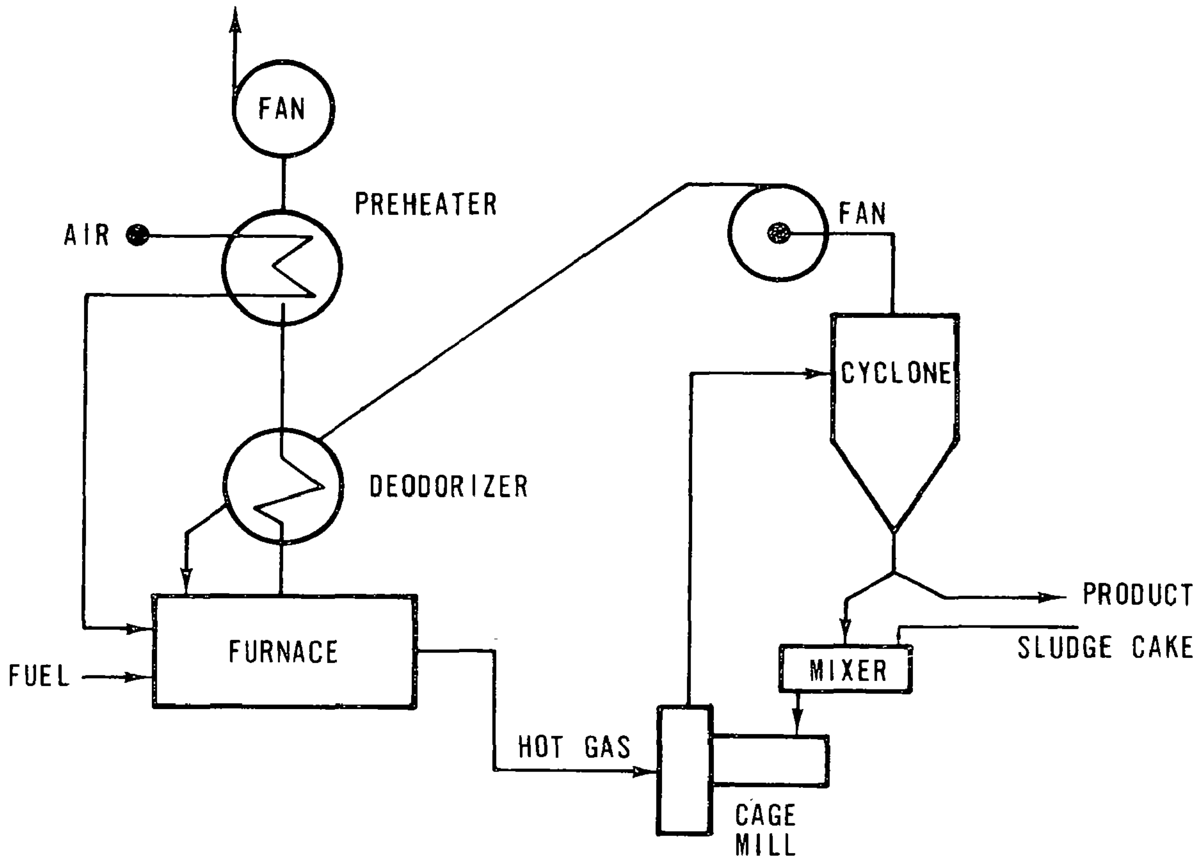


FIGURE TYPICAL SECTION OF A FLUID BED REACTOR (DORR-OLIVER, INC.)

FLASH DRYING



FIGURE

UPGRADING EXISTING SECONDARY TREATMENT PLANTS

UPGRADING EXISTING ACTIVATED SLUDGE PLANTS

1. Conventional Activated Sludge Process

A - Uses micro-organisms in suspension to oxidize soluble and colloidal organics to CO_2 and H_2O in presence of oxygen.

(1) Wastewater commonly aerated 6 to 8 hours

(2) Return sludge normally about 25 percent

(3) BOD loadings about 35 lbs/1000 cu.ft./day

B - Common characteristics

(1) High oxygen demand at head end of aeration tank

(2) Final clarifier has high solids loading

(3) Lack of operational stability with variations in hydraulic and organic loadings

2. Activated Sludge Modifications

A - Step aeration divides influent flow to aeration tank

(1) Reduces initial oxygen demand

(2) Distributes organic loading more evenly

(3) More efficient utilization of micro-organisms (loadings to 50 lbs BOD/1000 cu.ft. per day)

(4) Normally will not use more air

B - Contact stabilization

(1) Concentrated sludge is reaerated

(2) Shorter total contact time

(3) Handles greater shock and toxic loads

(4) Majority of activated sludge is isolated from main stream of plant

(5) Common detention times

(a) Contact tank: 0.5 - 1.0 hrs

(b) Stabilization tank: 2 - 6 hrs

(6) Most beneficial when organic load is present, mainly in colloidal state

(7) Smaller plants may require greater contact times due to extreme flow variations

C - Completely mixed

(1) Influent waste and recycled sludge introduced uniformly throughout aeration tank

(a) Uniform oxygen demand throughout tank

(b) Operational stability for slug loads

D - Oxygen aeration

(1) Covered aeration tank

(2) Uses pure (>90%) oxygen instead of air

(3) Oxygen can be site-generated or transported

(4) Potential advantages

(a) Reduced costs

(b) Reduced sludge

(c) Higher D.O.

(d) Reliable process control

3. Basic Design Parameters for Activated Sludge

A - BOD removal for specific operating conditions

(1) Influent BOD

(2) Sludge recycle

(3) MLVSS

(4) Aeration detention

B - Air requirements

Typical requirements for AS modifications:

Process	Cu.ft. air/lb BOD removed
Conventional	700 to 1,000
Step Aeration	500 to 700
Contact Stabilization	750
Complete Mix	600

C - Sludge production (excess)

(1) Excess sludge related to organic loading

(2) For common AS loadings (0.3 to 0.6 lb BOD/lb MLVSS/day) excess sludge about 0.5 to 0.7 lbs VSS/lb BOD removed

(3) For O_2 loadings of 0.4 to 0.8 excess sludge production about 0.3 to 0.45 lb VSS/lb BOD removed

D - Oxygen Transfer Rates

(1) Temperature

(2) Degree of turbulent mixing

(3) Liquid depth in aeration tank

(4) Type of aeration device

(5) Characteristics of wastewater

E - Activated sludge return

(1) Key tool for plant operator

(2) 50% min. for conventional and step aeration

(3) 100% min. for contact stabilization and complete mix

F - Pilot studies. Range up to 5 to 10 gpm to generate design parameters

(1) Evaluate performance and characteristics under various organic loadings (lbs BOD/day/lb MLVSS)

(a) BOD removal

(b) COD removal

(c) Oxygen consumption

(d) Concentration of biological solids

(e) Physical nature of effluent (ss, odor, color)

4. Upgrading Techniques

A - To relieve organic and hydraulic overloading. Provide higher air rate.

(a) Mechanical

(b) Diffused

B - Conventional AS to step aeration

(1) Requires minimum capital investment for overloaded plant

(a) Modify piping

(b) Renovate air system

(c) Increase secondary clarifier capacity

(2) Upgrading overloaded 5 mgd conventional AS to 8.4 mgd step aeration with same efficiency - $410,000

C - Conventional AS to contact stabilization

(1) Modify piping

(2) Expand sludge recycle

(3) Install new mechanical aerators

(4) Upgraded overloaded 1.2 mgd AS plant to 3.0 mgd contact stabilization for $370,000. Effluent from 40 mg/l BOD to 20 mg/l

D - Conventional AS to completely-mixed

E - Conventional AS to oxygen aeration

(1) Precast covers for aeration tanks

(2) Baffling may be required

(3) Piping modified

(4) Oxygen generating and/or storage

(5) Reduced sludge production

F - Upgrading non-overloaded AS plant to meet higher effluent standards

(1) Additional pre-AS treatment

(a) Roughing trickling filter

(b) Chemical clarification

(2) Additional post-AS treatment

(a) 2nd stage activated sludge

(b) Polishing lagoon

(c) Multi-media filters

(d) Microstraining

(e) Activated carbon

5. Chemical Clarification for Solids and BOD Reduction

A - Primary clarification

(1) Increase in primary sludge dewatered (more easily dewater and thickened)

(2) Decrease in quantity of secondary sludge

(3) Decrease in organic loading to secondary treatment units

B - Secondary clarification

(1) Hydraulic overloading - rise velocity of wastewater exceeds settling velocity of solids

(2) Organic overloading - increased solids load to secondary clarifier

C - Chemical addition to primary clarifier

(1) For intermittent or varying flows

(2) Limited space for additional clarifiers

(3) Industrial wastes hindering biological treatment

(4) Hydraulic or organic overload

(5) Interim improvement

(6) Chemicals used

(a) Salts of iron

(b) Salts of aluminum

(c) Lime

(d) Polyelectrolyte

D - Chemical addition to secondary clarifier - less experience

(1) Same chemicals as in primary

(2) Phosphorus removal added benefit (or vice-versa)

6. Miscellaneous Upgrading Techniques

A - Correction of poor initial design

(1) Inlet and outlet design

(2) Sludge withdrawal system

(3) Lack of scum removal devices

B - Use of tube settlers

(1) Used in primary or secondary clarifiers

(2) Capture solids at high overflow rates

(3) Do little for efficient primary clarifiers

(4) Do no remove colloidal solids

7. Effluent Polishing Techniques

A - Polishing lagoons

(1) Aerobic

a) Shallow - may have solids carryover due to algae

b) Deep - use mechanical aeration

(2) Facultative - aerobic and anaerobic zones

B - Microstraining

C - Filtration

(1) Deep bed coarse sand filters - 4 ft. depth, 1-3 mm diam

(2) Mixed media - anthracite and sand

(3) Multi-media - anthracite, sand, garnet

(4) Activated carbon

a) As "tertiary" treatment

b) Used as adsorption medium

c) Pre-filter is SS $>$50 mg/l

d) Requires regeneration

e) Used at Tahoe - effluent BOD 2-5 mg/l

(5) Pre-aeration: Upgrading for SS and BOD removal limited - used for reducing septicity and grease removal

(6) Post-aeration: Maintain D.O. in effluent

a) Diffused

b) Mechanical

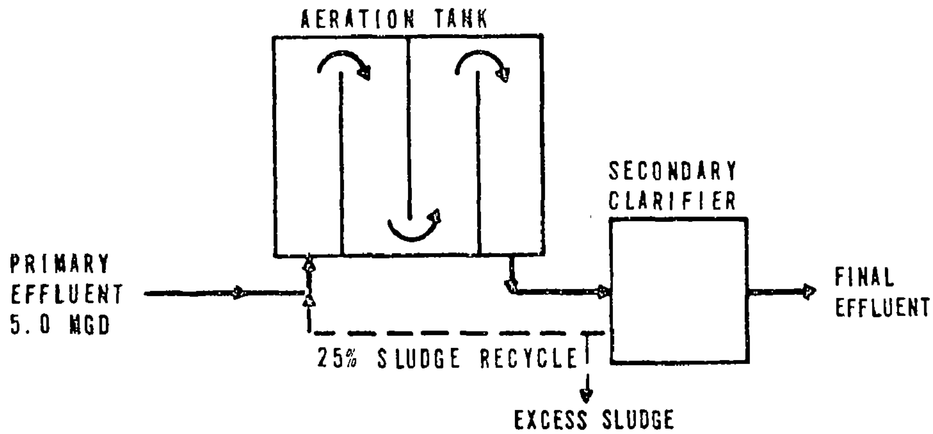
c) Cascade

d) U-Tube

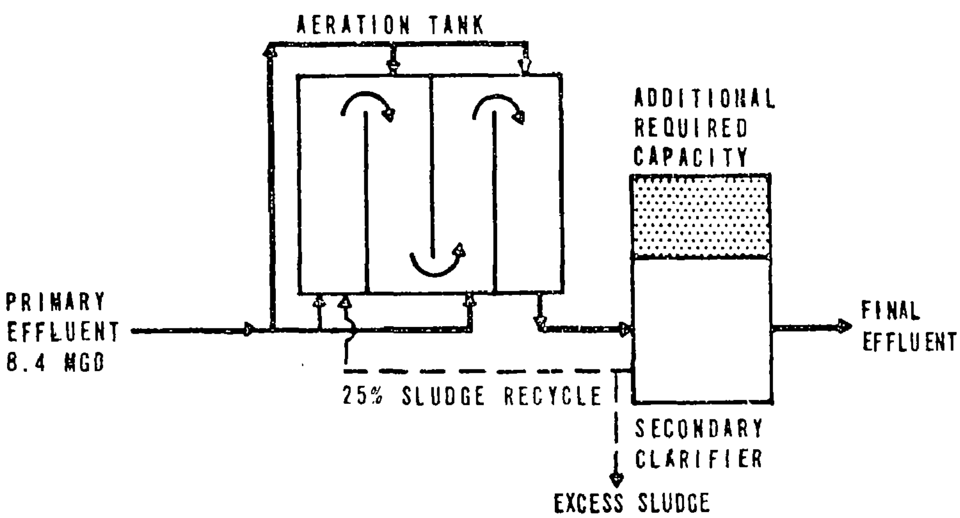
UPGRADING A CONVENTIONAL ACTIVATED SLUDGE PROCESS

TO STEP AERATION

EXAMPLE A



TREATMENT SYSTEM BEFORE UPGRADING
CONVENTIONAL ACTIVATED SLUDGE (DIFFUSED AIR SYSTEM)



TREATMENT SYSTEM AFTER UPGRADING
STEP AERATION PROCESS

FIGURE 1

Upgrading Conventional
Activated Sludge to Step Aeration - Example A

Description	Original Design Before Overloading	Overloaded Design Condition	Upgraded Design Condition
Flow, mgd	5.0	8.4	8.4
Influent BOD, mg/l	200	200	200
Primary Treatment			
Percent BOD Removal	30	30[1]	30
Aeration Tank			
MLSS, mg/l	2,000	-	2,000
Sludge Recycle, percent	25	15	25
Air Requirement, cu.ft. air/lb. BOD removed	800	-	700
Volumetric Loading, lbs. BOD/day/1,000 cu.ft.	35	62	62
Organic Loading, lbs. BOD/day/lb. MLSS	0.34	0.88	0.54
Detention Time in Aerator, minutes[2]	300	180	180
Secondary Clarifier			
Overflow Rate, gpd/sq.ft.	800	1,280	800
Secondary Treatment			
Percent BOD Removal	86.0	75.0	86.0
Effluent BOD, mg/l	20	35	20

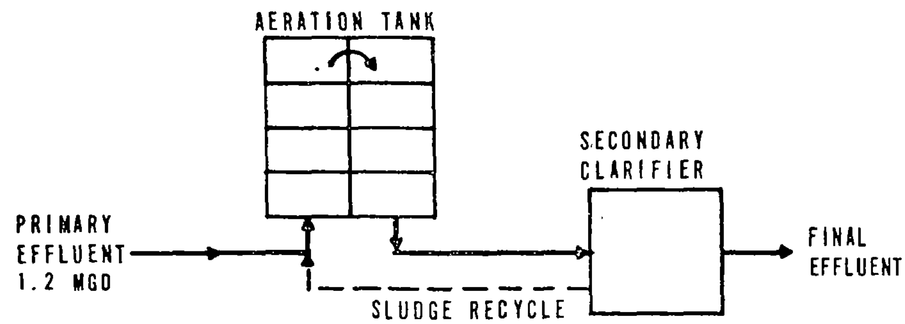
[1]Requires modification of primary clarifier to handle increased hydraulic load to achieve 30 percent BOD removal.

[2]Excluding sludge recycle.

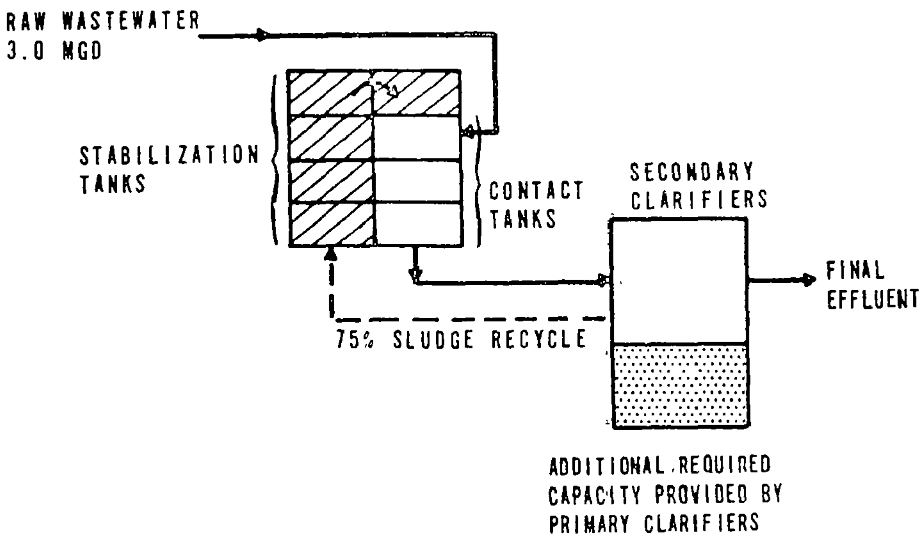
TABLE 1

UPGRADING A CONVENTIONAL ACTIVATED SLUDGE PROCESS TO CONTACT STABILIZATION

EXAMPLE B



TREATMENT SYSTEM BEFORE UPGRADING
CONVENTIONAL ACTIVATED SLUDGE (MECHANICAL AIR SYSTEM)



TREATMENT SYSTEM AFTER UPGRADING
CONTACT STABILIZATION PROCESS

FIGURE 2

Upgrading Conventional Activated
Sludge to Contact Stabilization - Example B

Description	Overloaded Design Condition	Upgraded Design Condition
Flow, mgd	3.0	3.0
Influent BOD, mg/l	200	200
Primary Clarifier		
Overflow Rate, gpd/sq.ft.	1,200	-[1]
BOD Removal, percent	20	-[1]
Aeration Tank		
Volumetric Loading, lbs. BOD/day/1,000 cu.ft.	44	60[2]
Sludge Recycle, percent	15	75
Detention Time, hours	4.4[3]	-
Contact Basin	-	1.1[4]
Stabilization Basin	-	4.2[5]
Secondary Clarifier		
Overflow Rate, gpd/sq.ft.	960	780[6]
BOD Removal in Secondary Units	75	90
SS Removal in Secondary Units	75	90
Effluent BOD, mg/l	40	20
Effluent SS, mg/l	30	18

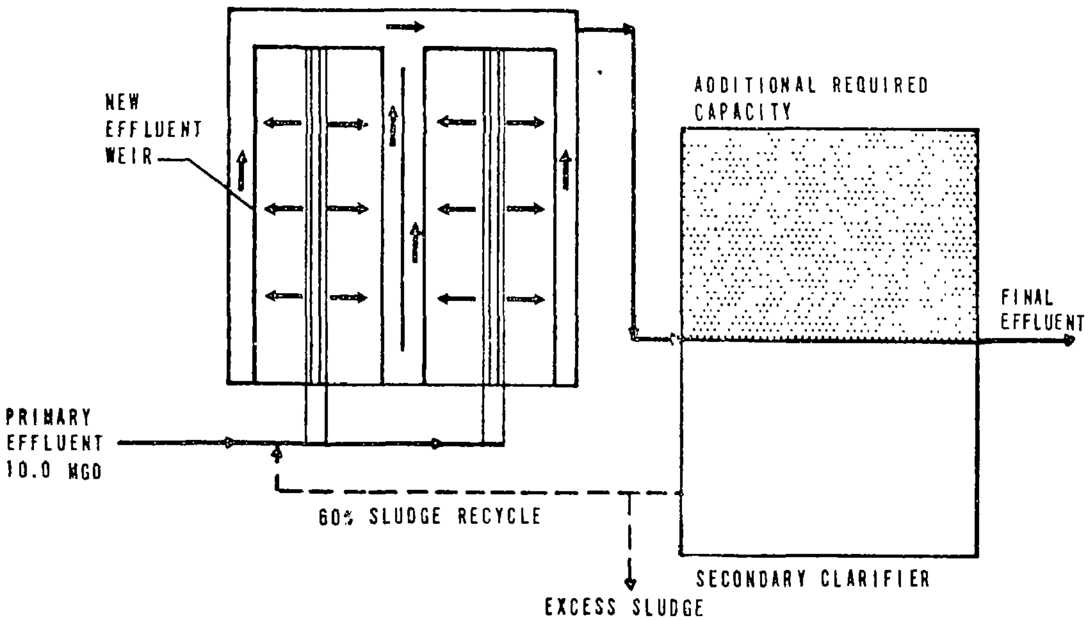
[1]Primary clarifier converted to secondary clarifier.
[2]Total organic loading increases due to elimination of primary treatment.
[3]Based on influent flow plus 15 percent sludge recycle to the total basin.
[4]Based on influent flow plus 75 percent sludge recycle to the contact basin.
[5]Based on 75 percent sludge recycle to the stabilization basin.
[6]Reduction in OFR is achieved by converting the primary clarifier to a secondary basin.

TABLE 2

UPGRADING CONVENTIONAL ACTIVATED SLUDGE
TO A COMPLETELY-MIXED SYSTEM

EXAMPLE C

TREATMENT SYSTEM AFTER UPGRADING TO
COMPLETELY-MIXED PROCESS



TYPICAL CROSS SECTION OF UPGRADED
AERATION TANK (26)

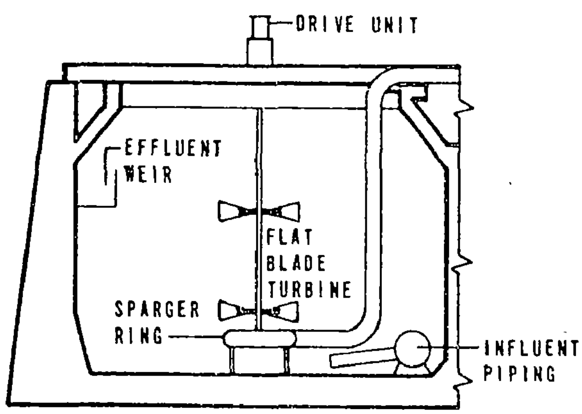


FIGURE 3

Upgrading Conventional Activated
Sludge to a Completely-Mixed System - Example C

Description	Original Design Before Overloading	Overloaded Design Condition	Upgraded Design Condition
Flow, mgd	5.0	10.0	10.0
Influent BOD, mg/l	200	305	305
Primary Treatment			
Percent BOD Removal	30	30[1]	30
Aeration Tank			
MLSS, mg/l	2,000	2,000	3,000
Sludge Recycle, percent	25	25	60
Air Requirements, cu.ft. air/lb. BOD removed	820	–	600
Volumetric Loading, lbs. BOD/day/1,000 cu.ft.	35	107	107
Organic Loading, lbs. BOD/day/lb. MLSS	0.34	1.04	0.69
Detention Time In Aerator, minutes[2]	300	150	150
Secondary Clarifier			
Overflow Rate, gpd/sq.ft.	800	1,600	800
Secondary Treatment			
Percent BOD Removal	86	62	91
Effluent BOD, mg/l	20	80	20

[1]Requires modification of primary clarifier to handle increased hydraulic load to achieve 30 percent BOD removal.

[2]Excluding sludge recycle.

TABLE 3

Upgrading Conventional Activated
Sludge to an Oxygen Aeration System - Example D

Description	Original Design Before Overloading	Overloaded Design Condition	Upgraded Design Condition
Flow, mgd	2	6	6
Influent BOD, mg/l	200	200	200
Primary Treatment			
Percent BOD Removal	30	30[1]	30
Aeration Tank			
MLSS, mg/l	2,000	2,000	4,000
Sludge Recycle, percent	25	25	50
Air Requirements, cu.ft. air/lb. BOD removed	800	–	–
Oxygen Requirements, lbs. O_2/lb. BOD removed	–	–	1.2
Volumetric Loading, lbs. BOD/day/1,000 cu.ft.	35	105	105
Organic Loading, lbs. BOD/day/lb. MLSS	0.34	1.02	0.51
Detention Time in Aerator, minutes[2]	300	100	100
Secondary Clarifier			
Overflow Rate, gpd/sq.ft.	800	–	800
Secondary Treatment			
Percent BOD Removal	86	64	86
Effluent BOD, mg/l	20	50	20

[1]Requires modification of the primary clarifier to handle increased hydraulic load to achieve 30 percent BOD removal.

[2]Excluding sludge recycle.

TABLE 4

Approximate Capital Costs for Upgrading

Example A:	Aeration Tank Modification	$160,000
	Secondary Clarifier Expansion	250,000
		$410,000

($120/1000 gpd incremental upgraded capacity)

Example B:	Aeration Tank Modification	$340,000
	Clarifier Conversion	30,000
		$370,000

($206/1000 gpd incremental upgarded capacity)

Example C:	Aeration Tank Modifications	$280,000
	Secondary Clarifier Expansion	420,000
		$700,000

($140/1000 gpd incremental upgraded capacity)

Example D:	Aeration Tank Modifications	$130,000
	Oxygen Generating and Dissolution Equipment	400,000
	Secondary Clarifier Expansion	170,000
		$700,000

($170/1000 gpd incremental upgraded capacity)

Costs based on ENR Index of 1500

TABLE 5

UPGRADING EXISTING SECONDARY TREATMENT PLANTS

Trickling Filters

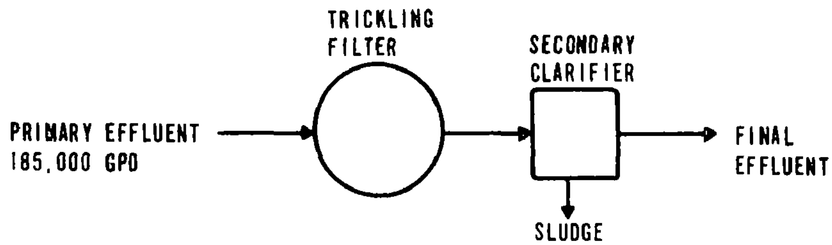
- Upgrade to relieve organic and/or hydraulic overloading
- Upgrade to increase organic removal efficiency
  - . Upgrade existing single stage filter
  - . Upgrade single stage filter to a two-stage biological system
  - . Upgrade two-stage filter to a multi-stage biological system
  - . Add processes prior to existing trickling filter plant
  - . Modify existing trickling filter plant
  - . Add processes following existing trickling filter plant
- Factors to consider prior to upgrading trickling filter plant
  - . Capacity of distributor arm
  - . Ventilation in all pipes, channels and drains
  - . Decide whether to use direct recirculation after filter or recirculation of clarified effluent
  - . Evaluate secondary clarifier capacity
  - . Performance and capacity of sludge collection and handling facilities - upgrading usually increases sludge production
- Example

  Upgrading low-rate trickling filter to high rate

  - . Original plant design
    - Flow - 185,000 gpd
    - Influent . BOD - 230 mg/1
      . S.S. - 210 mg/1
    - Effluent . BOD - 30 mg/1
      . S.S. - 23 mg/1
    - Overall plant performance
      . BOD Removal 87%
      . SS Removal 89%

. Overloaded conditions

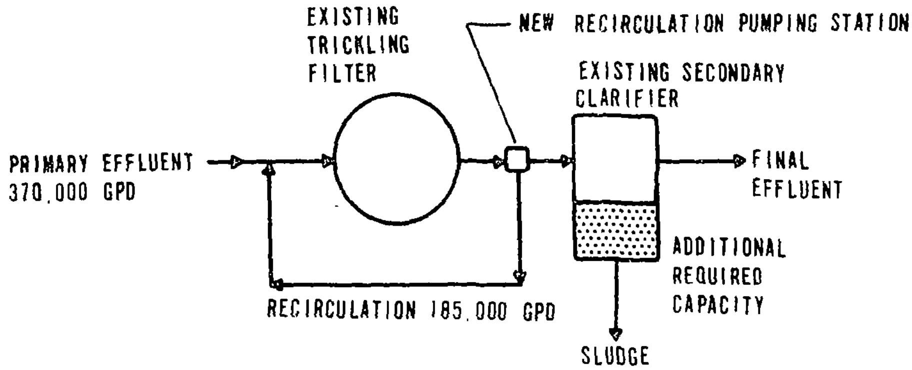
- flow - 370,000 gpd
- influent . BOD - 210 mg/1
  . S.S. - 200 mg/1
- effluent . BOD - 44 mg/1
  . S.S.- 36 mg/1
- overall plant performance
  . BOD Removal - 79%
  . S.S. Removal - 82%



TREATMENT SYSTEM BEFORE UPGRADING

. Upgrading considerations and conditions

- determined recycle rate 0.5
- replaced distributor arm (hydraulic capacity)
- motorized distributor arm (hydraulic head)
- existing filter media and drains were found to be sufficient
- constructed recirculation pumping station with variable - speed pumping capacity regulated with flow - proportioning pump controls
- increased primary and secondary clarifier capacities
- effluent . BOD - 30 mg/1
  . S.S. - 22 mg/1
- overall plant performance
  . BOD removal - 86%
  . S.S. removal - 89%



TREATMENT SYSTEM AFTER UPGRADING

- Capital costs estimated for upgrading

.	Trickling filter modifications -------	$51,000
.	Recirculation facilities -------------	15,000
.	Secondary clarifier expansion---------	30,000
	total -------------	$ 96,000

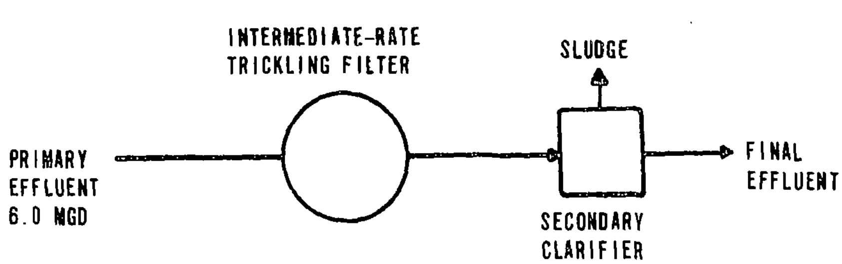
ENR index of 1,500

- Example

Upgrading single-stage trickling filter to a two-stage

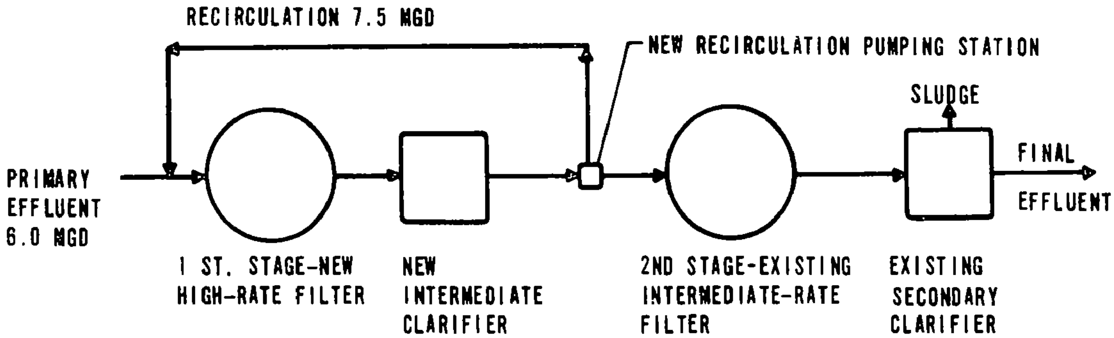
. Overloaded condition

-	flow		6 mg/l
-	influent	. BOD	335 mg/l
		. S.S.	340 mg/l
-	effluent	. BOD	99 mg/l
		. S.S.	85 mg/l
-	overall plant performance		
		. BOD removal	72%
		. S.S. removal	75%



TREATMENT SYSTEM BEFORE UPGRADING

- Upgrading considerations and conditions
  - decision to add a complete set of units was made
  - added a high-rate trickling filter and intermediate clarifier ahead of existing system
  - added new recirculation pumping station
  - effluent
    - BOD 20 mg/1
    - S.S. 15 mg/1
  - overall plant performance
    - BOD removal 94%
    - S.S. removal 96%



TREATMENT SYSTEM AFTER UPGRADING

- Capital costs estimated for upgrading

. Trickling filter additions ---------------	$ 1,000,000
. Recirculation facilities -----------------	100,000
. Intermediate clarifier -------------------	400,000
total ----------	$ 1,500,000

<u>ENR index of 1,500</u>

Lagoons

- Upgrade lagoons to relieve organic overloading and increase organic removal

  - Increased pond detention time increases BOD removal

  - Decrease areal BOD loading

    - pretreatment (primary sedimentation prior to raw sewage pond system)

  - Decrease areal BOD loading and increase detention time (increase number of ponds in system)

  - Use lagoon recirculation

    - interpond and intrapond systems

  - Lagoon - configuration

    - full use of wetted pond area
    - eliminate dead spots
    - eliminate short-circuiting
    - location of transfer inlets and outlets important
    - consider wind directions for possible scum problems

  - Evaluate feed and withdrawal design - maybe multiple entry and single exit

  - Evaluate dike construction

  - Consider aeration and mixing

  - Algae removal

    - mechanical
    - sedimentation pond

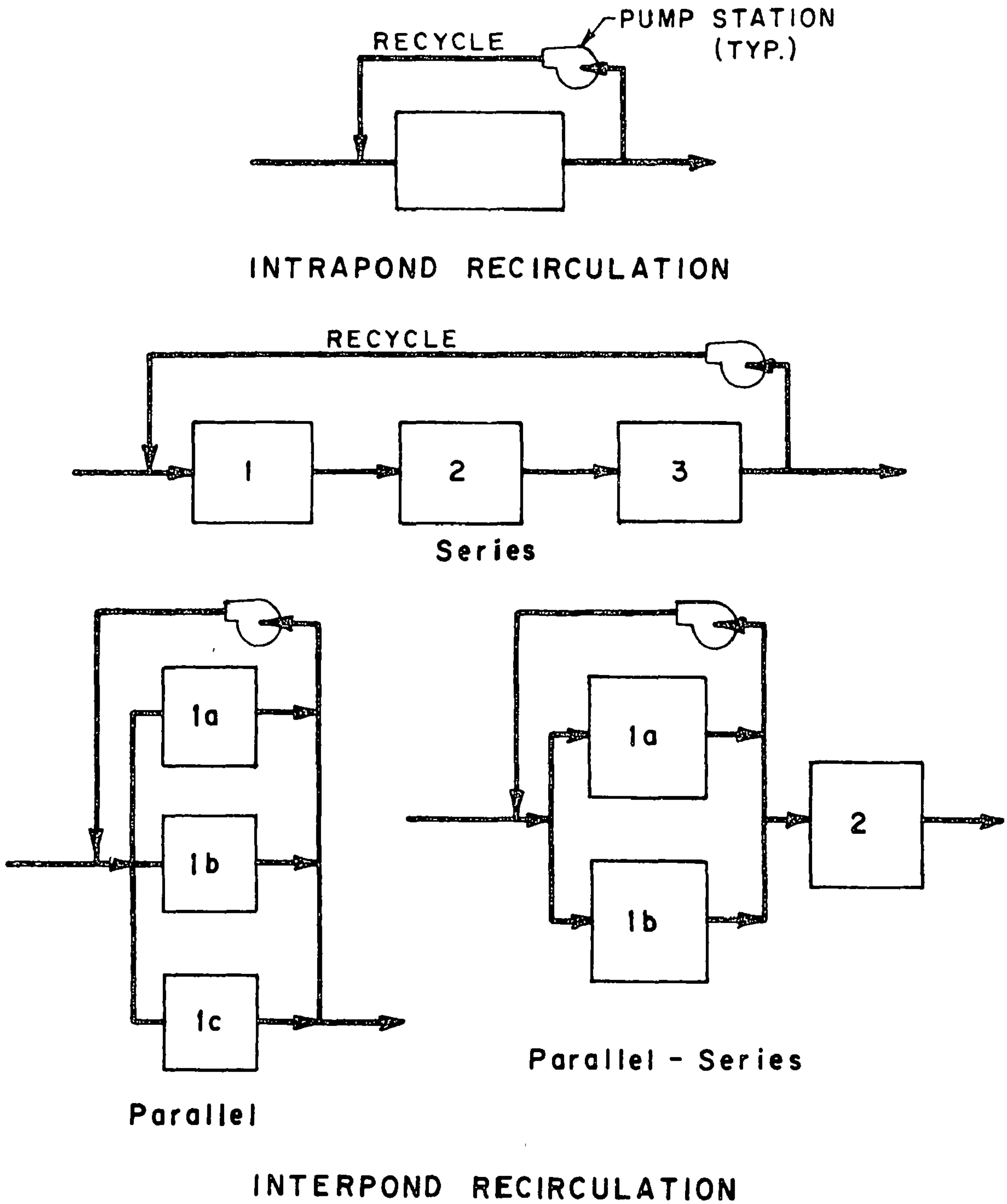


Fig. Common Pond Configurations and Recirculation Systems.