Example 13.1

Coagulation of a surface water using alum produces 10,000 lb (4540 kg) of dry solids/day, of which 20% are volatile. Both the settled sludge following coagulation and filter backwash water are concentrated in clarifier–thickeners to a solids density of 2.5%. Centrifugation can be used to increase the concentration to 20%, a consistency similar to soft wet clay, or the clarifier–thickener underflow can be dewatered to a 40% cake by pressure filtration. (1) Estimate the specific gravities of the thickened sludge, concentrate from centrifugation, and filter cake. (2) Calculate the daily sludge volumes from each process.

Solution:

1. Applying Eq. (13.1), one has

$$\frac{1.00}{S_s} = \frac{0.80}{2.50} + \frac{0.20}{1.00} = 0.52 \quad S_s = \frac{1}{0.52} = 1.9$$

From Eq. (13.2),

$$S(\text{thickened sludge}) = \frac{97.5 + 2.5}{(97.5/1.0) + (2.5/1.9)} = 1.0$$

$$S(\text{centrifuge discharge}) = \frac{80 + 20}{(80/1.0) + (20/1.9)} = 1.1$$

$$S(\text{filter cake}) = \frac{60 + 40}{(60/1.0) + (40/1.9)} = 1.2$$

2. Substituting these values into Eq. (13.3) with $W_s = 10{,}000$ lb/day gives

$$V(\text{thickened sludge}) = \frac{10{,}000}{(2.5/100)8.34 \times 1.0} = 48{,}000 \text{ gpd}$$

$$= \frac{4540 \text{ kg}}{(2.5/100)1000 \text{ kg/m}^3 \times 1.0} = 182 \text{ m}^3/\text{d}$$

$$V(\text{centrifuge discharge}) = \frac{10{,}000}{(20/100)8.34 \times 1.1} = 5400 \text{ gpd } (20.6 \text{ m}^3/\text{d})$$

$$V(\text{filter cake}) = \frac{10{,}000}{(40/100)8.34 \times 1.2} = 2500 \text{ gpd } (9.5 \text{ m}^3/\text{d})$$

Example 13.2

Estimate the quantity of sludge produced by a trickling-filter plant treating 1.0 mgd of domestic wastewater. Assume a suspended-solids concentration of 220 mg/l in the raw wastewater, a solids content in the sludge equivalent to 90% removal, and a sludge of 5.0% concentration withdrawn from the settling tanks.

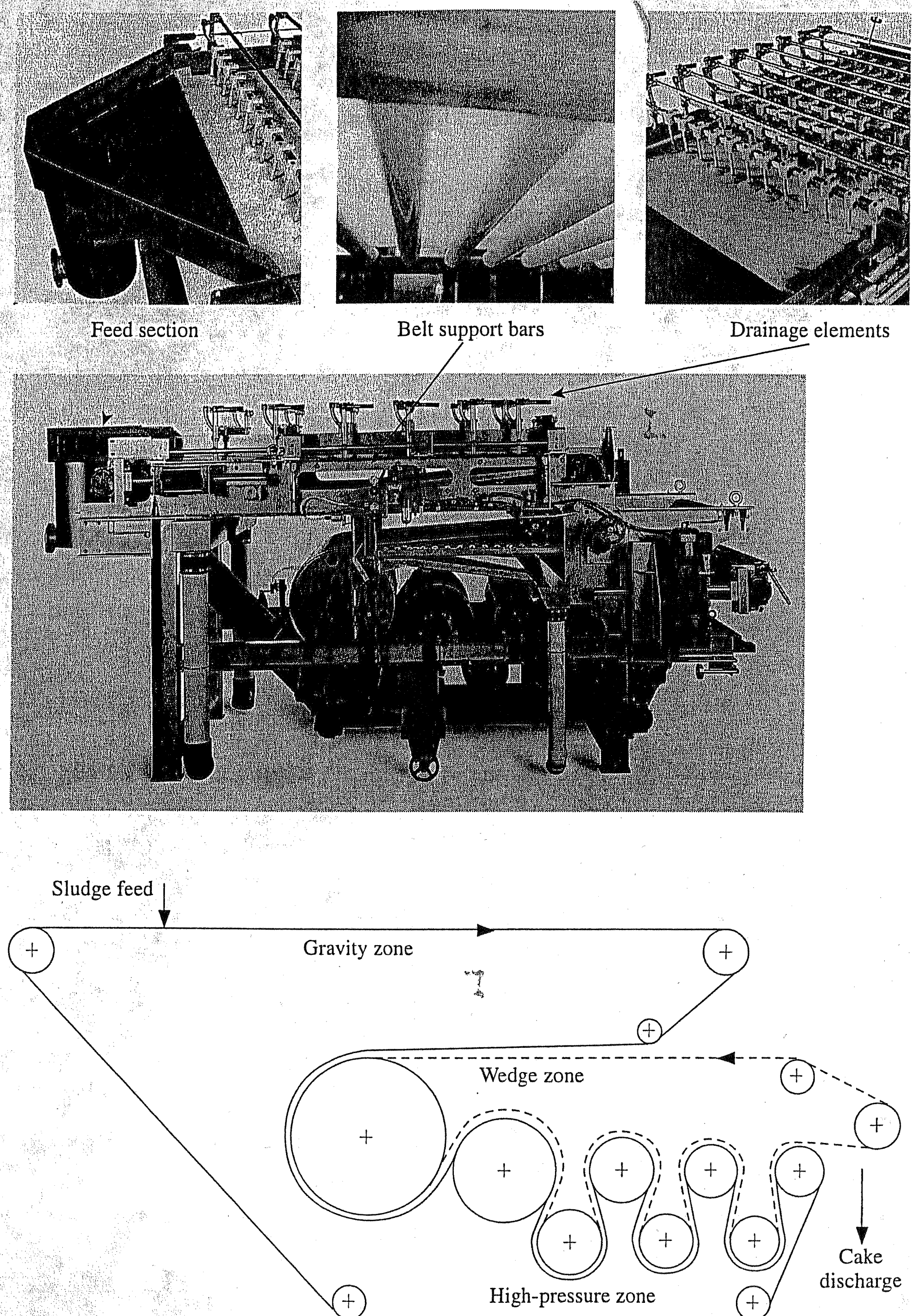


FIGURE 13.18 Two-belt filter press with a gravity drainage zone, wedge zone, and high-pressure zone. *Source:* Courtesy of Komline-Sanderson, Peapack, NJ.

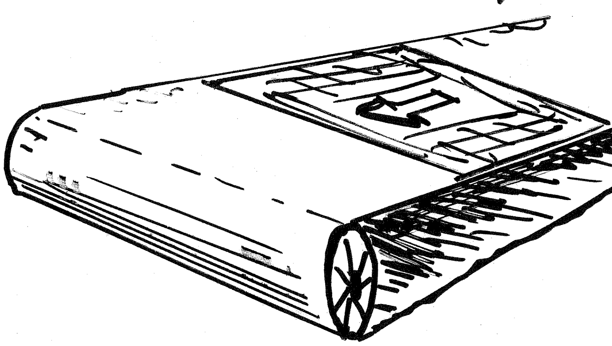
HYDRAULIC LOADING of FILTER BELT

$\frac{gal}{min}$ per m of belt width OR $\frac{m^3}{h}/m$

VOLUME OF SLUDGE APPLIED

i.e., $\frac{m^2}{h}$

"How many sq. meters of belt move past per hour"



POLYMER DOSE: $\frac{\text{lbs polymer}}{\text{ton dry solids fed}}$ OR $\frac{kg}{tonne}$

SOLIDS RECOVERY: $\frac{\text{lbs Dry Solids-CAKE}}{\text{lbs Dry Solids-FEED}}$

BUT EASIER TO CALC. AS: $\frac{\text{(Dry) solids FEED} - \text{Tot. Solids IN WASTE}}{\text{Dry Solids FEED}}$

EXAMPLE CALC'NS:

HYDR. LOADING RATE

$$\frac{18.2 \ m^3/h \text{ FEED}}{2 \ m \text{ WIDTH}} = 9.1 \frac{m^3}{m \cdot h} \left(\frac{m^2}{h}\right)$$

SOLIDS LOADING RATE

$$\frac{18.2 \frac{m^3 \text{ SLUDGE}}{h} \times 0.035 \frac{\text{kg-SOLIDS}}{\text{kg-SLUDGE}} \times \frac{1000 \text{ kg SLUDGE}}{m^3\text{-SLUDGE}}}{2 \ m \text{ WIDTH}}$$

$$= 320 \text{ kg}/m \cdot h \text{ SOLIDS}$$

← CAN INTEPRET AS 1 m of belt length acculates 320 kg dry solids per hour

$$\left(320 \frac{kg}{h} / 2m^2 = 160 \frac{kg/m^2}{h}\right)$$

POLYMER DOSE

$$\frac{0.002 \frac{\text{kg POLYMER}}{\text{kg DOSE LIQ}} \times 1.8 \frac{m^3 \text{ DOSE}}{h} \times \frac{1000 \text{ kg DOSE}}{m^3 \text{ DOSE}} \times 1000 \frac{\text{kg-SOL}}{\text{tonne}}}{(320 \text{ kg-solids}/m) \times (2 \ m \text{ WIDTH})}$$

$$= 5.7 \text{ kg-POLYMER/tonne solids}$$

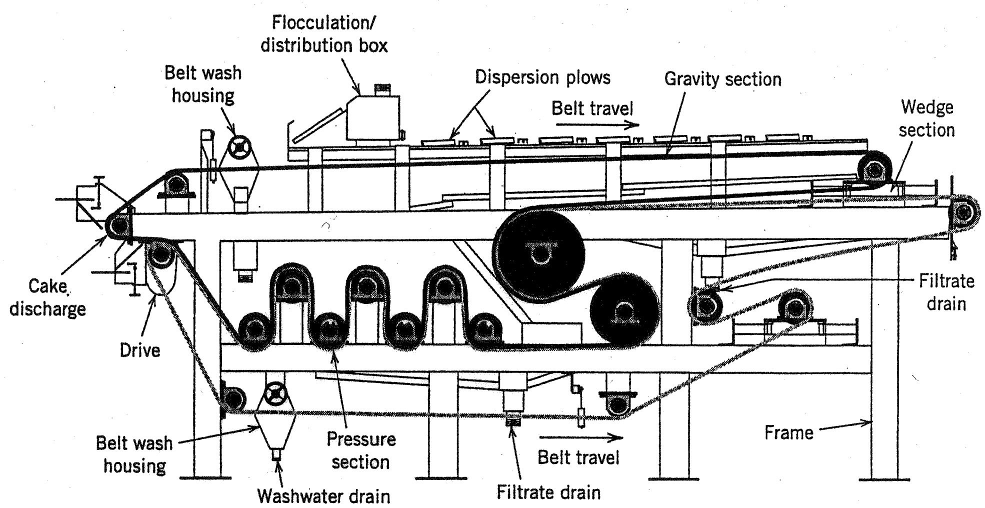
SOLIDS RECOVERY

$$\text{WASTE WATER} = \frac{\left(15.4 \ m^3 \text{ WASH}/h \times 2600 \frac{\text{g-SOLIDS}}{m^3 \text{ WASH}}\right) + \left(17.7 \frac{m^3\text{-FILTRATE}}{h} \times 550 \frac{\text{g-SOLIDS}}{m^3\text{-FILT}}\right)}{(2 \ m \text{ WIDTH}) \times (1000 \ g/kg)}$$

$$= 24 \frac{kg}{m \cdot h}$$

$$\text{RECOVERY} = \frac{320 \text{ kg}/m \cdot h - 24 \text{ kg}/m \cdot h}{320 \text{ kg}/m \cdot h} \times 100 = 93\%$$

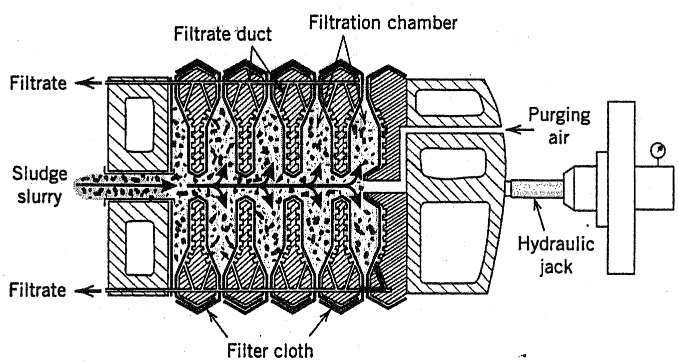
(80% of WHICH IS WASH)



Horizontal belt press. Courtesy of Envirex.

7. Concentration of solids in the reject liquid.
8. Space requirements. Mechanical processes require much smaller areas than land dewatering.

More details on the design and operation of the most common concentration operations are given in later sections.



Filter press. Courtesy of Degrémont Infilco.

20.3 SLUDGE CONDITIONING

Sludges are conditioned to improve their dewatering and cake forming properties in processes described in the above section and below. The tables in Section 20.2 show that both product cake concentrations and percentage solids capture generally improve with chemical addition. Common coagulating agents such as ferric chloride and lime in addition to a variety of synthetic chemicals are good conditioning agents. Inorganic chemical conditioning is associated principally with vacuum and pressure filtration processes with lime and ferric chloride being the most often used agents (USEPA,

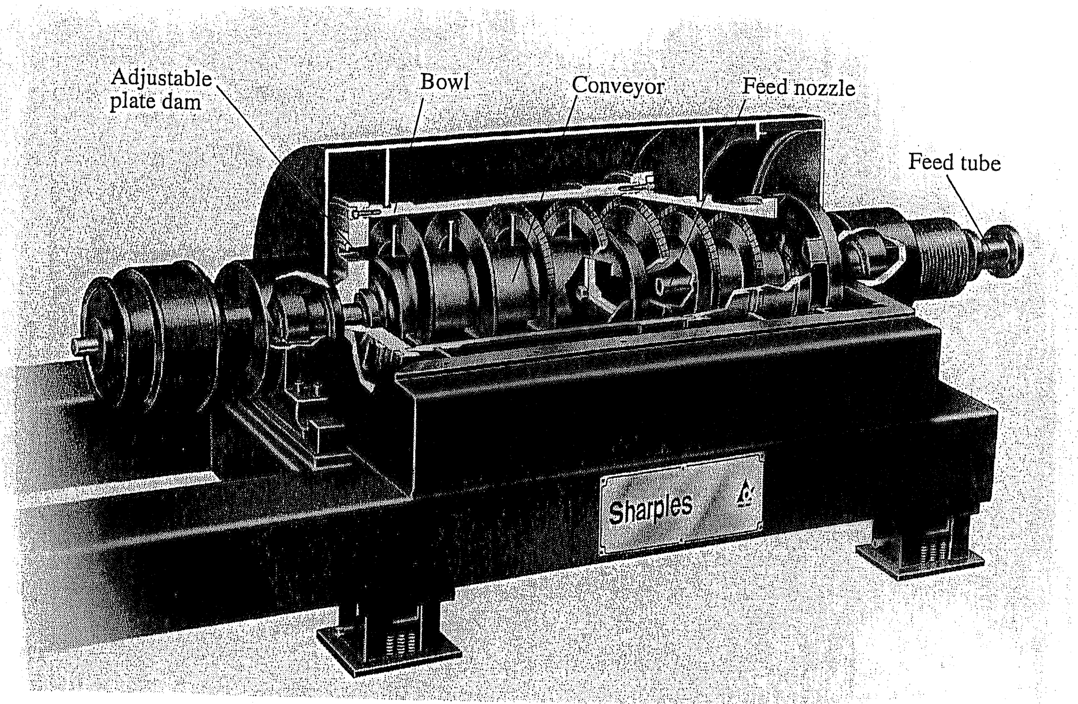


FIGURE 13.23 Solid-bowl decanter centrifuge. *Source:* Courtesy of Alfa Laval Sharples, Alfa Laval Separation Inc.

cake to a thickened liquid slurry. Feed rates, solids content, and prior chemical conditioning can also be varied to influence performance.

The performance of centrifuge dewatering for given feed and machine-operating conditions depends on the dosage of polymers and other chemical coagulants. Suspended-solids removal and usually cake dryness increase with greater chemical additions, while carryover of solids in the centrate decreases. There is, however, a saturation point at which flocculent dosage does not significantly improve centrate clarity. Optimum chemical conditioning without overdosing can be determined most reliably by full-scale or pilot-plant tests. For some wastes, centrate recycling can improve overall suspended-solids removal, but for others it may cause upset, owing to an accumulation of fine particles.

13.26 APPLICATIONS OF CENTRIFUGATION

The characteristics of a wastewater sludge to be dewatered determine the centrifugation capacity, chemical conditioning, cake dryness, and solids recovery. The ratio of primary to waste-activated solids in a sludge has a significant effect. For illustration, consider the following typical performance data in dewatering different kinds of sludges by using an adequate polymer dosage for a minimum of 90% solids recovery: raw primary, cake solids of 28%–34% and polymer dosage of 2–4 lb/ton of dry solids; raw primary plus waste-activated sludge, cake solids of 18%–25% and polymer dosage of 6–14 lb/ton; and raw waste-activated sludge, cake solids of 14%–18% and polymer dosage of 12–20 lb/ton [3]. Usually, the cake solids can be increased a few

Compared to belt presses, filter presses are more expensive, have higher operating costs, and are substantially larger machines for the same sludge processing capacity. Dewatering of wastewater sludge requires lime and ferric chloride conditioning; polymer flocculation is not suitable. High cake dryness is the principal advantage of pressure filtration with cake solids content greater than 35% and up to 40%–50% possible.

A pressure filter consists of depressed plates held vertically in a frame for proper alignment and pressed together by a hydraulic cylinder (Fig. 13.20). Each plate is constructed with a drainage surface on the depressed portion of the face. Filter cloths are

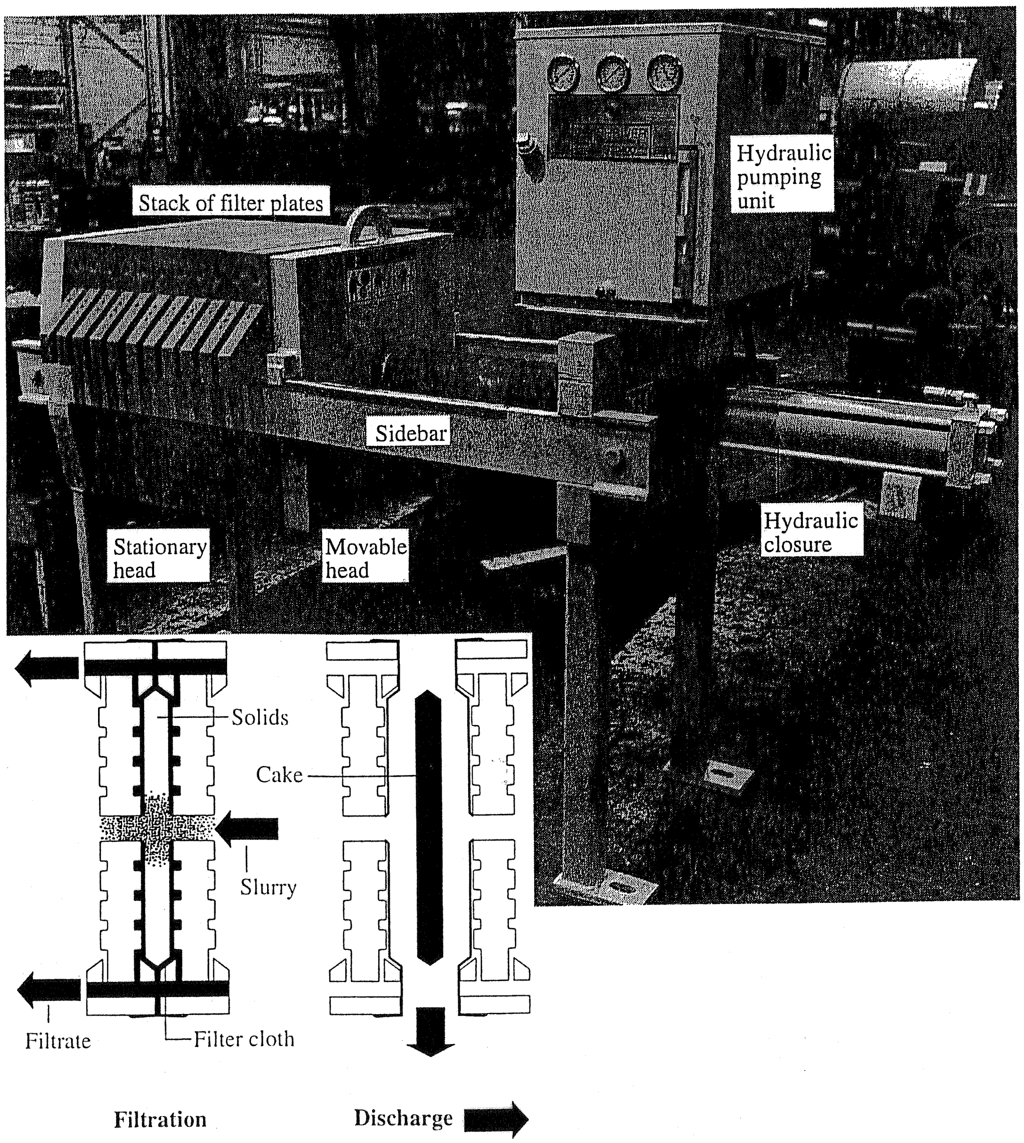


FIGURE 13.20 Pressure filter for dewatering waste slurries from water and wastewater processing. The two major components of the filter press are the skeleton frame and plate stack. With the plates clamped together, as shown on the left, waste slurry is pumped under pressure into the cavities between the plates and filtrate passes through the filter cloths to discharge as the cavities fill with solids. The cake is released, as shown on the right, by opening the plates. *Source*: Courtesy of EIMCO Process Equipment.