CH402 Chemical Engineering Process Design

Class Notes L6

Solids Handling

Types of conveyors

- screw and belt, figure 12-60, page 573
- bucket , figure 12-61, page 574
- pneumatic , figure 12-63, page 575 (&12-15)
- vibrating, figure 12-64, page 575
- chutes and gates, figure 12-65, page 576

Screw Conveyors

$$P_{horizontal} = 0.07 \cdot \dot{m}_s^{.85} \cdot L$$

$$P_{veritcal} = 0.012 \cdot \dot{m}_S \cdot \Delta z$$

Table 12-14, p. 562

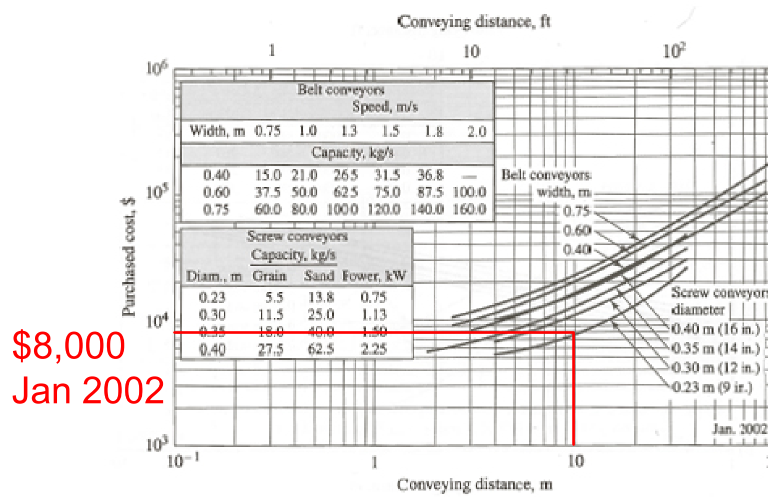
$P = $ power in kW

$\dot{m}_S = $ flow rate of solid in kg/s

$L = $ horizontal length of conveyor (run) in m

$\Delta z = $ height of conveyor in m

http://www.directindustry.com/prod/flexicon/flexible-screw-conveyor-15544-34850.html



Purchased Cost, Figure 12-60, page 573

Total cost is cost to purchase equipment plus cost of power to run the equipment

Example: A 10-m screw conveyor with a diameter of 0.23 m moves with a run of 8 m and a vertical rise of 6 m moves 5.5 kg/s of sand. Determine the cost of the conveyor and the energy cost for 1 year of continuous operation if electricity cost is 0.179 \$/kWh.

$$P_{horizontal} = 0.07 \cdot 5.5^{.85} \cdot 8 = 2.385 \text{ kW}$$

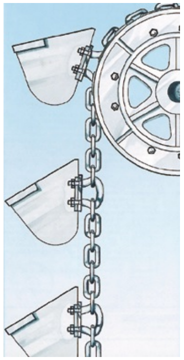
$$P_{veritcal} = 0.012 \cdot 5.5 \cdot 6 = 0.396 \text{ kW}$$

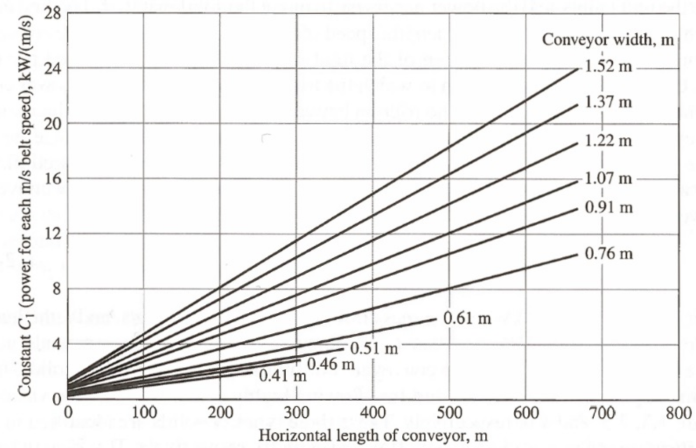
$$P_{total} = 0.396 + 2.385 = 2.781 \text{ kW}$$

$$\text{Energy Cost} = 2.781 \text{ kW} \cdot 8760\text{h} \cdot \frac{\$0.179}{\text{kWh}} = \$4{,}360$$

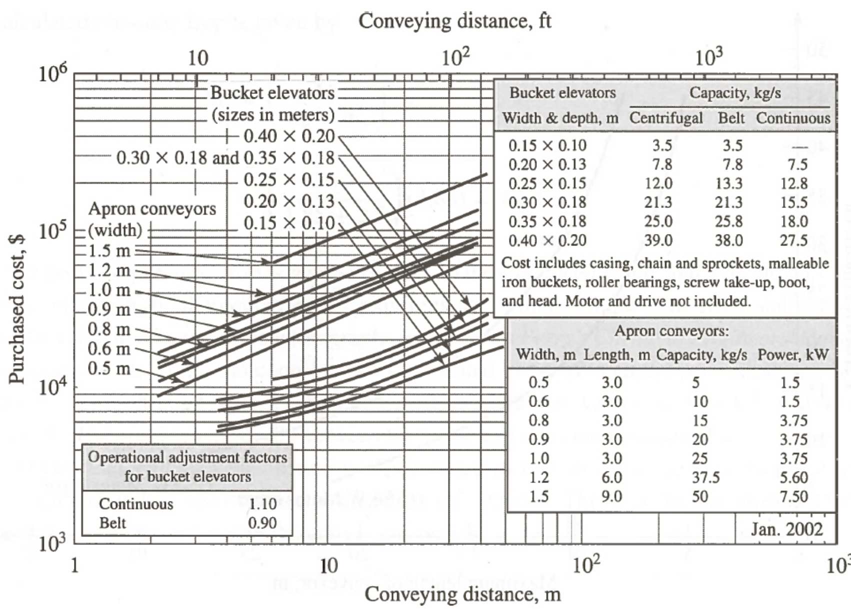
Bucket Conveyors

http://new.gronemeyer-conveyor.com/
http://www.becherwerk.de





C_1 is from figure 12-58 on p. 566



Bucket elevators	Capacity, kg/s		
Width & depth, m	Centrifugal	Belt	Continuous
0.15 × 0.10	3.5	3.5	—
0.20 × 0.13	7.8	7.8	7.5
0.25 × 0.15	12.0	13.3	12.8
0.30 × 0.18	21.3	21.3	15.5
0.35 × 0.18	25.0	25.8	18.0
0.40 × 0.20	39.0	38.0	27.5

Cost includes casing, chain and sprockets, malleable iron buckets, roller bearings, screw take-up, boot, and head. Motor and drive not included.

Apron conveyors:

Width, m	Length, m	Capacity, kg/s	Power, kW
0.5	3.0	5	1.5
0.6	3.0	10	1.5
0.8	3.0	15	3.75
0.9	3.0	20	3.75
1.0	3.0	25	3.75
1.2	6.0	37.5	5.60
1.5	9.0	50	7.50

Operational adjustment factors for bucket elevators

Continuous	1.10
Belt	0.90

Costs are in Figure 12-61, page 574

$$P = P_{empty} + P_{horizontal} + P_{veritcal}$$

$$= C_1 V_{BS} + 0.0295\left(0.4 + \frac{L}{91.42}\right)\dot{m}_s$$

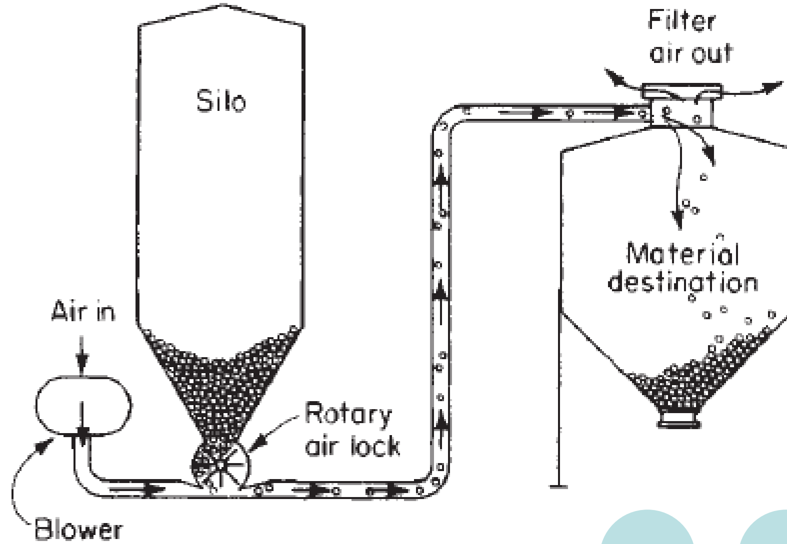
$$+ 0.00969 \cdot \Delta z \cdot \dot{m}_s$$

V_{BS} is the belt speed in m/s

Pneumatic Conveyors

Special Application of Pipe Flow

(See p. 569; we will work Ex. 12-8)



Total power is compressor (blower) power plus power to overcome frictional losses

$$P_{total} = 0.001\left(\frac{P_C \dot{m}_a}{\eta} + P_f\right)$$

p. 569, eq 12-58

frictional losses

Frictional losses are due to frictional losses for air and solids

$$P_f = P_a + P_s$$

P_f = frictional pressure losses

$\frac{V^2}{2}$ $\quad \Delta z \cdot g \quad$ $1.155 \cdot f_s \cdot g$

centrifugal losses in elbows, p. 569, eq 12-56

$$P_s = \left(W_{KE} + W_L + W_{sf} + W_{el}\right)\dot{m}_s$$

$W_{sf} = f_s \cdot L \cdot g = 1.0 \cdot L \cdot g$

"sliding friction," p. 569, eq 12-55; L is length of conveyor

given, page 571

Compressor work is given by eq. 12-22a, p. 527

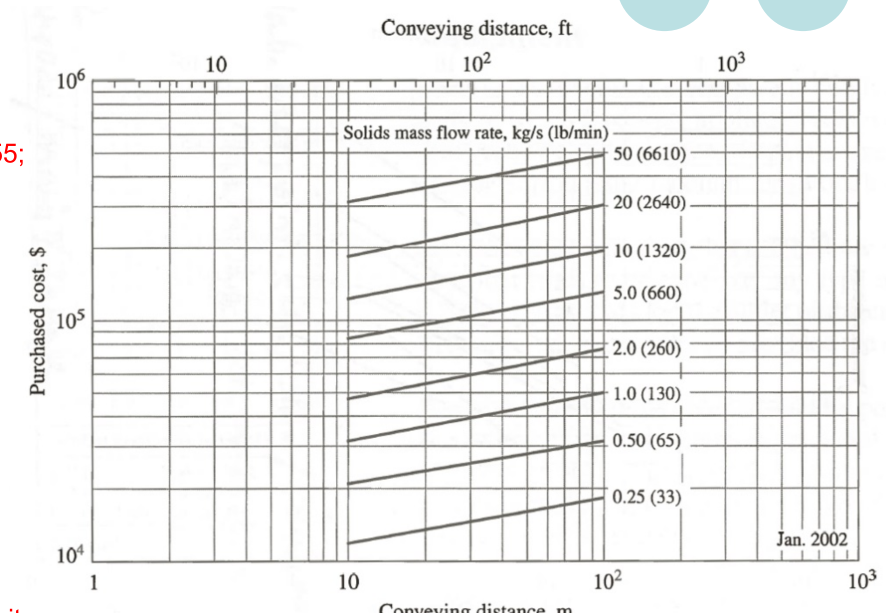
$$P_C = \dot{m}_a R T\left(\frac{k}{k+1}\right)\left[\left(\frac{P_{outlet}}{P_{inlet}}\right)^{(k-1)/k} - 1\right] \quad (kW)$$

$k = C_P / C_V$

Pressure drop in the line is due to the movement of the "psuedofluid" air-solid mixture, eq. 12-56, p. 569

$$\text{pressure drop} = \frac{0.001 \cdot P_f \cdot \rho_m}{\dot{m}_a + \dot{m}_s}$$

average density of solids and air



Costs are in Figure 12-63, page 575

Size Reduction

Costs are in Figures 12-67 to 12-74, pp. 583-586

http://www.kleemann.info/en/technologies/crushing-technology/

Table 12-19 Work indices for grinding specific materials

Material	Density, kg/m^3	Work index, kJ/kg
Cement clinker	3140	53.76
Cement (raw material)	2665	41.62
Coal	1395	51.48
Coke	1305	59.91
Granite	2655	59.91
Gravel	2655	63.60
Iron ore	3520	50.85
Limestone	2655	50.45
Quartz	2645	53.74
Shale	2625	62.85
Slate	2565	56.63

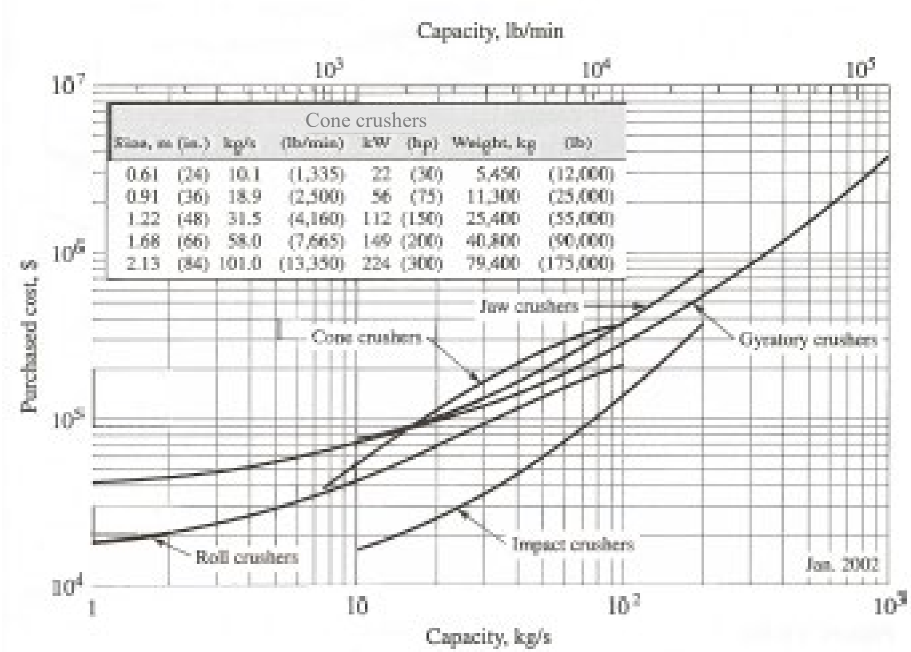


Fig. 12-67 Crushers, including motor and drive

$$P = 0.01 \cdot \dot{m}_s \cdot W_i \cdot \left(\frac{1}{\sqrt{D_{pp}}} - \frac{1}{\sqrt{D_{pf}}} \right)$$

$P =$ power in kW

$\dot{m}_s =$ flow rate of solid in kg/s

$D_{pp} =$ particle size of product in m

$D_{pf} =$ particle size of feed in m

$W_i =$ work index

Work index is the total energy per kg needed to reduce the particle size of the feed so that 80% of product passes through a 100-μm mesh.

Size Reduction

Costs are in Figures 12-67 to 12-74, pp. 583-586

Table 12-18. Design criteria for size reduction equipment under closed circulation operation. [a]

Equipment type	Solid hardness, moh	Max. capacity, kg/s	Max. reduction ratio R	Power, kW [b]
Jaw crusher	8-10	400 (coarse)	8	$P = 3\ \dot{m}_s^{0.88}\ R$
		200 (intermediate)		
Gyratory crusher	8-10	4000 (coarse)	8	$P = 2.5\ \dot{m}_s^{0.88}\ R$
		400 (intermediate)		
Impact crusher	1-3	400	35	$P = 1.0\ \dot{m}_s^{0.88}\ R$
Roll crusher	8-10	125	16	$P = 0.6\ \dot{m}_s^{0.88}\ R$
	4-7			$P = 0.3\ \dot{m}_s^{0.88}\ R$
Disk or attrition mill	1-3	15	15	$P = 10\dot{m}_s$ to $50\dot{m}_s$
Tumbling mills				
Rod mill	8-10	50	15	$P = 0.007\dot{m}_s / D_{pp}$
Ball mill	8-10	15	20	$P = 0.008\dot{m}_s / D_{pp}$
Vibratory mill	8-10	0.1	30	$P = 40\dot{m}_s / D_{pp}^{0.3}$
Ring-roll grinder	4-7	15	15	$P = 0.3\ \dot{m}_s\ R$
Hammer mill	1-3	2	50	$P = 40\dot{m}_s \ln R$
Jet mill	8-10	1	50	$P = 1-10\,\text{kg air}\ (800\,\text{kPa / kg solid})$
Rotary Cutter	1-3	50	50	$P = 100\dot{m}_s$ to $500\dot{m}_s$

[a] Modified from G.D. Ulrich, *A Guide to Chemical Engineering Process Design and Economics*, J. Wiley, New York, 1984, R.H. Snow, *in Perry's Chemical Engineers' Handbook*, 7th Ed., McGraw-Hill, New York, 1997, and vendor literature.

[b] Power P in kW, solids mass flow rate $\dot{m}_s$ in kg/s, reduction ratio R dimensionless, and product particle diameter D_{pp} in m.

Homework

Example 12-8

A 0.154-m-diameter tube is used by a pneumatic conveyor to transport a finely-crushed material with a bulk density of 1000 kg/m^3 at a solids transport rate of 2.5 kg/s. The 100-m conveyor tube contains two 90-degree long sweep elbows and provides a lift of 15 m. Air for the transport is available from another source at a velocity of 73.4 m/s, a temperature of 38 °C, a pressure of 101.3 kPa, and a density of 1.132 kg/m^3. After compression and cooling of the gas, the inlet conditions to the pneumatic conveyor system are 38 °C and 186 kPa. What is the theoretical power requirement for this solids transport system?

(For a quick first estimate, assume the pressure drop through the conveyor pipe is 40 kPa.)

Problem 12-15

Air at 15 °C and 275 kPa is admitted to the entrance of a horizontal steel pipe with an inside diameter of 0.0779 m. The entering velocity is 15 m/s. Spherical particles with a 60-mesh average particle size are picked up by the air stream immediately down stream from the entrance to the pipe. The weight ratio of the solid particles to the air is 4:1, and the density of the particle is 2690 kg/m^3. If the pipe is 50 m in length, what is the pressure loss in the pipe?

A mesh size of 60 is roughly 250 μm and corresponds to a mesh size opening of 0.0098 inches. See http://delloyd.50megs.com/moreinfo/mesh.html

This problem is similar to Example 12-8. Cadets are to submit a completed spreadsheet.

Questions?