CornellEngineering
Civil and Environmental Engineering

CEE 4540

Sustainable municipal drinking water treatment

Topic: Residual Handing

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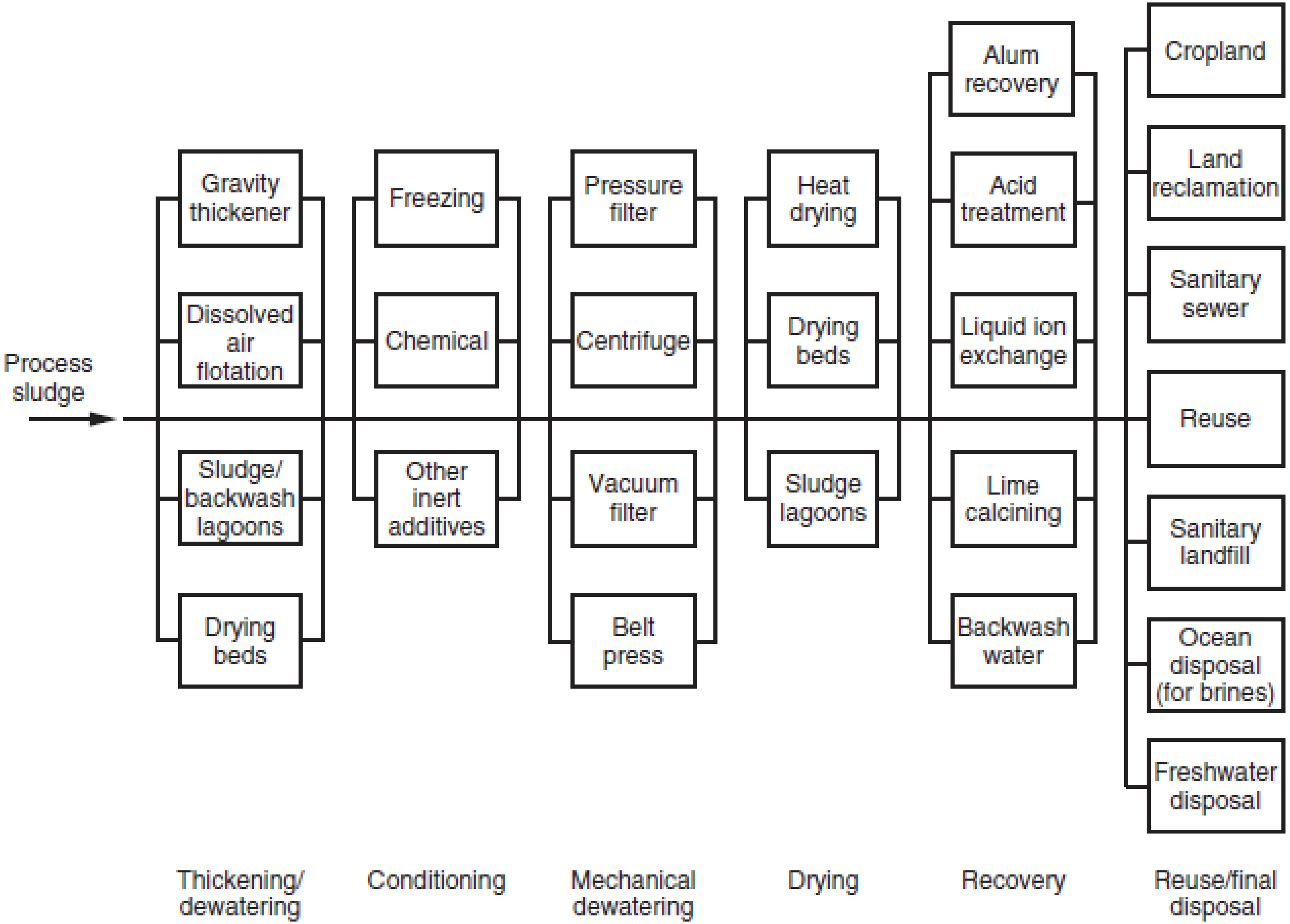
Class #20 11/12/2018 2:55 – 4:10pm

Overview of WTP Sludge Treatment/Disposal

- Physical
- Chemical Conditioning
- Final Disposal
- Beneficial Reuse



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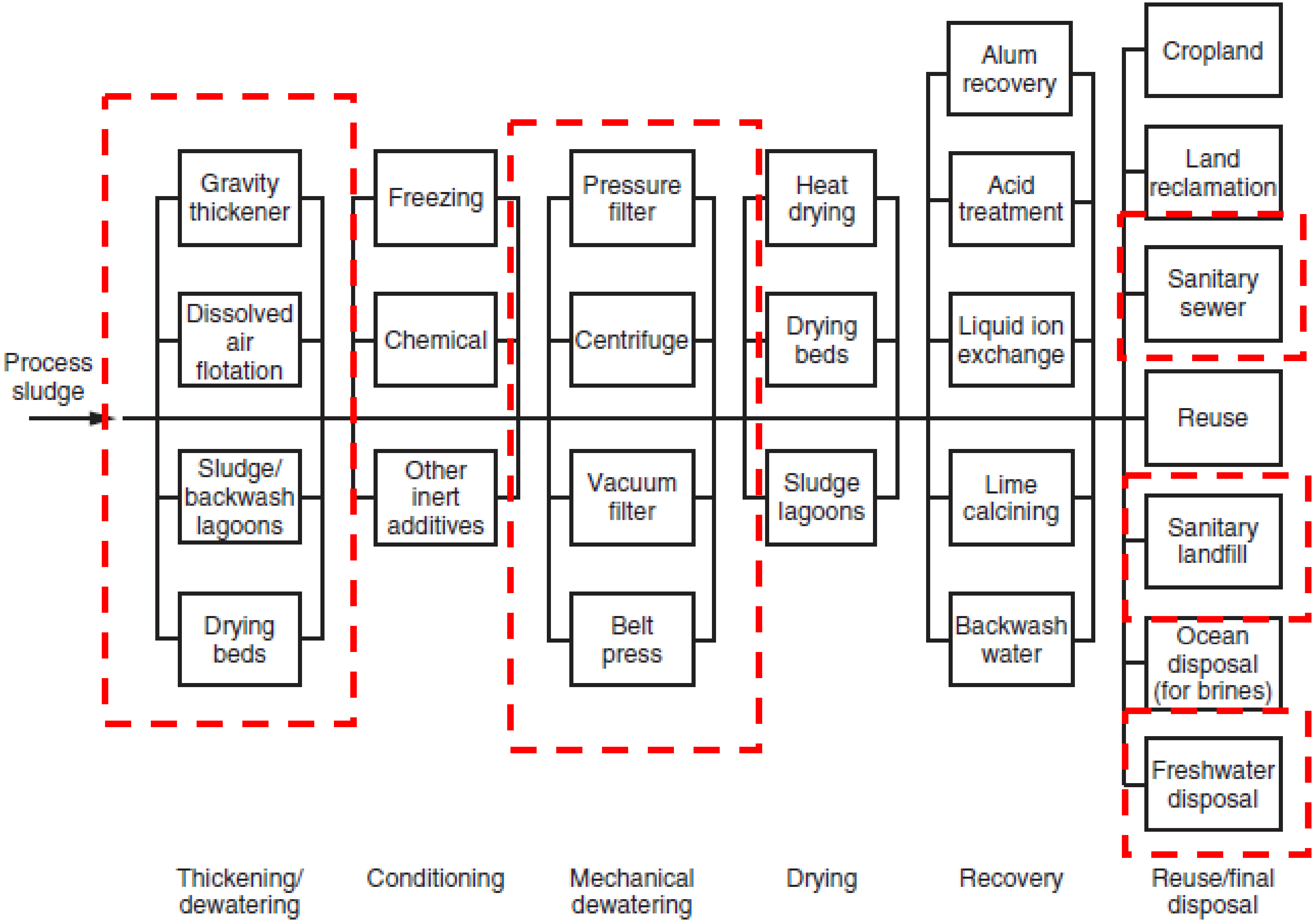


Types of Residual from WTP: Liquid Stream

- Liquid waste stream
  - Filter to waste (15 – 60 min)
  - Backwash wastewater (usually containing 10 – 400 mg/L of solids)
  - Chemical cleaning wastewater (needs to be neutralized for pH or oxidation/reduction power)
  - Sludge dewatered wastewater
- Collected liquid wastes stream can be
  - Discharged back to river (downstream of intake)
  - Treated to further increase overall recovery if higher water recovery is desirable

Considerations for Recycling Backwashed Wastewater

- Recycling undesirable materials
  - Pathogens
  - Taste & Odor causing compounds or carried over algae
  - Increased Disinfection by Products (DBPs)
- Recycled waste stream will required additional treatment prior to returned to the had of the plant, with sedimentation/decanting with disinfection being the minimum requirement
- Equalization Tank required for more homogenous water quality returning back to the plant
- Discharge of liquid waste stream to a receiving water source may require EPA NPDES permit

Other Types of Liquid Waste from WTP

- Ion Exchange Resin (IXR) regeneration brine waste
  - Containing substances removed by ion exchange
    - High TDS (Na, Cl, Ca, Mg, SO4 etc.)
    - All other constituents removed by IX, e.g., NOM, and potential contaminants
- Some IXR uses acids or bases for regeneration, therefore the initial treated water immediately following regeneration may contains high or low pH
- MF/UF Membrane Wastewater
  - Backwash wastewater
  - CIP chemical wastewater
- RO Membrane Wastewater
  - CIP chemical cleaning wastewater
  - RO reject brine (covered in SWRO & BWRO), require neutralization of pH and ORP

Types of Residual from WTP: Solid Waste

- Sludge collected from
  - Intake Screening
  - Sedimentation basin or skimmed off from DAF
- Sludge from backwash wastewater recovery
  - Backwash wastewater collected, settled, and decanted; with decant water pumped back to the head of the plant (mixed with raw water inflow)
- Solid waste contains particulates/silts/ from water supply as well as metal hydroxides formed by the coagulants added, such as Fe and Al based coagulants
- Solid waste (sludge) from different sources is usually collected in the same sludge holding tank/basin, thickened (increasing sludge concentration), then dewatered.

Types of Residual from WTP: Solid Waste (Continued)

- Precipitated Salts from softening processes (with the addition of Lime & Soda Ash), typically 80 – 95% of the softening sludge is $CaCO_3$, with remaining solid being MgOH
- Spent adsorptive media, such as Granular Activated Carbon (GAC) and Ion Exchange Resins (IXR)
- Additional Considerations for solid waste disposal
  - Solid waste may contain pathogens removed from the water (pending on local regulations on disposal)
  - Does solid waste contain regulated contaminants?
    - Arsenic, Selenium, Chromium 6+, PFAS, etc.
    - May require certified testing results prior to disposal
      - EPA's Toxic Contaminant Leaching Testing Protocol (TCLP)
      - Regional toxicity testing requirements, such as WET test in CA

Characteristics of Alum Sludge

- Quantity of Alum sludge is usually much more than ferric-based sludge due the gelatinous nature of the solid (high water content)
- Typical solid content in alum sludge is only 0.5– 2% (5,000 – 20,000 mg/L)
- Note: Alum: Al2SO4(14 H2O) with MW = 594

Solid Production, $S = (8.34Q)(0.44Al + SS + A)$

S = sludge produced (lbs/day)
Q = plant flow, million gallons per day (mgd)
Al = liquid alum dose (mg/L, as 17.1% Al_2O_3)
SS = raw-water suspended solids (mg/L)
A = net solids from additional chemicals added, such as polymer or powdered activated carbon (PAC) (mg/L)

Ferric Sludge

- Ferric Based Coagulants:
  - Ferric Chloride: $FeCl_3$
  - Ferric Sulfate: $Fe_2(SO_4)_3$
  - Ferrous Sulfate $FeSO_4$-$7H_2O$
- With per Lb (0.45 kg) of ferric sulfate added, 0.54 lb (0.25 kg) of ferric hydroxide ($FeOH_3$) is formed

Softening Sludge

- Assuming only Calcium Carbonate ($CaCO_3$) and Magnesium Hydroxide (MgOH) solids are formed:

$$S = 8.336\,(Q)(2.0\ Ca + 2.6\ Mg)$$

S = sludge produced, lb/day (kg/d)
Q = plant flow, mgd (m^3/s)
Ca = calcium hardness removed as $CaCO_3$, mg/L
Mg = magnesium hardness removed as $CaCO_3$, mg/L
8.336 = constant for use with English units (86.4 is the constant for use with the metric units shown)

Overall Sludge Production for Surface Water Treatment

$$S = 8.143(Q)(2.0\ \mathrm{Ca} + 2.6\ \mathrm{Mg} + 0.44\ \mathrm{Al} + 1.9\ \mathrm{Fe} + \mathrm{SS} + A)$$

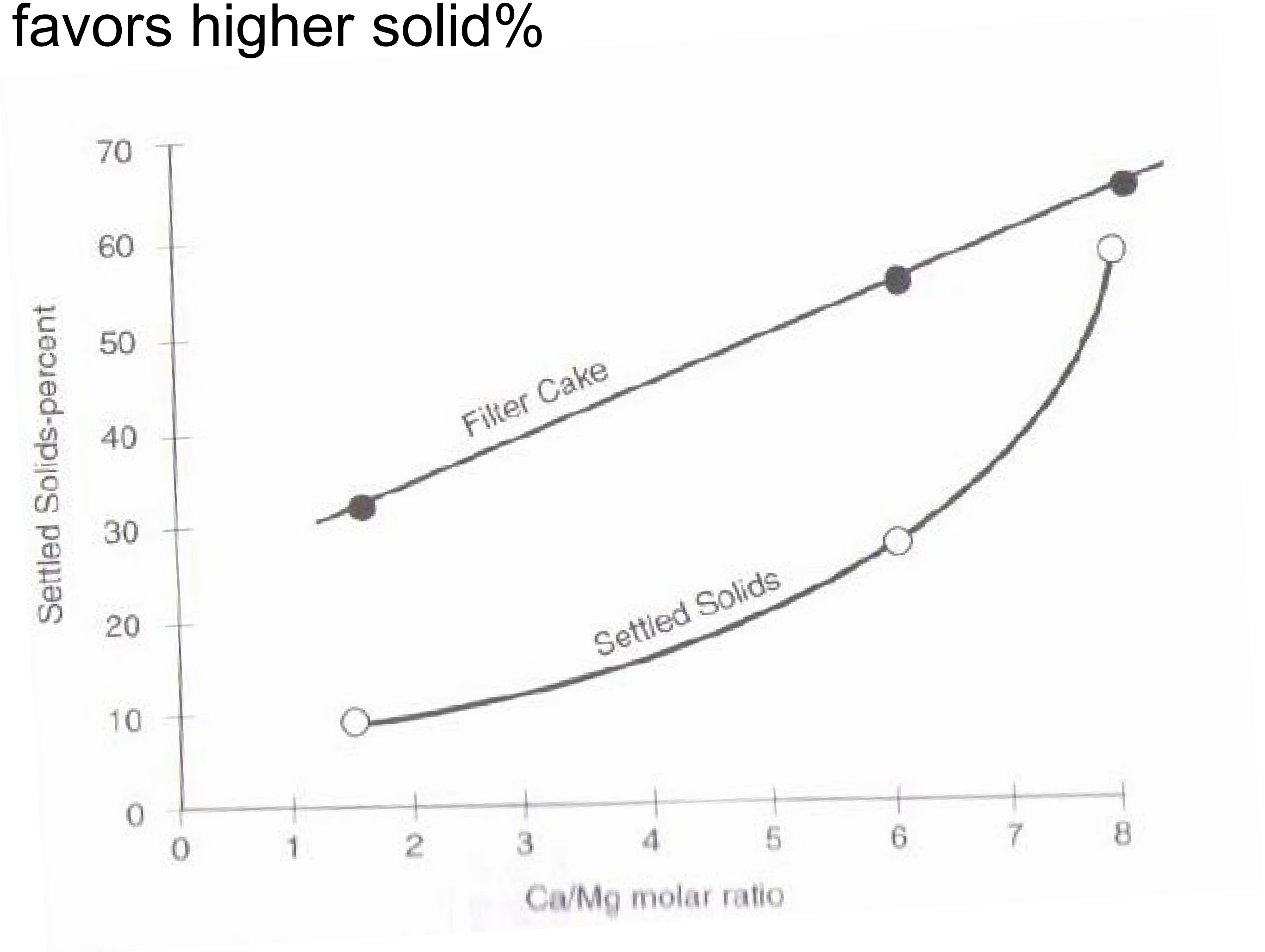
S = sludge produced, lb/day (kg/d)
Q = plant flow, mgd (m^3/s)
Al = alum dose as 17.1 percent Al_2O_3, mg/L
Fe = iron dose as Fe, mg/L
SS = raw-water suspended solids, mg/L
A = additional chemicals such as polymer, clay, or activated carbon, mg/L
8.143 = constant for use with English units (84.4 is the constant for use with the metric units shown)

Typical Solid Concentration in Sludge

- Volume of sludge is about 1 – 1.5% of the WTP flow
- Spent Filter Backwash Wastewater Solid: ~ 50 – 400 mg/L
- Ultimate thickened sludge solid: ~6%
- Vacuum Dewatered sludge: 42%

Effect of Ca/Mg Ratio on Softening Sludge Solid Content

- Hither Ca/Mg ratio favors higher solid%



Calculation of Specific Resistance for Sludge Cake

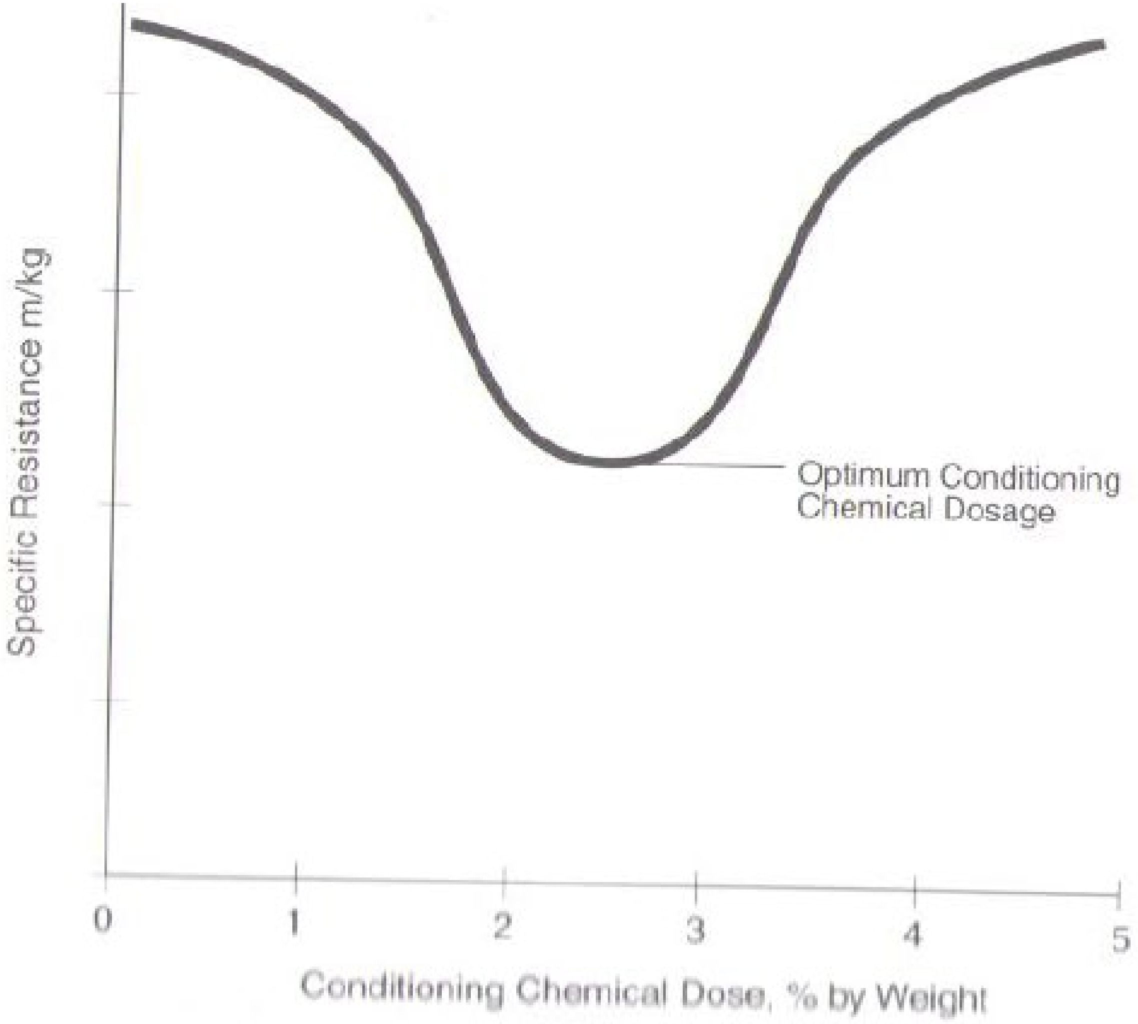
$$r = \frac{2PA^2b}{\mu c}$$

where:

r = specific resistance to filtration
P = pressure drop across sludge cake
A = surface area of filter
μ = filtrate viscosity
c = weight of dry solids deposited per volume of filtration
b = slope of a plot of t/V versus V
t = time of filtrate
V = filtrate volume

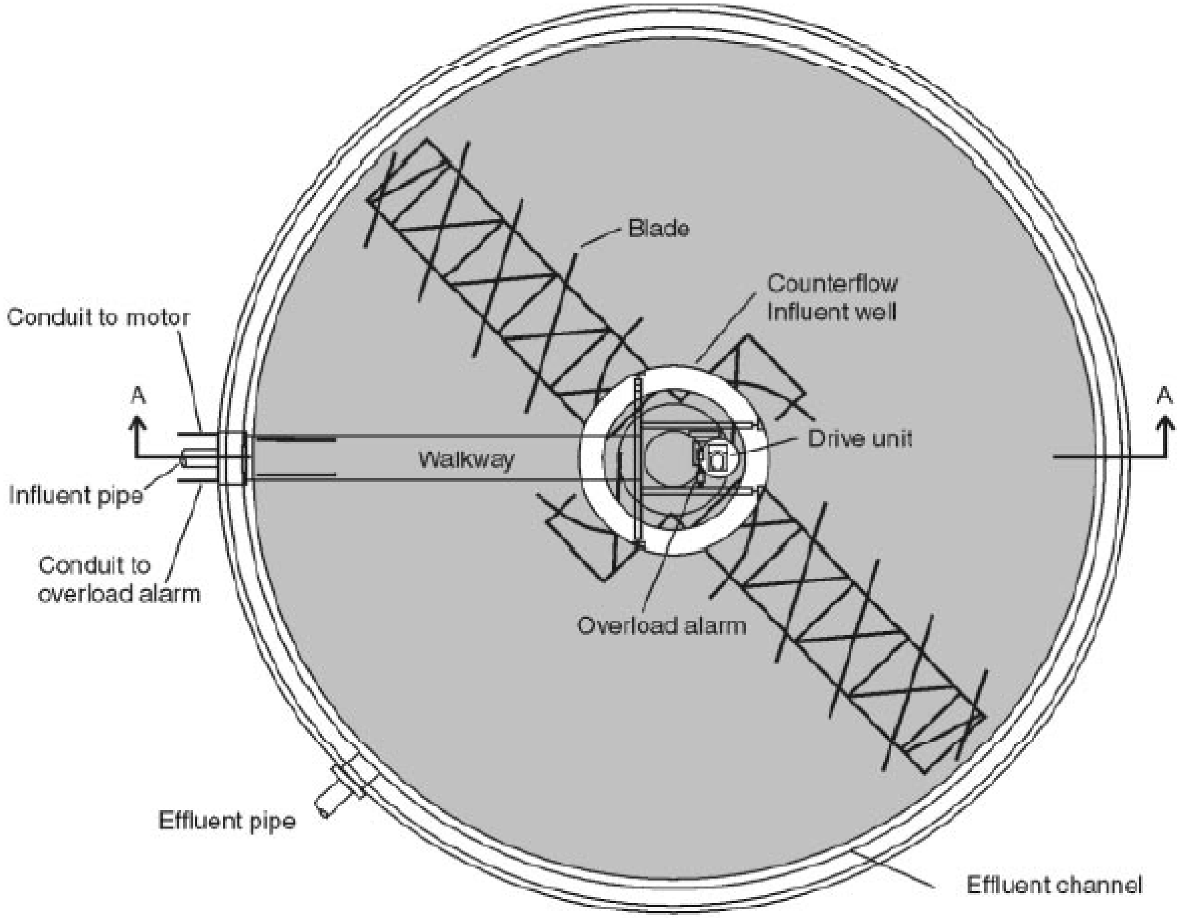
Conditioning Sludge for Optimum Dewatering

- Sludge's dewatering characteristics can be enhanced by adding polymers
- Higher Molecular Weight Polymers usually work better; but need to watch out for potential handling issues if the viscosity is too high
- Typical polymer dosage:
- 1 g/kg sludge – 10 g/kg sludge

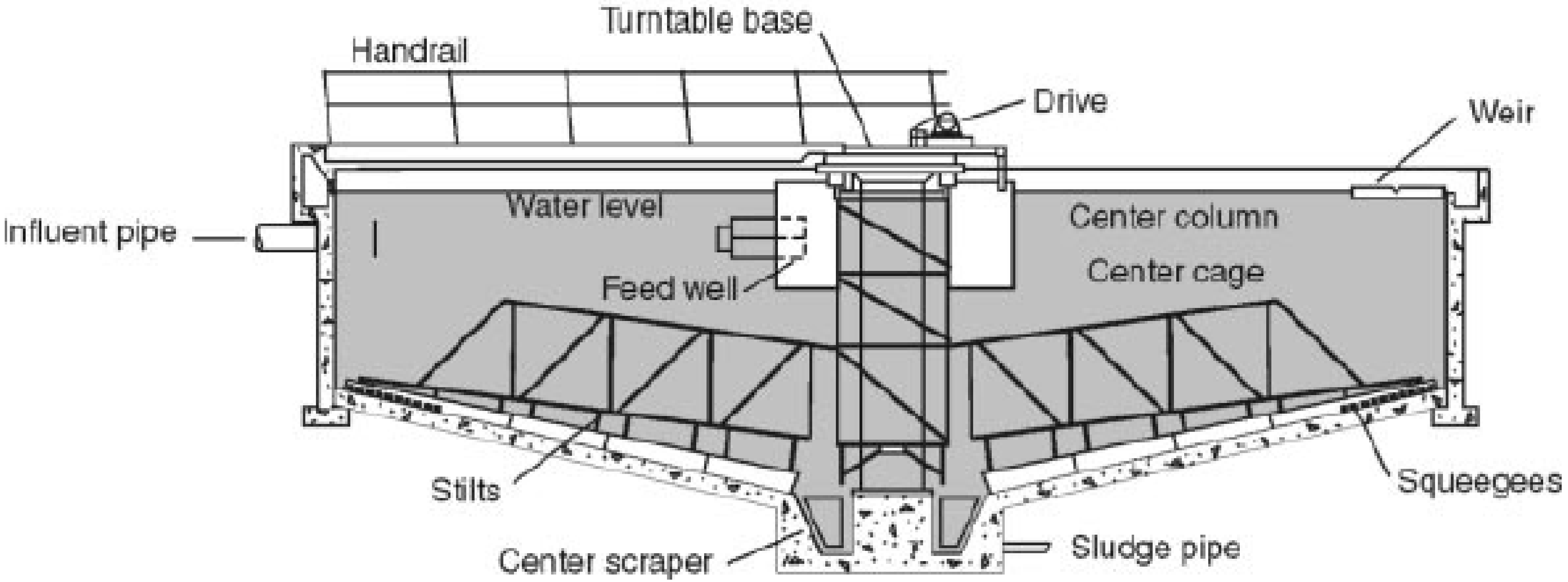


Mechanical Gravity Thickening

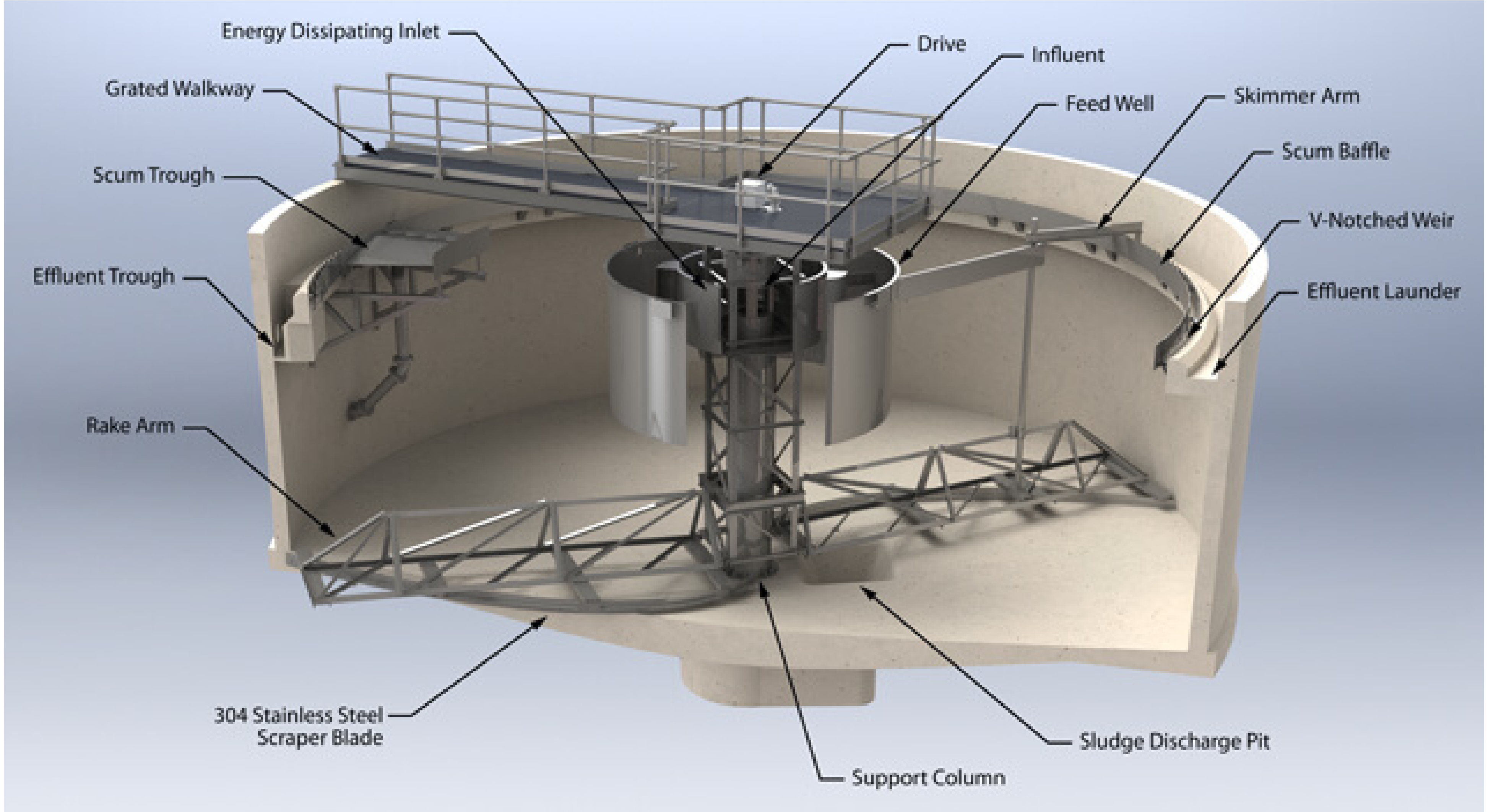
- Commonly used for typical WTP and softening plants
- With proper operation solid of thicken sludge can be ~ 2 – 6% for alum sludge and ~ 30% for softening sludge



Gravity Thickeners



Gravity Sludge Thickener



Typical Design & Operation Parameters

Table 21-13
Typical performance and design data for gravity mechanical thickening of coagulant and lime sludges

		Type of Sludge	
Parameter	**Unit**	**Coagulant**	**Lime Softening**
Feed solids	%	0.2–1	1–4
Thickened solids	%	2–3	>5
Solids recovery	%	80–90	80–90
Solids loading	$kg/m^2 \cdot d$	20–80	100–200
	$lb/ft^2 \cdot d$	4–16	20–40

Thickening with DAF

– Ideal for solids that doesn't settle well (e.g., some membrane filtration backwash wastewater)

Table 21-14
Typical performance and design data for dissolved air flotation thickening for coagulant and lime-softening sludges

Parameter	Unit	Type of Sludge: Coagulant	Type of Sludge: Lime Softening
Feed solids	%	0.5–1	0.5–1
Thickened solids	%	3–5	3–5
Solids recovery	%	80–90	80–90
Solids loading	$kg/m^2 \cdot d$	48–120	48–120
	$lb/ft^2 \cdot d$	10–24	10–24
Volumetric loading	$m^3/m^2 \cdot d$	110–150	110–150
	$gal/ft^2 \cdot d$	2800–3600	2800–3600

Sludge Lagoon

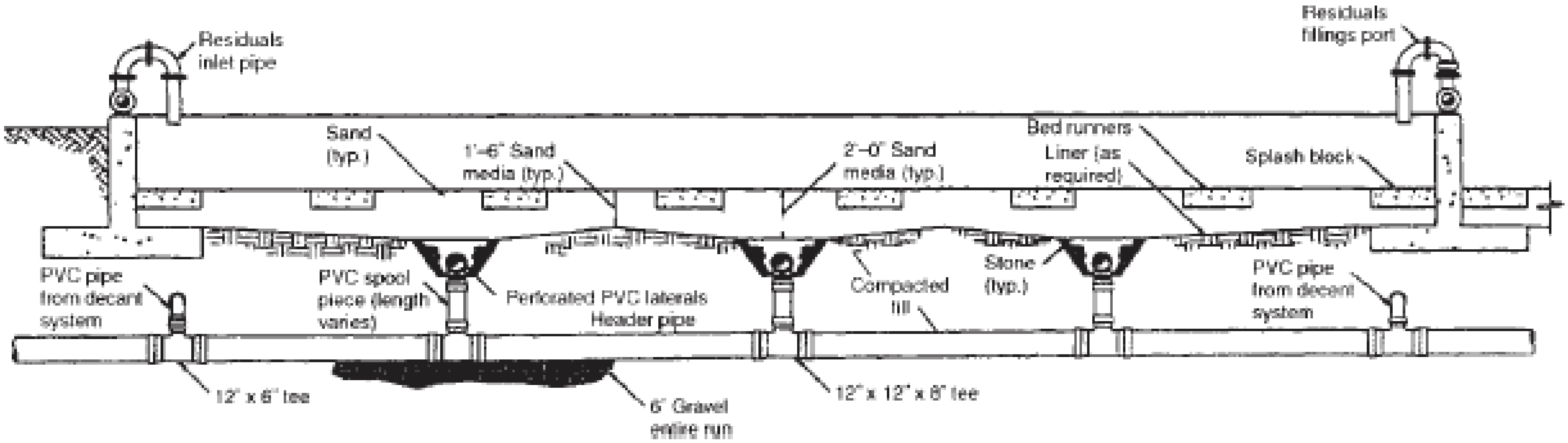
- Non-chemical, conventional and typical sludge thickening process
- Cost effective for sludge thickening, drying and storage, if land is available
- Solid can be increased to 30 – 50%, depending on the types of solids
  - Usually ~ 3 months for filling and another 3 months for drying

Filtration Sludge Lagoon

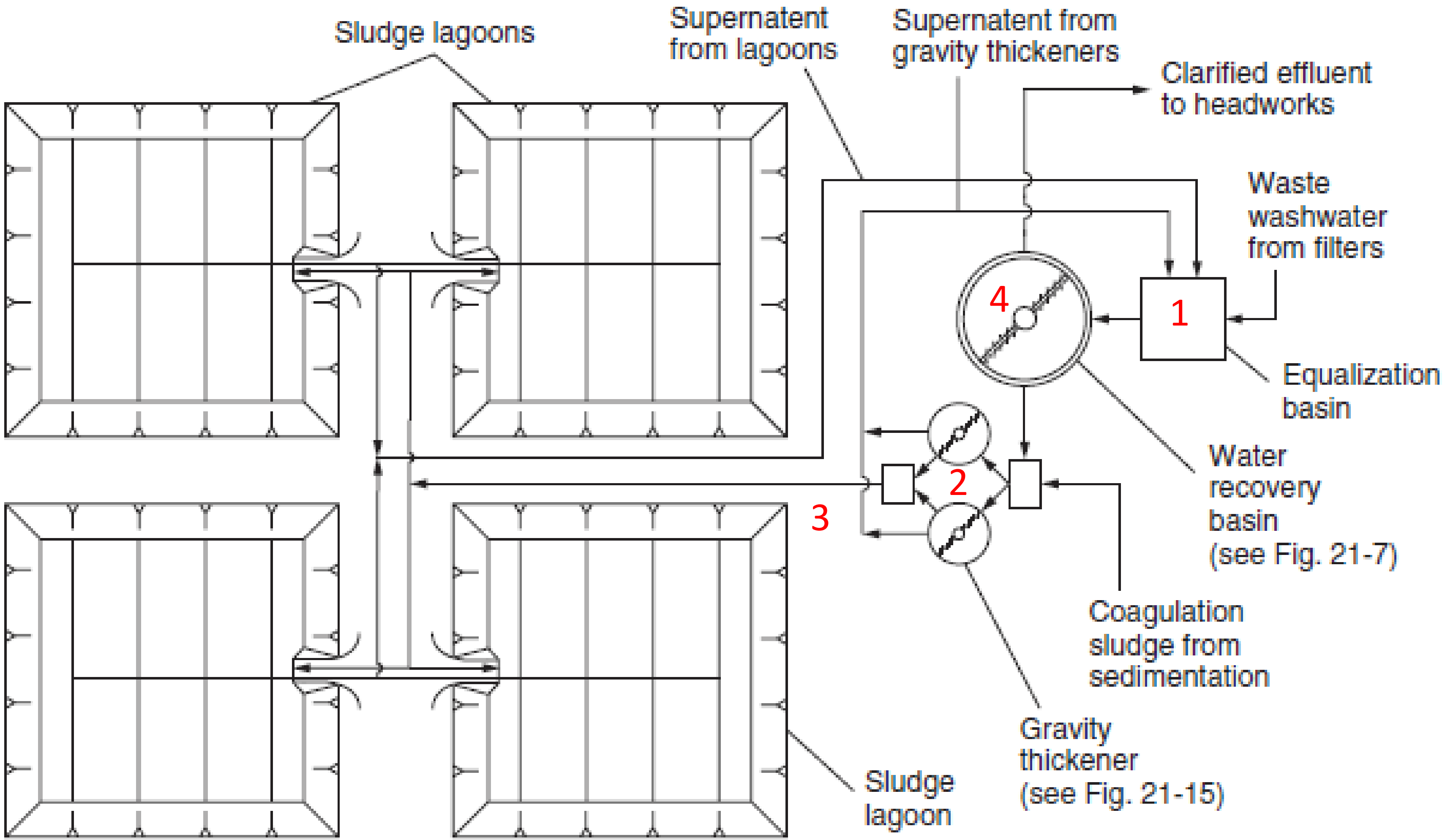
Softening Sludge Lagoon

Typical Sludge Lagoon Loading Rate

- 8.2 lb/ft2 for wet sludge
- 16.4 lb/ft2 for dried sludge
- Sand layer is used to support sludge
- Lagoon is usually lined



Overall Water Recovery & Sludge Thickening/Storage



Alternative Sludge Drying Processes

- Freezing
  - Destroy the gelatinous characteristics of ferric/alum sludge; making it coarse and granular. Concentration can be increased from 2% to 20%, and further drained to reach 30%
  - Only available during winter, not applicable to places with short or no freezing weather in the winter
- Heat Treatment: Applied in wastewater sludge, but cost prohibitive for WTP sludge

Common Sludge Dewatering Processes used in WTP

- Vacuum Filtration
- Plate and frame filter presses
- Belt filter presses, and
- Centrifuges.

Vacuum Filtration for WTP Sludge Dewatering

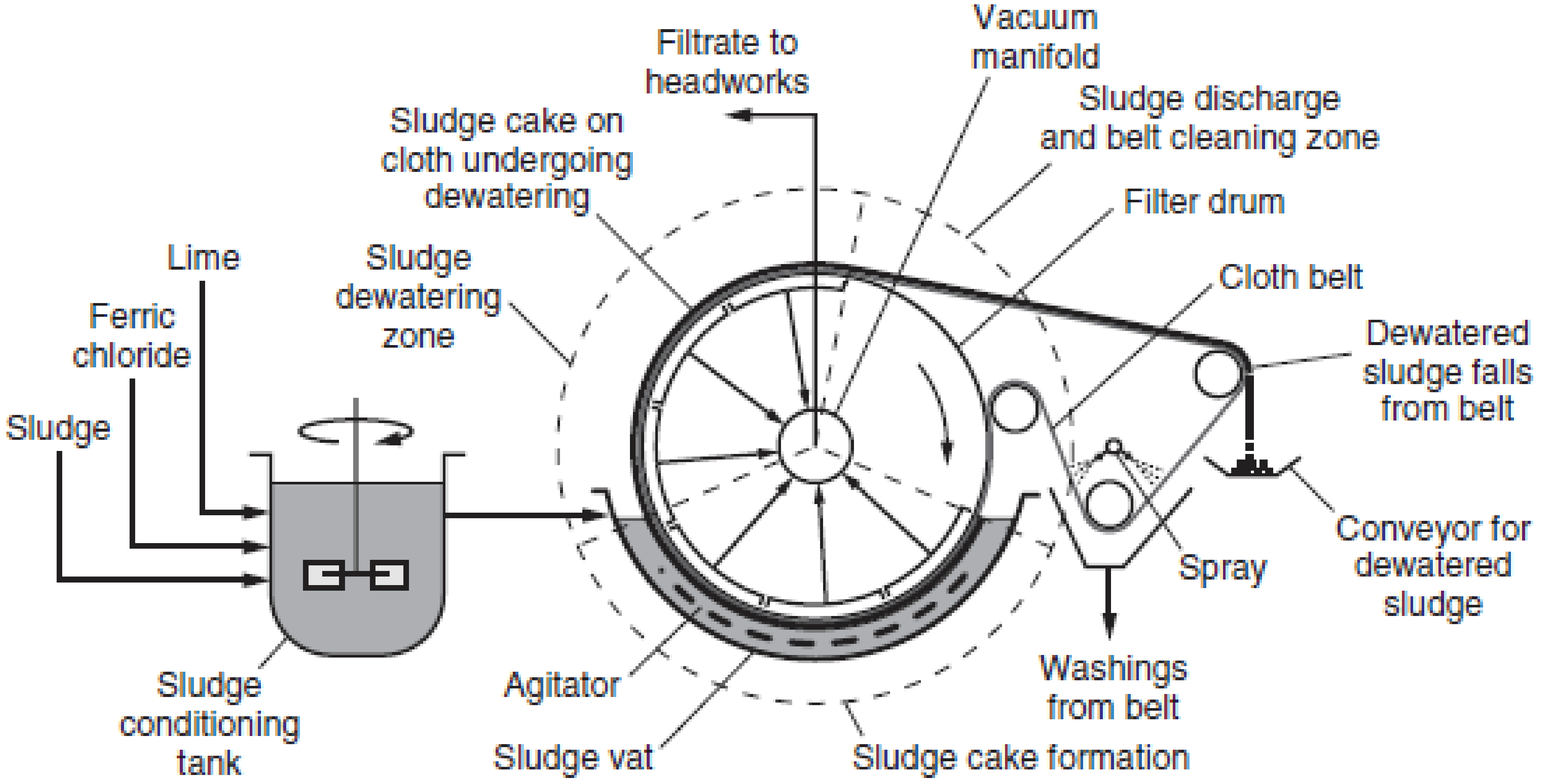
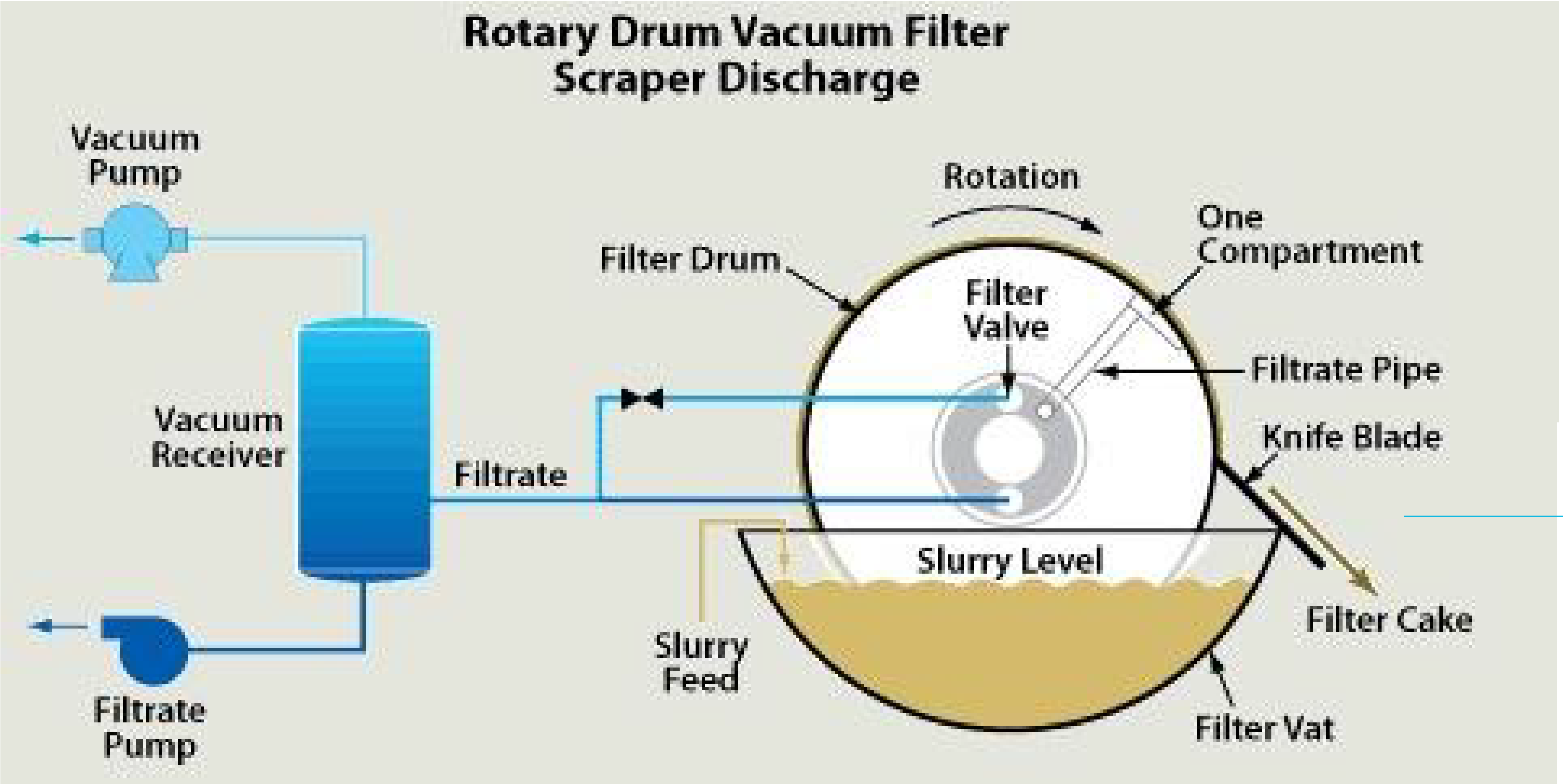
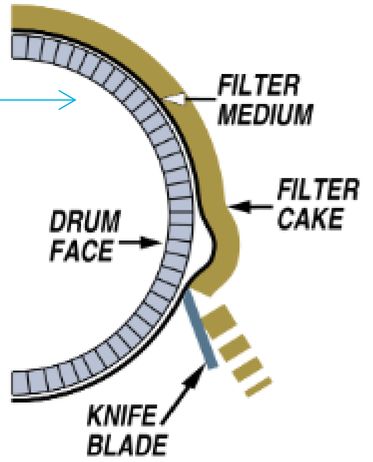


Figure 21-21
Schematic diagram of typical vacuum filtration installation.

Vacuum Filtration for WTP Sludge Dewatering





Performance of Vacuum Filtration Dewatering System

Parameter	Unit	Range of Values
Feed solids	%	2–6
Feed rate	$L/m^2 \cdot h$	0.7–2.1
	$gal/ft^2 \cdot h$	2–6
Solids recovery	%	96–99+
Dry-solids yield	$kg/m^2 \cdot h$	0.2–0.3
	$lb/ft^2 \cdot h$	1.0–1.5
Thickened solids		
Alum sludges	%	15–25
Lime sludges	%	20–40
Filtrate suspended solids	mg/L	10–20
Precoat recovery	%	30–35
Precoat rate	$kg/m^2 \cdot h$	0.02–0.04
	$lb/ft^2 \cdot h$	0.1–0.2
Precoat thickness	mm	38.1–63.5
	in.	1.5–2.5
Drum speed	rev/min	0.2–0.3
Operating vacuum	mm Hg	127–508
	in. Hg	5–20

Plate & Frame Filter Press for WTP Sludge Dewatering

- Very commonly seen in small & medium size WTP
- Sludge filled between plates
- Filter cloths attached to each plate
- Plates got pressurized hydraulically to “squeeze” out water from the sludge
- Can achieve 30 – 40% of solids with lime/polymer conditioning

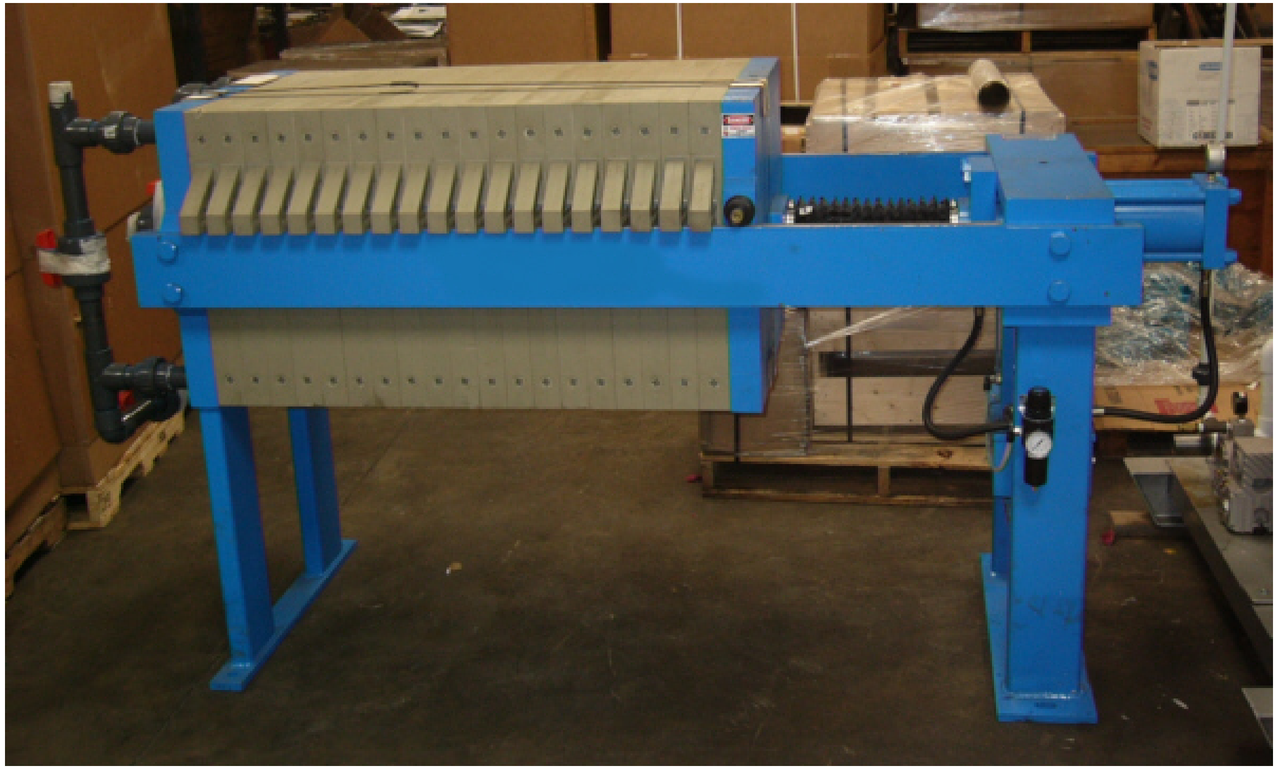
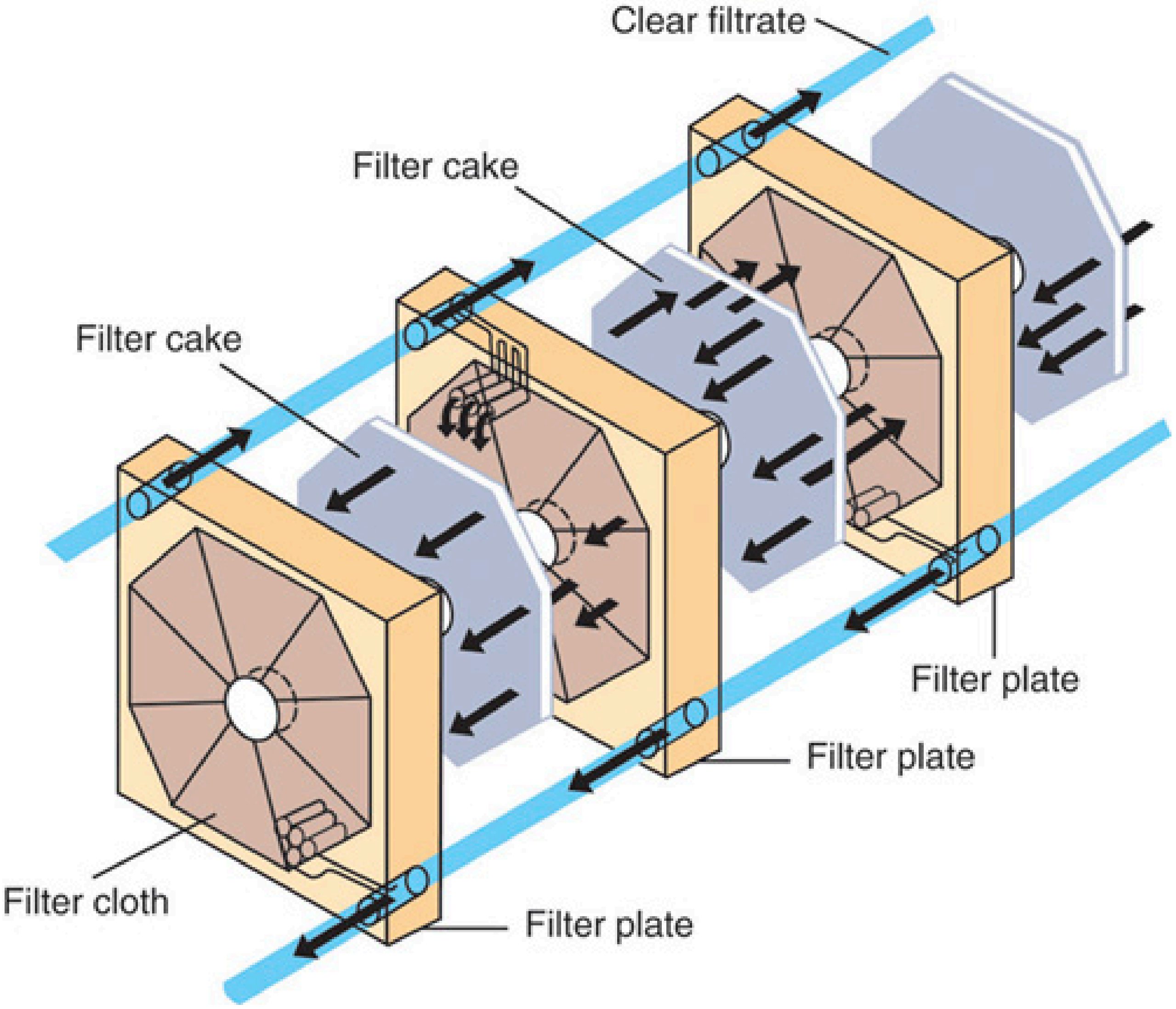
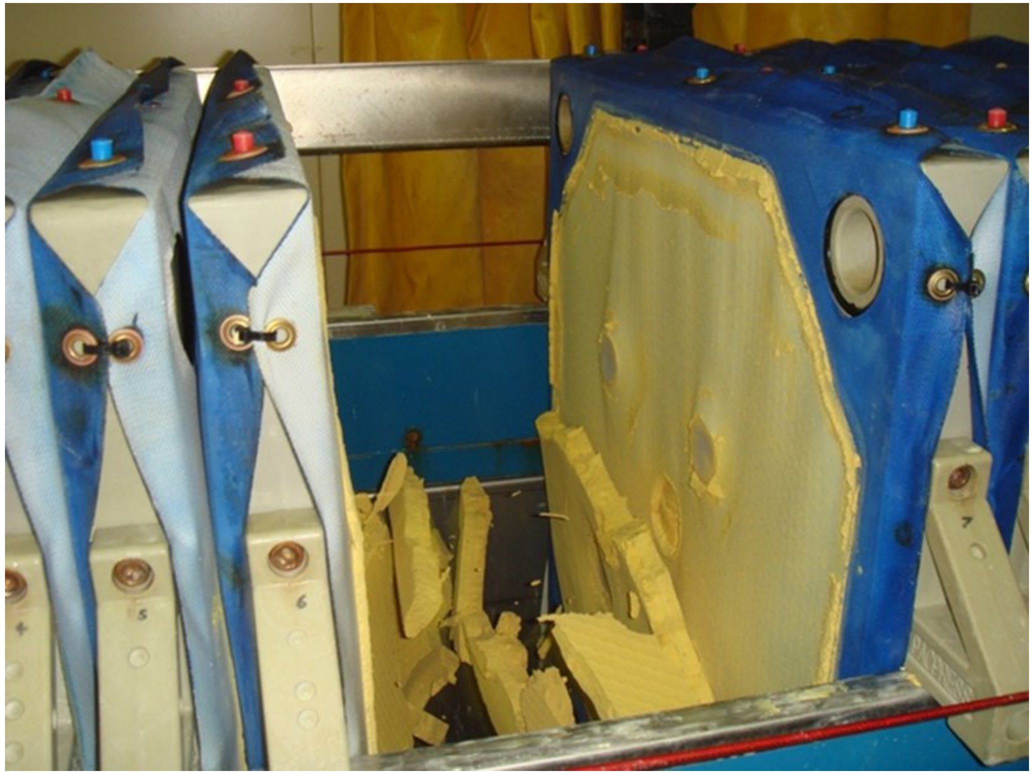


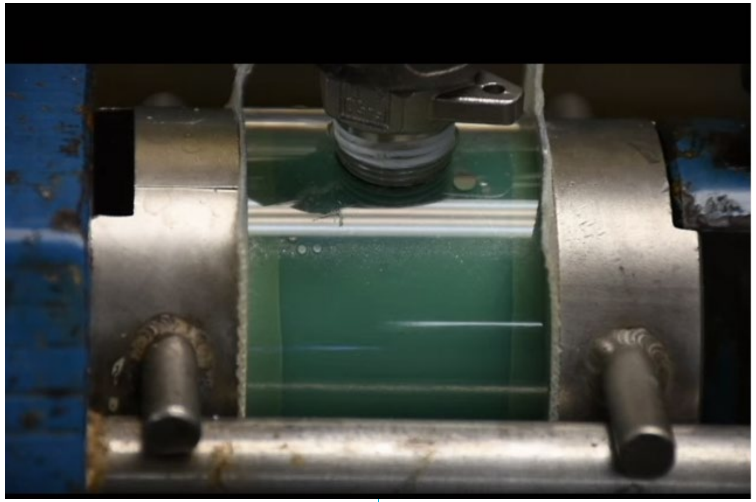
Plate & Frame Filter Press for WTP Sludge Dewatering

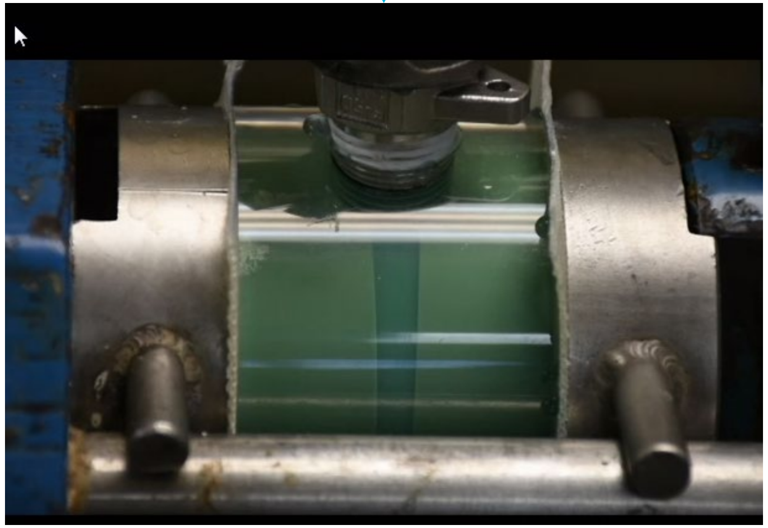


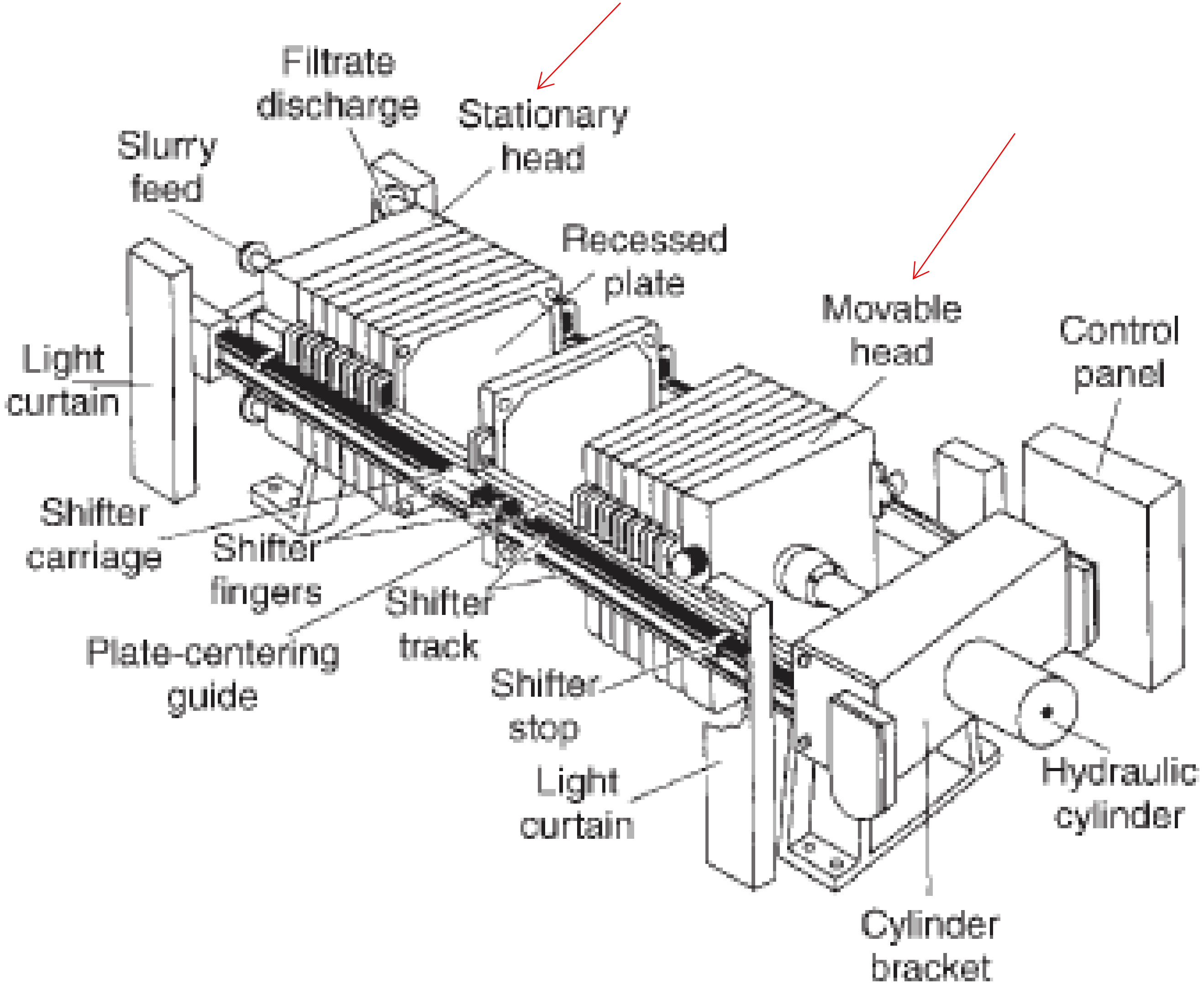


Key Components of a Plate & Frame System

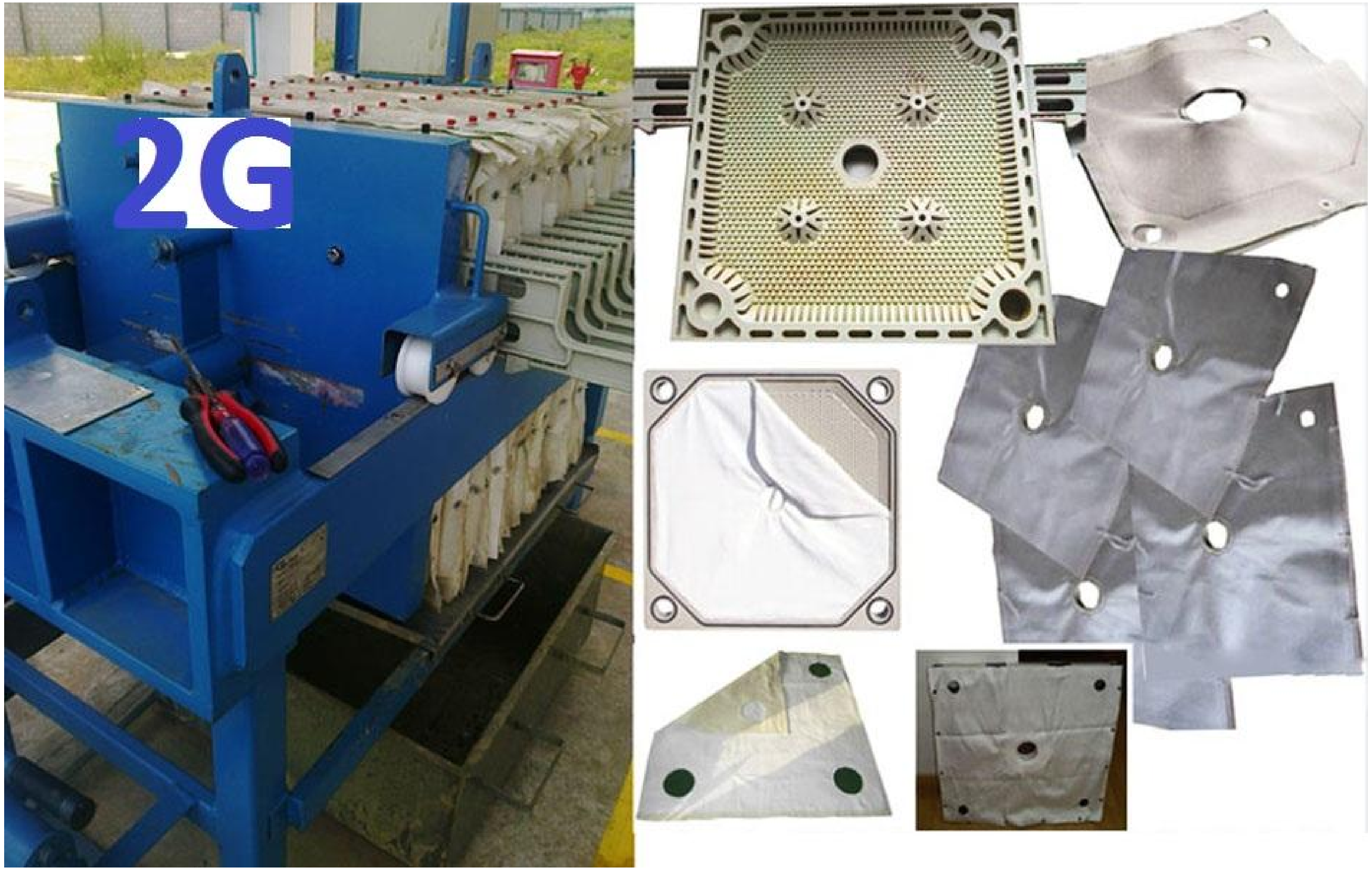
- Can produce 30 – 40% solids





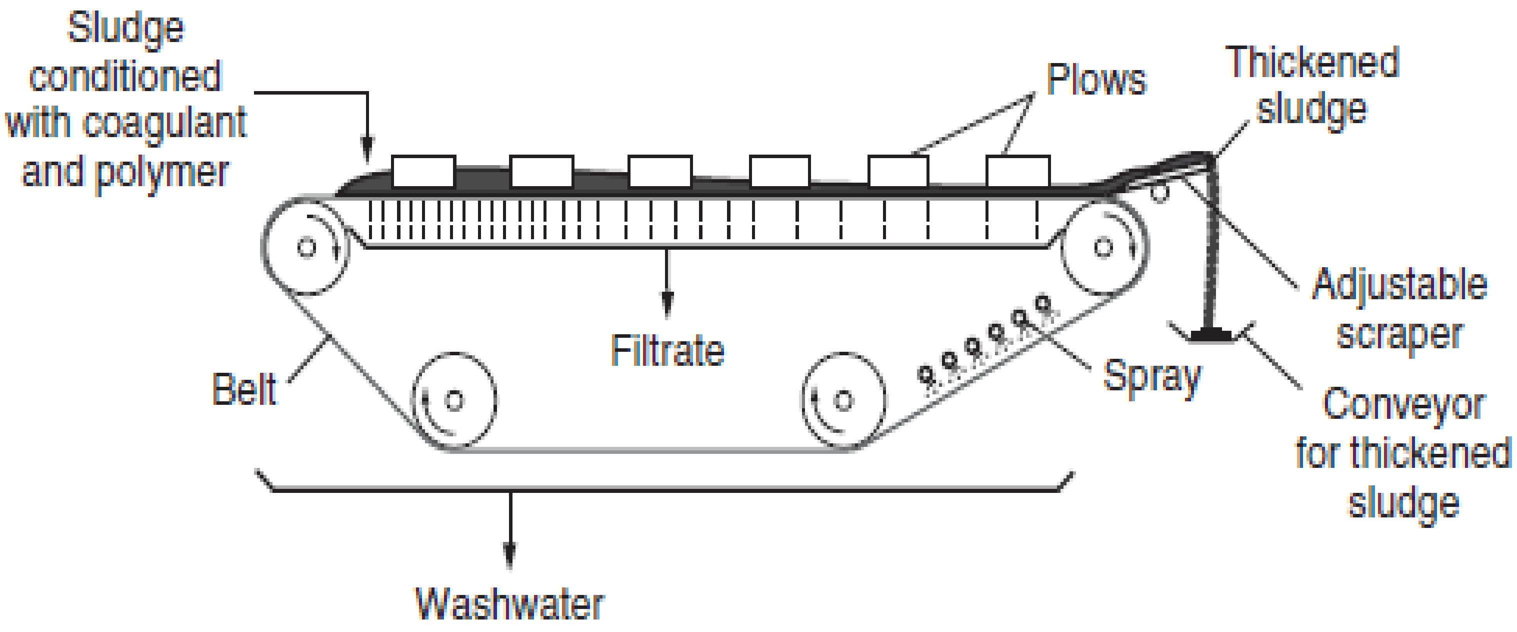


Parts & Filter of a Plate & Frame Filter Press System

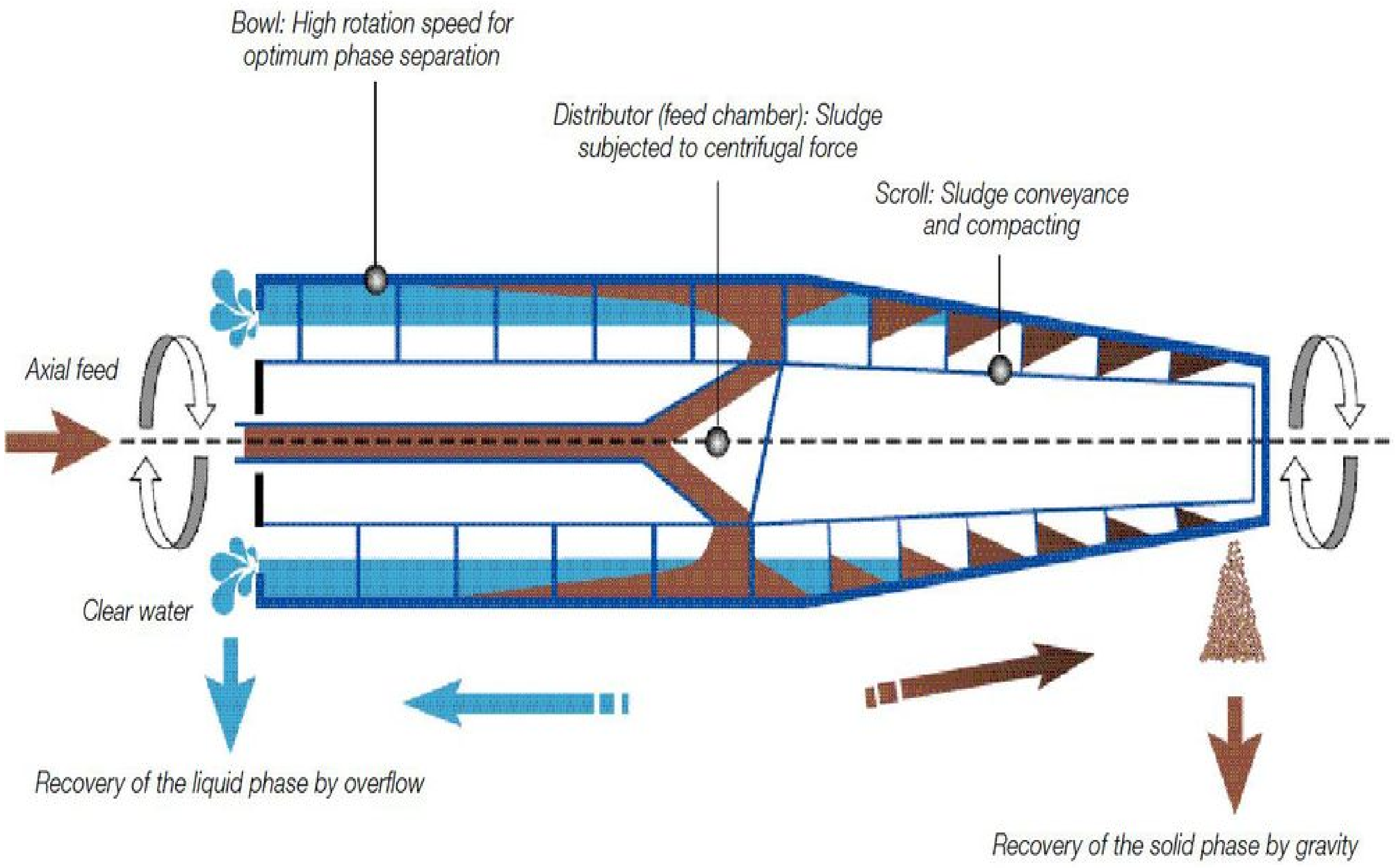


Belt Filters (Gravity Filters)

- Simpler mechanism
- Lower energy
- Can achieve ~ 20% solid



Centrifuge for WTP Sludge Dewatering



Final Solid Waste Disposal

- ❑ Landfilling
- ❑ Disposal on land (reuse as a soil amendment)
- ❑ Discharge to a wastewater collection system
- ❑ Co-disposal with wastewater biosolids
- ❑ Reuse in building or fill materials

Additional Considerations for Waste Disposal

- Does residual containing regulated contaminants?
  - Radionuclides
  - Regulated contaminants (adsorbing to the solids)
- Additional testing for hazardous material may be required prior to disposal
  - EPA Toxicity Characteristic Leaching Procedure(TCLP)
  - California Water Extraction Test (WET)
- Land application is regulated under USEPA's Resource Conservation and Recovery Act (RCRA)

Homework & Reading

- Problem 21-7
- Assume the use of Plate & Frame sludge dewatering system for the sludge from Problem 21-7, estimate the mass and volume of the final sludge coming out of the Plate & Frame filter Press.

- Reading Assignment: Chapter 21 Residual Management