

# CH402 Chemical Engineering Process Design

## Class Notes L6

### Solids Handling

Three General Categories: Conveyors, Size Reduction, & Classifiers  
FEE Manual, pages 253-256

# CHEMCAD Solids Handling

CONVEYORS – only pneumatic available using pipe (problem 12-15)

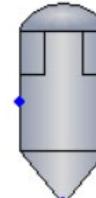
**CLASSIFIERS I**  
CHANGES PARTICLE  
SIZE DISTRIBUTION  
WITH SORTING



centrifugal  
sedimentation



cyclone



baghouse  
filter



centrifugal  
filtration



screen

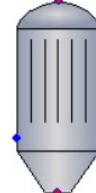


filter

**CLASSIFIERS II**  
CHANGES AMOUNT  
OF SOLID IN A STREAM



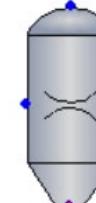
solids washer



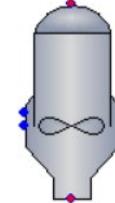
electrostatic  
precipitator



dryer



venturi  
scrubber



crystallizer  
(melter)

**SIZE REDUCERS**  
CHANGES PARTICLE  
SIZE DISTRIBUTION



crusher/grinder

Single unit that can model

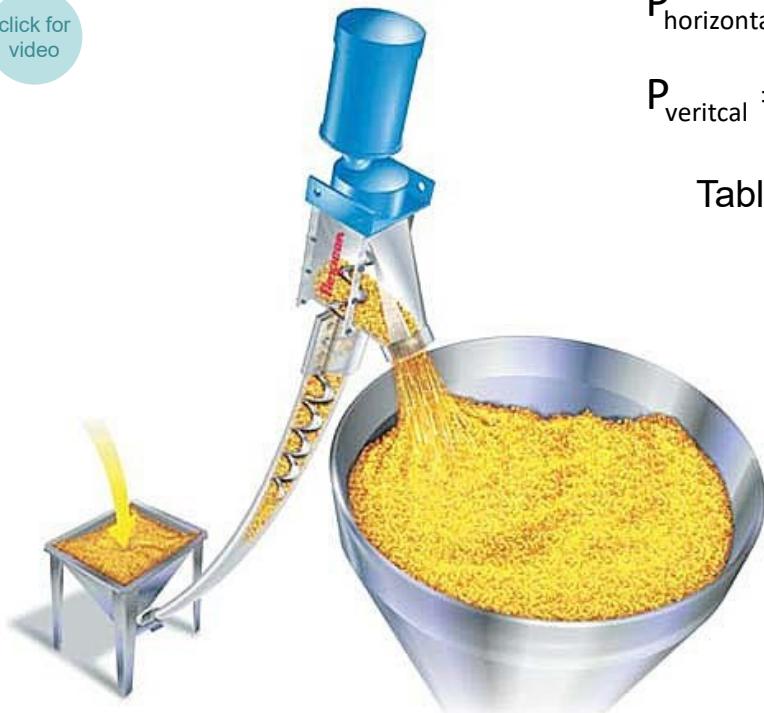
- jaw crushers
- gyrator cone crushers
- roller crushers
- user specified (generic)

# 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

click for video



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

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.

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

$$P_{\text{vertical}} = 0.012 \cdot \dot{m}_s \cdot \Delta z$$

Table 12-14, p. 562

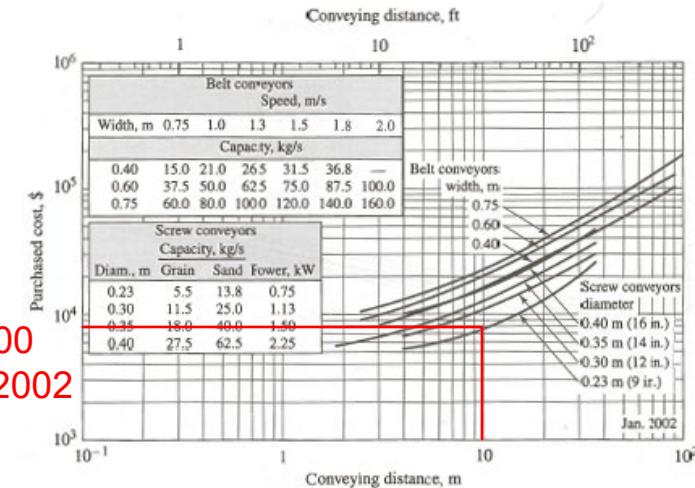
P = power in kW

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

L = horizontal length of

conveyor (run) in m

$\Delta z$  = height of conveyor in m



Purchased Cost, Figure 12-60, page 573

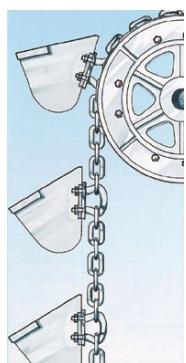
$$P_{\text{horizontal}} = 0.07 \cdot 5.5^{.85} \cdot 8 = 2.385 \text{ kW}$$

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

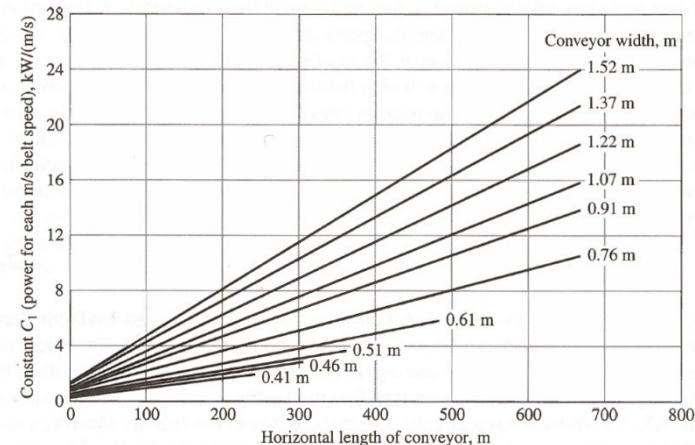
$$P_{\text{total}} = 0.396 + 2.385 = 2.781 \text{ kW}$$

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

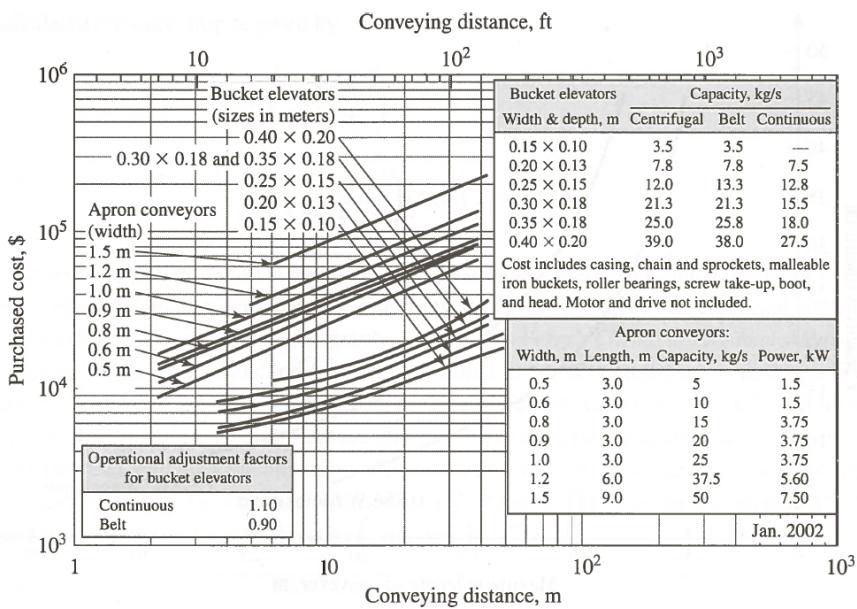
# Bucket Conveyors



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



$C_1$  is from figure 12-58 on p. 566



Costs are in Figure 12-61, page 574

$$\begin{aligned}
 P &= P_{\text{empty}} + P_{\text{horizontal}} + P_{\text{vertical}} \\
 &= C_1 V_{BS} + 0.0295 \left( 0.4 + \frac{L}{91.42} \right) \dot{m}_s \\
 &\quad + 0.00969 \cdot \Delta z \cdot \dot{m}_s
 \end{aligned}$$

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

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

# Pneumatic Conveyors

## Special Application of Pipe Flow

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

$$P_{\text{total}} = 0.001 \left( \frac{P_C m_a}{\eta} + P_f \right) \quad \text{p. 569, eq 12-58}$$

frictional losses

Frictional losses are due to frictional losses for air and solids

$$P_f = P_a + P_s$$

$P_f$  = frictional pressure losses

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

$\frac{V^2}{2}$

$\Delta z \cdot g$

$1.155 \cdot f_s \cdot g$

$W_{sf} = f_s \cdot L \cdot g = 1.0 \cdot L \cdot g$  "sliding friction," p. 569, eq 12-55;  
L is length of conveyor

given, page 571

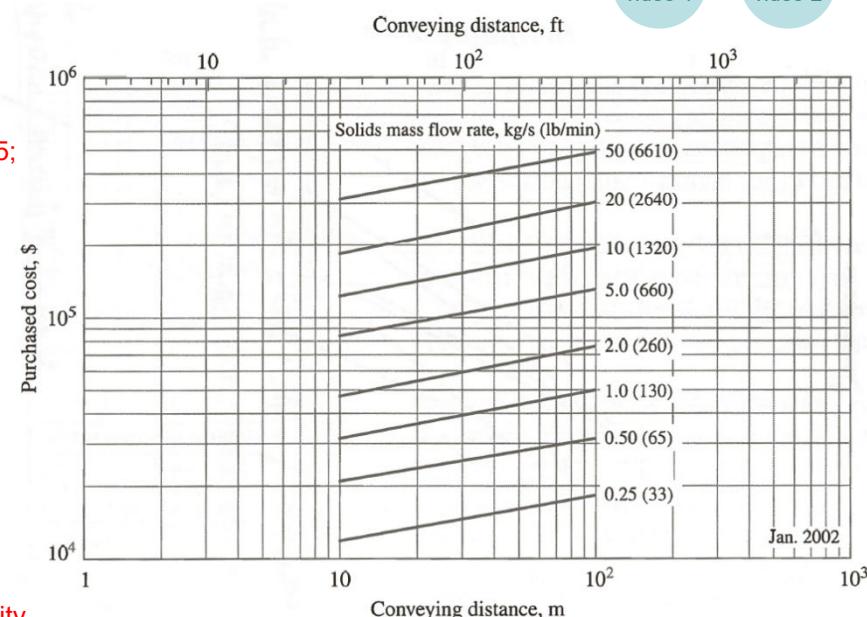
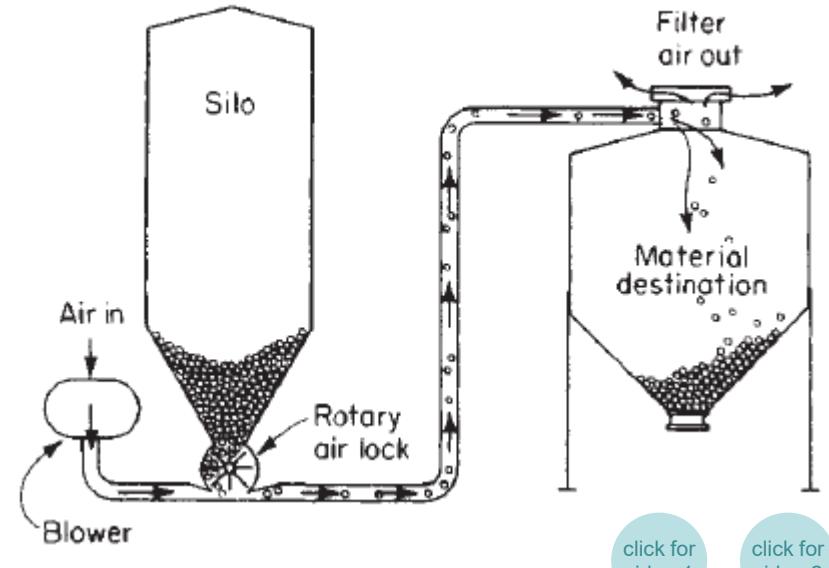
Compressor work is given by eq. 12-22a, p. 527

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

$k = C_P / C_V$

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

$$\text{pressure drop} = \frac{0.001 \cdot P_f \cdot \rho_m}{\dot{m}_a + \dot{m}_s} \quad \text{average density of solids and air}$$



Costs are in Figure 12-63, page 575

click  
here

# Size Reduction

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



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

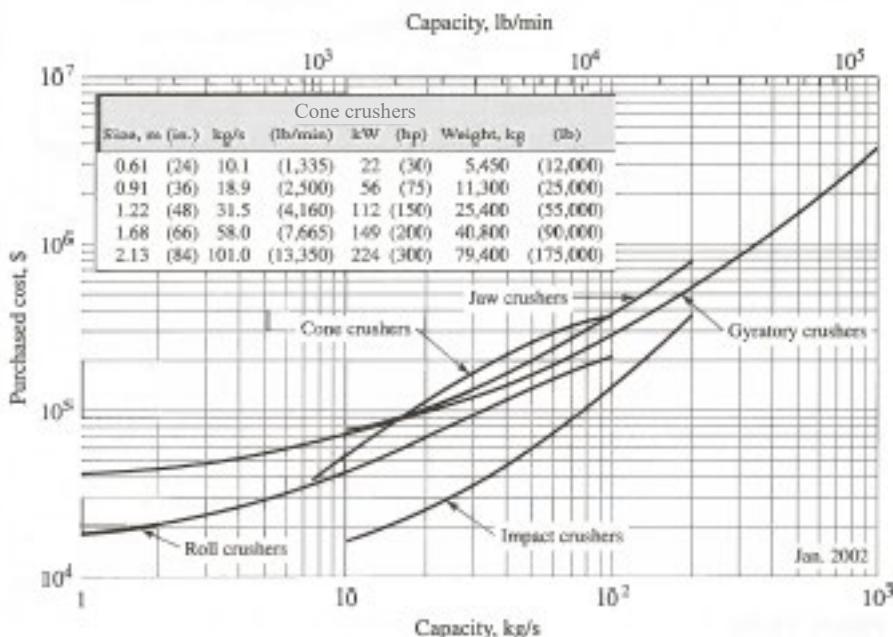


Fig. 12-67 Crushers, including motor and drive

**Table 12-19** Work indices for grinding specific materials

Material	Density, kg/m <sup>3</sup>	Work index, kJ/kg
Cement clinker	3140	53.26
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

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

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.<sup>a</sup>

Equipment type	Solid hardness, moh	Max. capacity, kg/s	Max. reduction ratio R	Power, kW <sup>b</sup>
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	$P = 1-10 \text{ kg air (800 kPa / kg solid)}$
Rotary Cutter	1-3	50	50	$P = 100 \dot{m}_s$ to $500 \dot{m}_s$

<sup>a</sup> 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*, 7<sup>th</sup> Ed., McGraw-Hill, New York, 1997, and vendor literature.

<sup>b</sup> 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.

# Questions?