

Flotation

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Flotation involves separation of solids from the water phase by attaching the solids to fine air bubbles to decrease the density of the particles so that they float instead of sinking. The rising solids are called the "float". The float is skimmed off the surface and further processed in the sludge train.

Advantages of flotation over sedimentation:

- high rise velocity permits small tankage
- ability to handle variable solids loading (can adjust air flow)
- can provide high float concentration (good thickening)
- can remove low density particles which would require long settling periods.

Disadvantages:

- capital costs
- energy, operating costs

Dispersed (induced) air flotation

Air is introduced by propellers or air pumped through diffusers. Bubble size is relatively large 100 – 1000 μm . High shear and high bubble rise rate limit this to processes such as ore benefaction (separation). In wastewater or water treatment the floc is not generally strong enough for the high shear induced by propellers or high air pumping rate.

Dissolved Air Flotation (DAF)

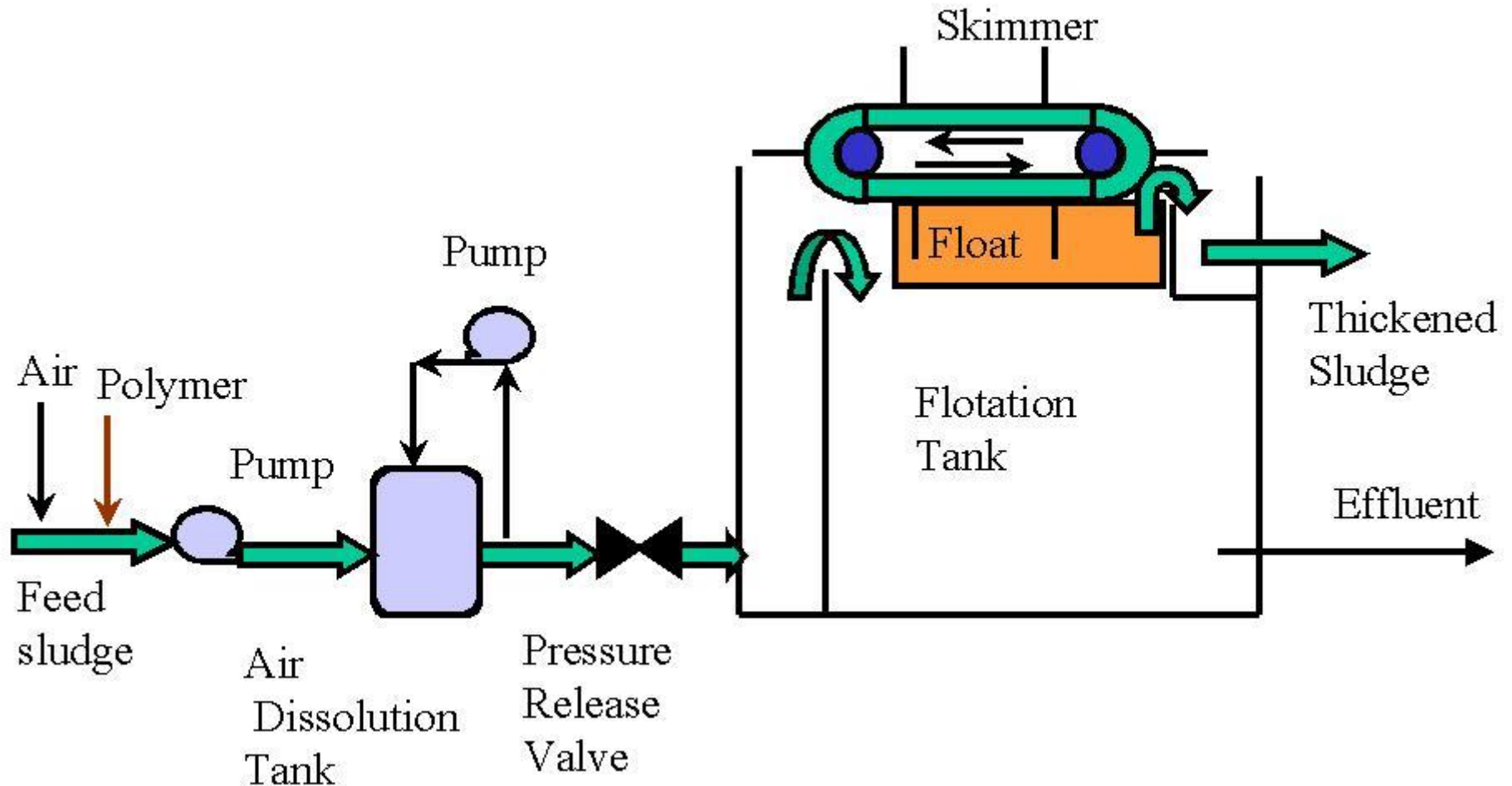
In this case the suspension is saturated with air at high pressure (40-50 psig). This suspension is then pumped to a flotation chamber at 1 atm (14.7 psi). Bubbles are released to the water (since the water was previously supersaturated) and will attach to the suspended solids. These bubbles are smaller than in dispersed air flotation (30 -120 μm) --smaller bubbles adhere to solids better. This is the most important type of flotation for wastewater treatment.

Vacuum Flotation

In this case the suspension is saturated with air at 1 atm then a vacuum is applied to create relative supersaturation. This results in bubble formation. Because there is a maximum of 1 atm pressure difference there is a severe limitation on the amount of air available for flotation. This limits the applicability of this process.

Design of Flotation Systems

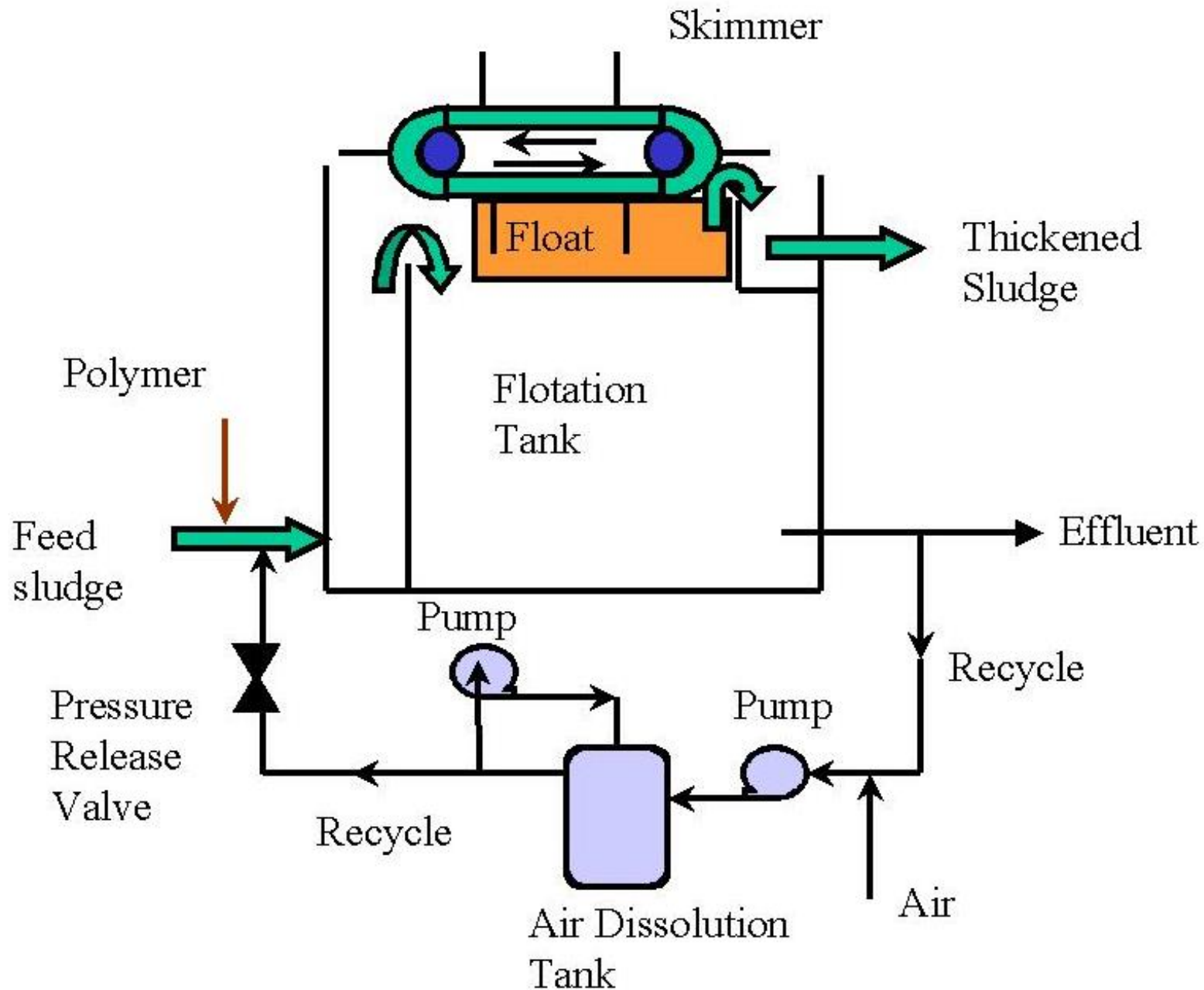
Single pass system:



Recycle:

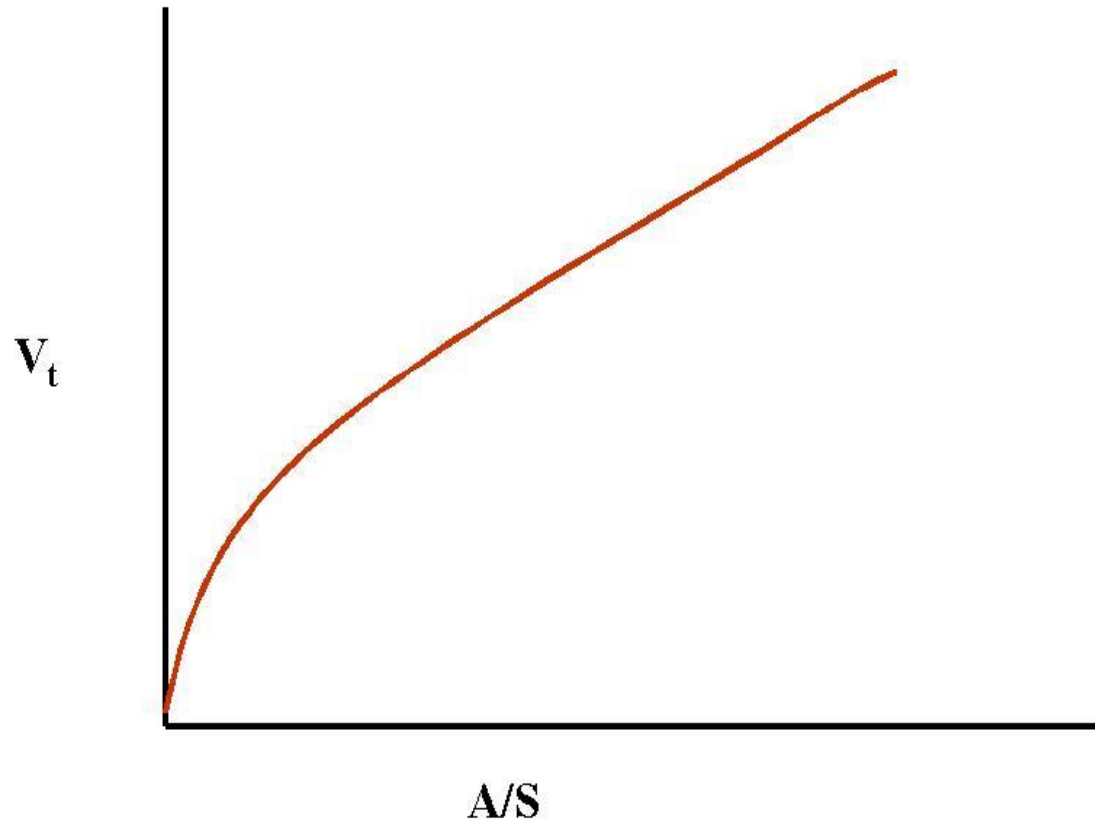
Often recycle is employed because the flocculent suspended solids are too fragile to be directly aerated and because larger quantities of air can be introduced since recycle flow can be greater than feed flow.

Process flow with recycle:

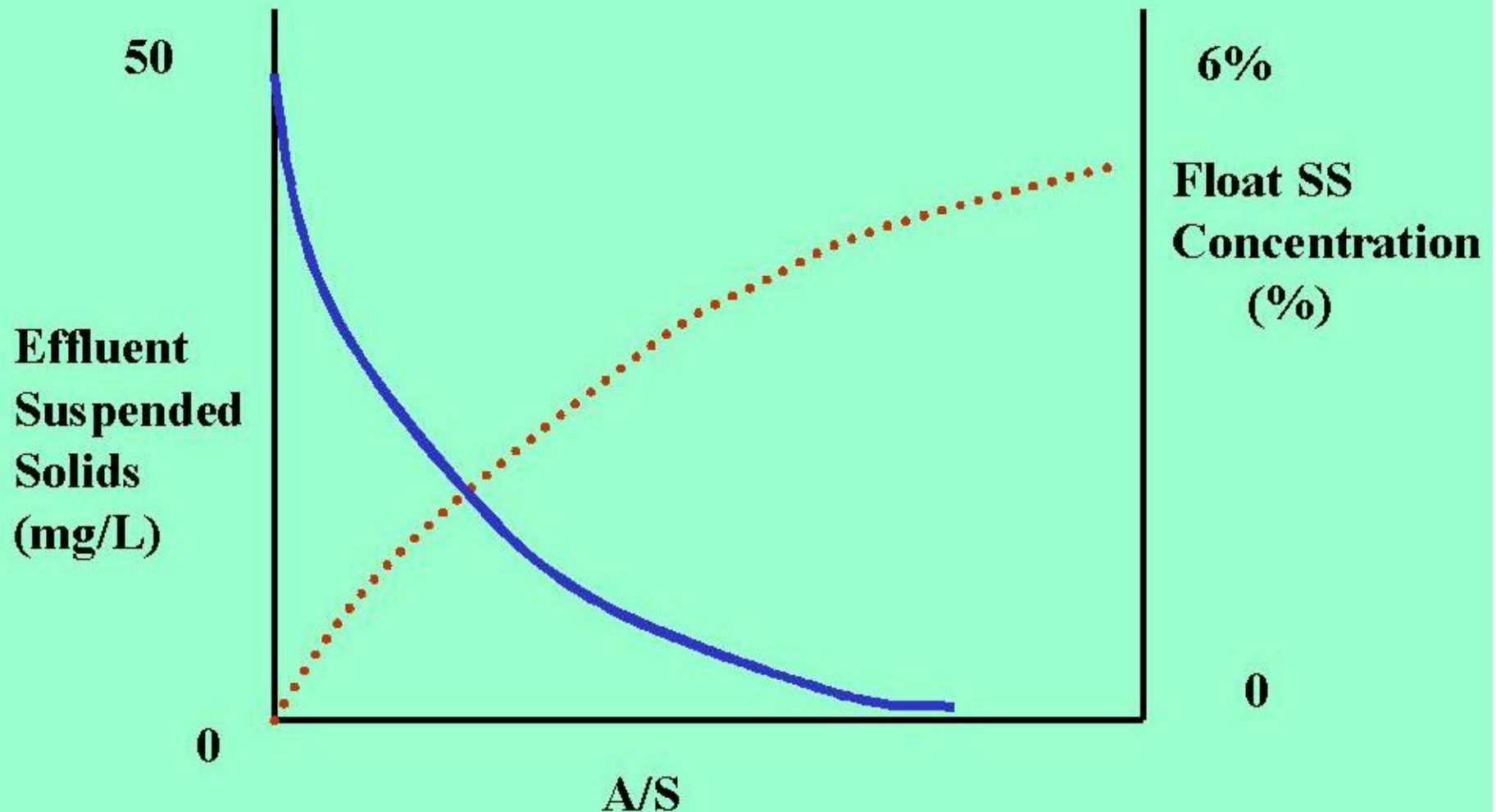


Although the batch flux concept and method applies to flotation analysis a simpler approach is used in the design of a flotation system. The rise velocity of the sludge, V_t , is equivalent to the ZSV for gravity sedimentation. However, there is an additional parameter in flotation which affects rise velocity. This parameter is the air to solids ratio (A/S).

In general the relationship between A/S and rise velocity looks like:



The relationship between A/S and float concentration and effluent quality looks like:



Calculating A/S

A/S can be computed from mass balances on air and suspended solids:

Define:

C_s = saturation value for dissolved air at 1 atm pressure (mg/L)

<u>C_s (mg/L)</u>	<u>T (°C)</u>
32.7	0
29.3	10
24.3	20
20.9	30

C_p = concentration of air dissolved in water
leaving the pressure chamber (mg/L)

P = operating pressure of pressure chamber
(atm)

f = fraction of saturation achieved in pressure
chamber.

Then:

$$C_p = fC_s(P/1\text{atm})$$

Amount of air available for flotation (assuming release pressure is 1 atm) is given by:

$$C_p - C_s = C_s \left(\frac{f \cdot P}{1 \text{ atm}} - 1 \right)$$

Then if X_0 = suspended solids content of feed (mg/L):

$$\frac{A}{S} = \frac{C_s \left(\frac{f \cdot P}{1 \text{ atm}} - 1 \right)}{X_0}$$

f has values from 0.5 to 0.8 and depends on the mixing level and detention time in the pressure chamber.

For recycle systems:

Define:

Q_o = feed flow rate (L/min)

R = recycle flow rate (L/min)

$Air_{out} = C_s(Q_o + R)$ *This is really just the total mass of air left in solution after the flotation chamber.*

$$\frac{A}{S} = \frac{(\text{Air}_{\text{in}} - \text{Air}_{\text{out}})}{\text{Solids}_{\text{in}}}$$

$$= \frac{\{(f \cdot C_s \cdot P / 1\text{atm}) \cdot R + Q_0 \cdot C_s\} - C_s (Q_0 + R)}{Q_0 \cdot X_0}$$

$$\frac{A}{S} = \frac{C_s \cdot R ((f \cdot P / 1\text{atm}) - 1)}{Q_0 \cdot X_0}$$

Thus, if T , X_o and Q_o are fixed then $A/S = f(R,P,f)$ and A/S can be varied accordingly.

Note that the effect of changing A/S on float concentration, effluent SS, and rise velocity has been shown in previous graphs. These plots were derived by changing A/S by a single parameter manipulation such as R , P or f . Although A/S can be manipulated by changing R , P or f to produce the same A/S , clarification or thickening performance could differ for each type of manipulation.

Design steps:

- Perform batch tests (vary A/S) to get the highest possible V_t . For the recycle system this batch test can be done in a graduated cylinder in the following fashion. In a one-liter graduated cylinder place 500 ml of the sludge to be floated. To this add 500 ml of supersaturated "recycle" water. As the recycle water is added it will release its air and attach to solids, after a float forms measure the rate of rise to get V_t .

Compute A/S from:

$$\frac{A}{S} = \frac{C_s \cdot R ((f \cdot P / 1\text{atm}) - 1)}{Q_0 \cdot X_0}$$

with $R/Q_0 = 1$, repeat with different A/S by changing R/Q_0 . For example if 800 ml of sludge are mixed with 200 ml of "recycle" water, $R/Q_0 = 0.25$, etc.

It is usually assumed that $f = 1$ for these graduated cylinder tests. (note that if a single pass system is to be used, the sludge has to be aerated directly and discharged to the flotation chamber. A/S can be changed by varying the pressure of air applied to the saturation chamber).

- Select R/Q_0 (A/S) for design at the optimum (highest V_t)
- Compute surface area of the flotation chamber based on:

$$V_t = \frac{Q_0 + R}{A_s}$$

Increase this area by a factor of 1.4 (safety factor).

- Check solids loading flux capacity using the guidelines given below.
- Choose geometry so that depth/width is in the range of 0.3 to 0.5 and so that the horizontal velocity in the flotation tank is $< 3\text{ft/min}$

Sludge Type	Loading lbs/ft ² -da
Activated Sludge	5 -15
Settled Sludge	10 -20
Primary + AS	20 -40
Primary	< 55

Guideline (rule of thumb): 30 – 40 lbs/ft²-day
(~150 kg/m²-da)

Typical design:

$$P = 25\text{-}70 \text{ psig}$$

$$A/S = 0.01 - 0.1$$

$$\theta = 20 - 60 \text{ min (flotation chamber)}$$

$$Q_{\text{total}}/A_s = 500 - 4000 \text{ gpd/ft}^2$$

$$R = 5 - 120 \% \text{ of } Q_0$$

$$f = 0.5 - 0.8$$

A typical flotation system is shown here:

