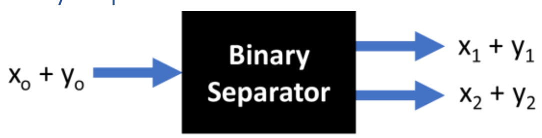
Separation of Municipal Solid Waste

I. Binary Separator



x and y are in units of <u>mass per time</u>

[x] and [y] are in units of <u>concentration</u>

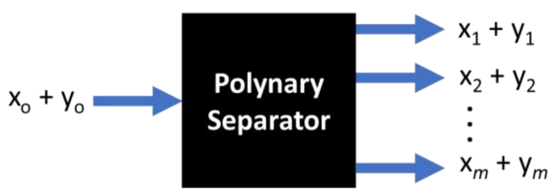
Equation	Formula for component x in stream 1	Formula for component y in stream 2
Percent Recovery (%); mass per time basis	$R_{x_1} = \left(\frac{x_1}{x_0}\right) * 100$	$R_{y_2} = \left(\frac{y_2}{y_0}\right) * 100$
Percent Recovery (%); concentration basis	$R_{x_1} = \frac{[x_1]([x_0] - [x_2]) * 100}{[x_0]([x_1] - [x_2])}$	$R_{y_2} = \frac{[y_2]([y_0] - [y_1]) * 100}{[y_0]([y_2] - [y_1])}$

Mass balance: $x_0 = x_1 + x_2$

$$R_{x_1} = \left(\frac{x_0 - x_2}{x_1 + x_2}\right) * 100$$

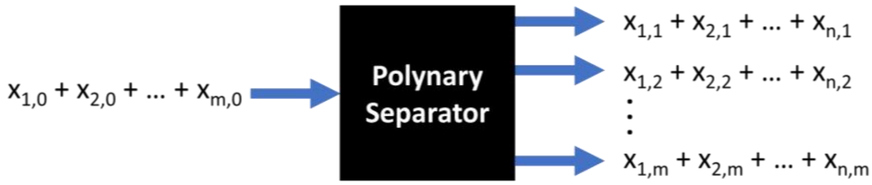
Equation	Formula for stream 1 in terms of x	Formula for stream 2 in terms of y
Purity (%); mass per time basis	$P_{x_1} = \left(\frac{x_1}{x_1 + y_1}\right) * 100$	$P_{y_2} = \left(\frac{y_2}{x_2 + y_2}\right) * 100$
Purity (%); concentration basis	$P_{x_1} = \frac{[x_1]\rho_x * 100}{[x_1]\rho_x + [y_1]\rho_y}$	$P_{y_2} = \frac{[y_2]\rho_y * 100}{[y_2]\rho_y + [x_2]\rho_x}$

II. Polynary Separator



$$R_{x_1} = \left(\frac{x_1}{x_0}\right) * 100 \qquad R_{x_m} = \left(\frac{x_m}{x_0}\right) * 100$$

$$P_{x_1} = \left(\frac{x_1}{x_1+y_1}\right) * 100 \qquad P_{x_m} = \left(\frac{x_m}{x_m+y_m}\right) * 100$$



$$R_{x_{1,1}} = \left(\frac{x_{1,1}}{x_{1,0}}\right) * 100$$

$$P_{x_1} = \left(\frac{x_{1,1}}{x_{1,1} + x_{2,1} + \cdots + x_{n,1}}\right) * 100$$

Effectiveness: $E_{x,y} = 100 * \left(\frac{x_1}{x_0} * \frac{y_2}{y_0}\right)^{1/2}$

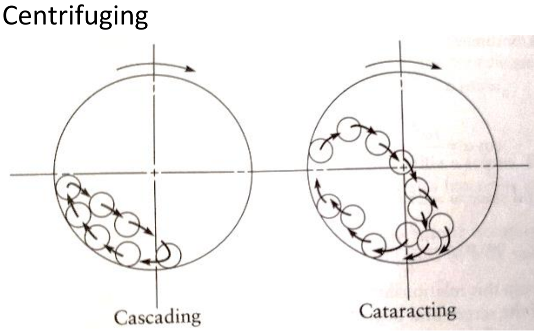
III. Trommel Screens

Screen Recovery: $R_{x_1} = \left(\frac{x_1}{x_0}\right) * 100$

x_1 = amount of material recovery as extract (i.e., material falling through the holes); (mass/time)

x_0 = amount of undersized material that *could have* fallen through the holes; (mass/time)

- Resistant to clogging
- Drum rolls at a slow speed (10-15 rpm)
- Often used at the beginning of the process line
- Three types of motion:
    - Cascading – slower speed, less turbulent
    - Cataracting – speed is sufficient to fling material into air, more turbulent, more efficiency
    - Centrifuging

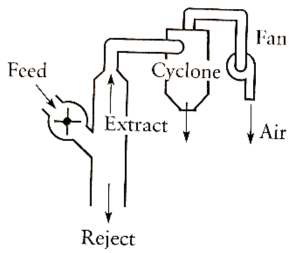


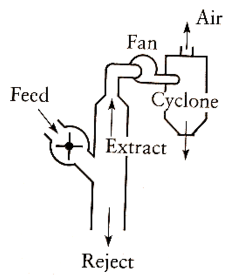
- Critical speed = when particle movement goes from cataracting to centrifuging = n_c

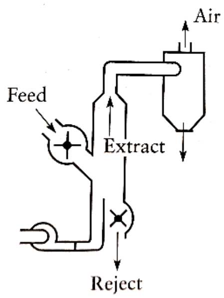
$$n_c = \sqrt{\frac{g}{4\pi^2 r}} \qquad \text{(rotation/second)}$$

g = 980 cm/s^2
r = drum radius (cm)

IV. Air Classifiers







- Separates waste based on aerodynamic velocity
- Aerodynamic velocity of representative particles to be separated can be measured with a "drop test"
- Terminal settling velocity of a particle can be calculated from drop test data:

  $$y = \frac{v_s^2}{g} * \ln\left(\frac{1}{2}\right) * [e^{v_s^{gt}} - e^{v_s^{gt}}]$$

  y = distance traveled, ft
  v_s = terminal settling velocity, ft/s
  g = 32.2 ft/s^2
  t = time to travel distance y, s
- Terminal settling velocity can also be estimated with an empirical equation:

  $$v_s = 1.9 + 0.092\rho_s + 5.8A$$

  ρ_s = particle density, lb/ft^3
  A = particle area (e.g., for a plate, A = length x width)
- The feed rate (of waste) into the air classifier can affect the performance. If more heavy particles are present, these interfere with the speed of the air stream and can interfere with the acceleration of smaller particles that would otherwise be recovered. Therefore, the average residence time of particles in the throat of the air classifier can be described by:

  $$t = \left(\frac{V}{Q}\right)^n$$

  t = average residence of time of particles
  V = volume within throat section
  Q = feed flow rate
  n = factor that accounts for the congestion within the throat; n > 1.0
- Better performance can be achieved by using achieving separation on the basis of density only, and not on the aerodynamic velocity. To do this, air classifiers have been modified to cause particles to continually accelerate and decelerate. This may be done with geometric modifications (i.e., zig-zag, baffled or constricted air classifiers), or with a pulsed flow.

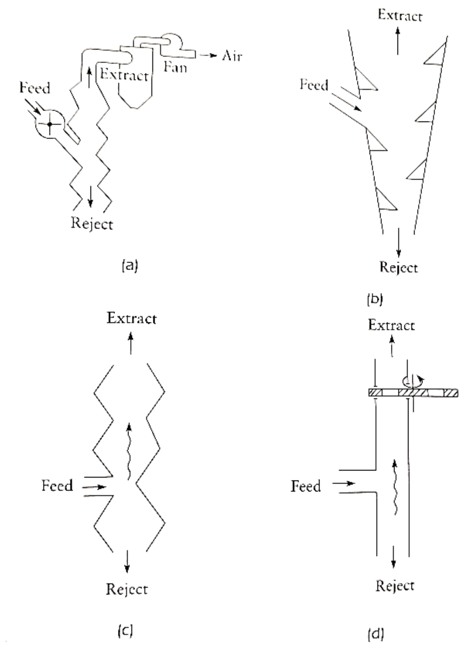


Figure 6-23 Various air classifiers: (a) zig-zag, (b) baffled, (c) constricted, and (d) pulsed flow.

V. Cyclones

- Extracted material must be removed from the air stream of an air classifier. Settling chambers are large and inefficient, so cyclones are often used.
- Air and solids enter the cyclone at a tangent. Solids are collected from the bottom, while air exits at the top.
- Particles are moved to the outside of the cyclone by centrifugal action. The objective is to have the highest possible radial velocity of a particle, which is achieved by having a high tangential velocity, a high particle settling velocity, and a small radius.

$$v_R = \frac{d^2(\rho_s - \rho)\omega^2 r}{18\mu}$$

v_R = radial velocity of a particle
d = particle diameter, m
ρ = density of air, kg/m^3
ρ_s = density of particle, kg/m^3
ω = rotational velocity, rad/s
r = radius, m
μ = air viscosity, N-s/m^2

$$v_R = v_s \frac{v_{tan}^2}{gr}$$

v_s = particle settling velocity
v_{tan} = tangential velocity = r*ω
g = gravitational acceleration

$$S \approx \frac{d^2 \rho_s v_{tan}}{36 \mu \pi}$$

S = the radial distance traveled by a particle during one rotation

d = particle size

- The objective of design is to increase S because if particles collide faster with the wall, the faster they are removed from the air stream.

Reference

Vesilind, P. A., Worrell, W., & Reinhart, D. (2002). *Solid Waste Engineering*. Pacific Grove, CA: Brooks Cole.