

CH402 Chemical Engineering Process Design

Class Notes L16

Plant Cost Scaling and Breakeven

L15 lookback: Estimating capital cost for an industrial facility

Method C – percentage method

- Method C.1 – percentage of FCI – Example 6-1.
- Method C.2 – percentage of PEC – Colorful worksheet.
- Need to set the different components of capital investment. *Each of these components has a well-known percentage.*
- Example 6-1 and problem 6-8.
- We also discussed Method 2c – Lang Factors - in Lesson 15.

Methods D – Lang factors

- Not as precise as method C but easy to apply.

Methods E and F – scaling against a known price

- Scaling methods for equipment extended to entire facilities.
- Problems 6-9 and 6-10 and Table 6-11).
- Method F is the same as E but with an exponent of 1.

Methods G – turnover ratio

- Scaling methods for equipment extended to entire facilities (problems 6-9 and 6-10).

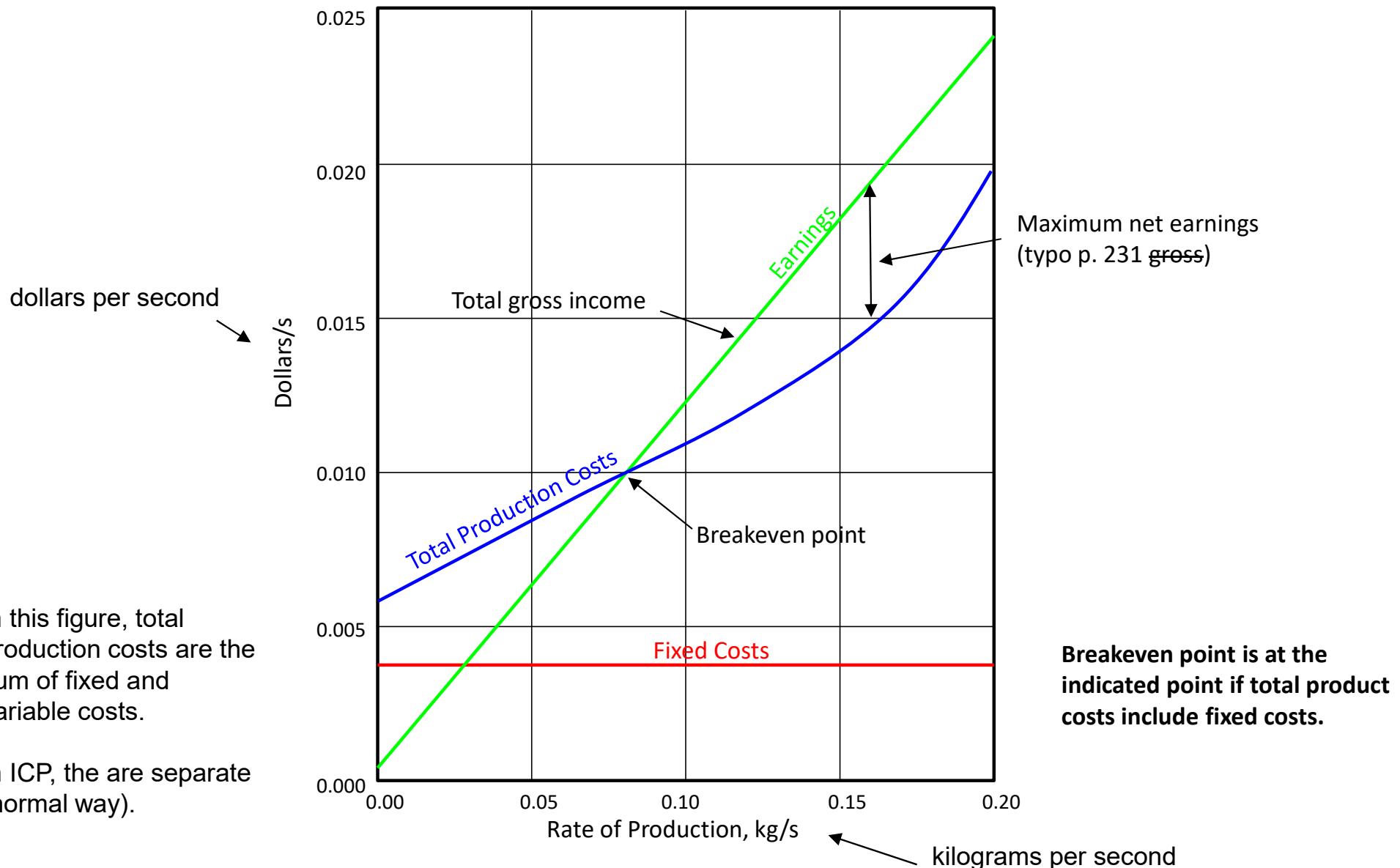
Objectives for Lesson 16:

1. Estimate capital costs using scaling factors.
2. Estimate capital costs based on turnover ratio.
3. Determine breakeven point given production data.

Break-Even Analysis – ICP

PTW Figure 6-3; equation: gross earnings – variable costs – fixed costs

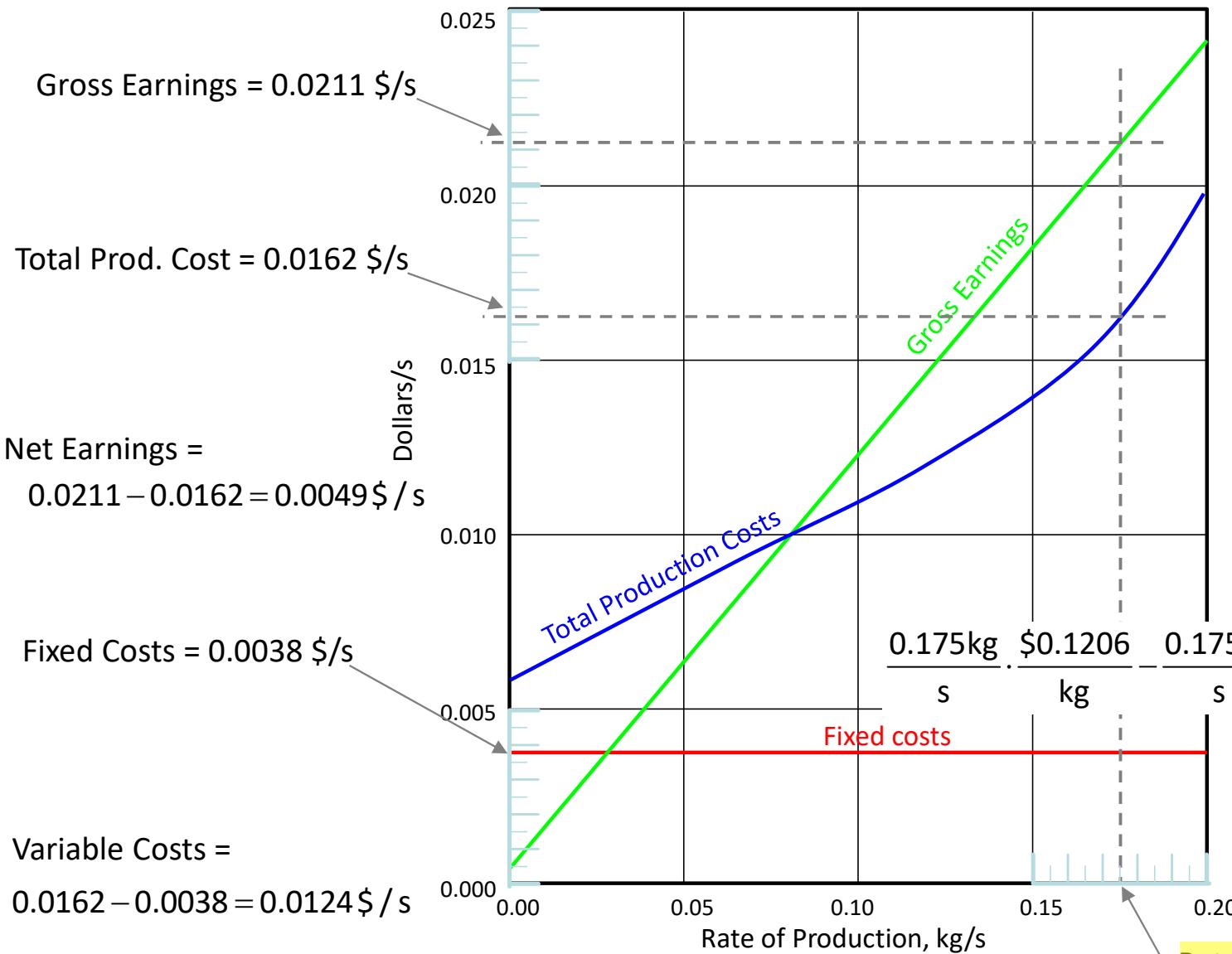
apply this equation



Break-Even Analysis – Ex1

PTW Figure 6-3; equation: gross earnings – variable costs – fixed costs

apply this equation



product market price x , \$/kg:

$$\frac{0.175\text{kg}}{\text{s}} \cdot x = \frac{\$0.0211}{\text{s}}$$

$$x = \frac{\$0.1206}{\text{kg}}$$

variable production cost y , \$/kg:

$$\frac{0.175\text{kg}}{\text{s}} \cdot y = \frac{\$0.0124}{\text{s}}$$

$$y = \frac{\$0.0709}{\text{kg}}$$

$$\frac{0.175\text{kg}}{\text{s}} \cdot \$0.1206 = \frac{\$0.0709}{\text{kg}}$$

$$\frac{\$0.0709}{\text{kg}} - \frac{\$0.0038}{\text{s}} = \frac{\$0.0049}{\text{s}}$$

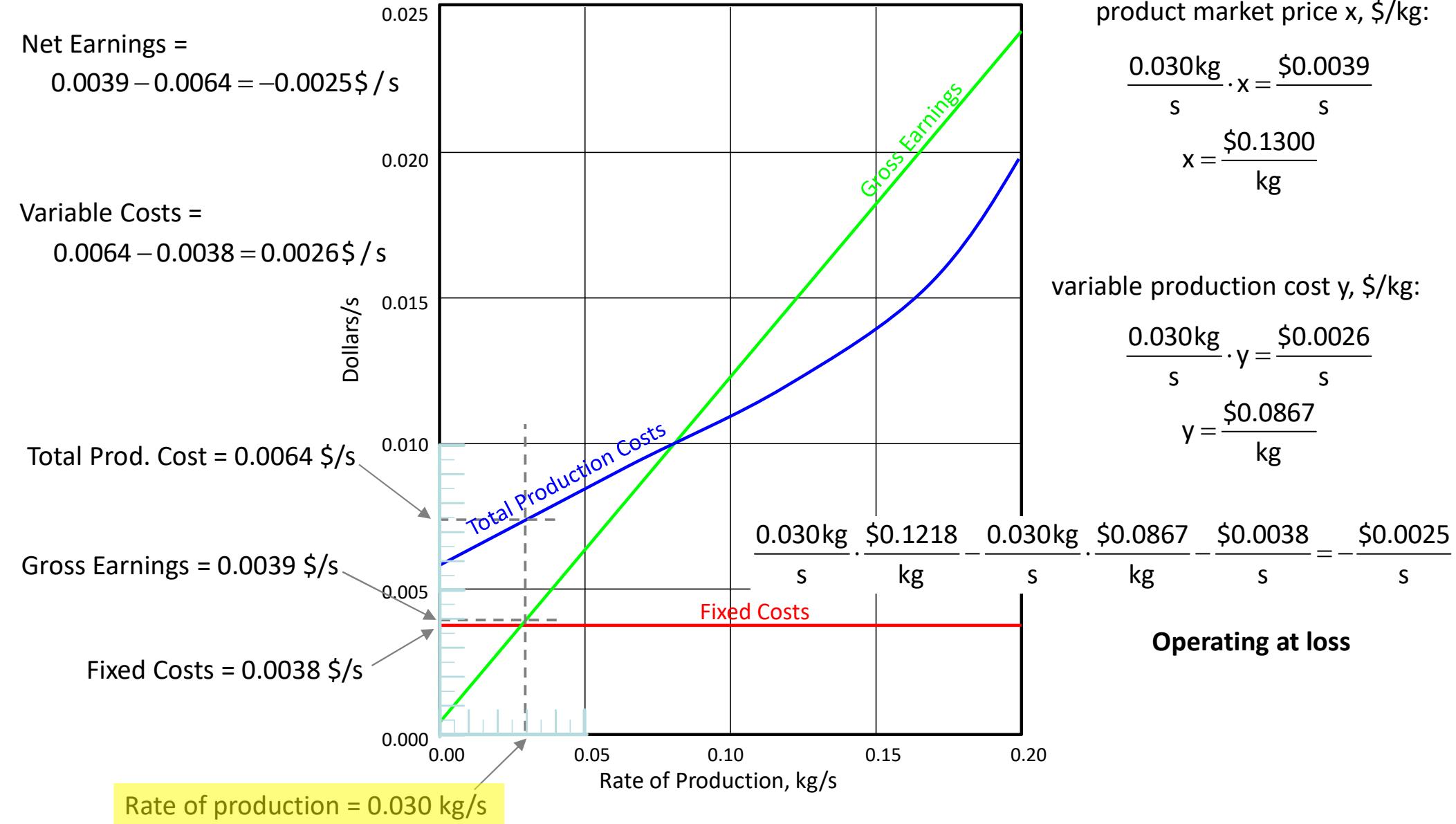
Operating at a profit

Rate of production = 0.175 kg/s

Break-Even Analysis – Ex2

PTW Figure 6-3; equation: gross earnings – variable costs – fixed costs

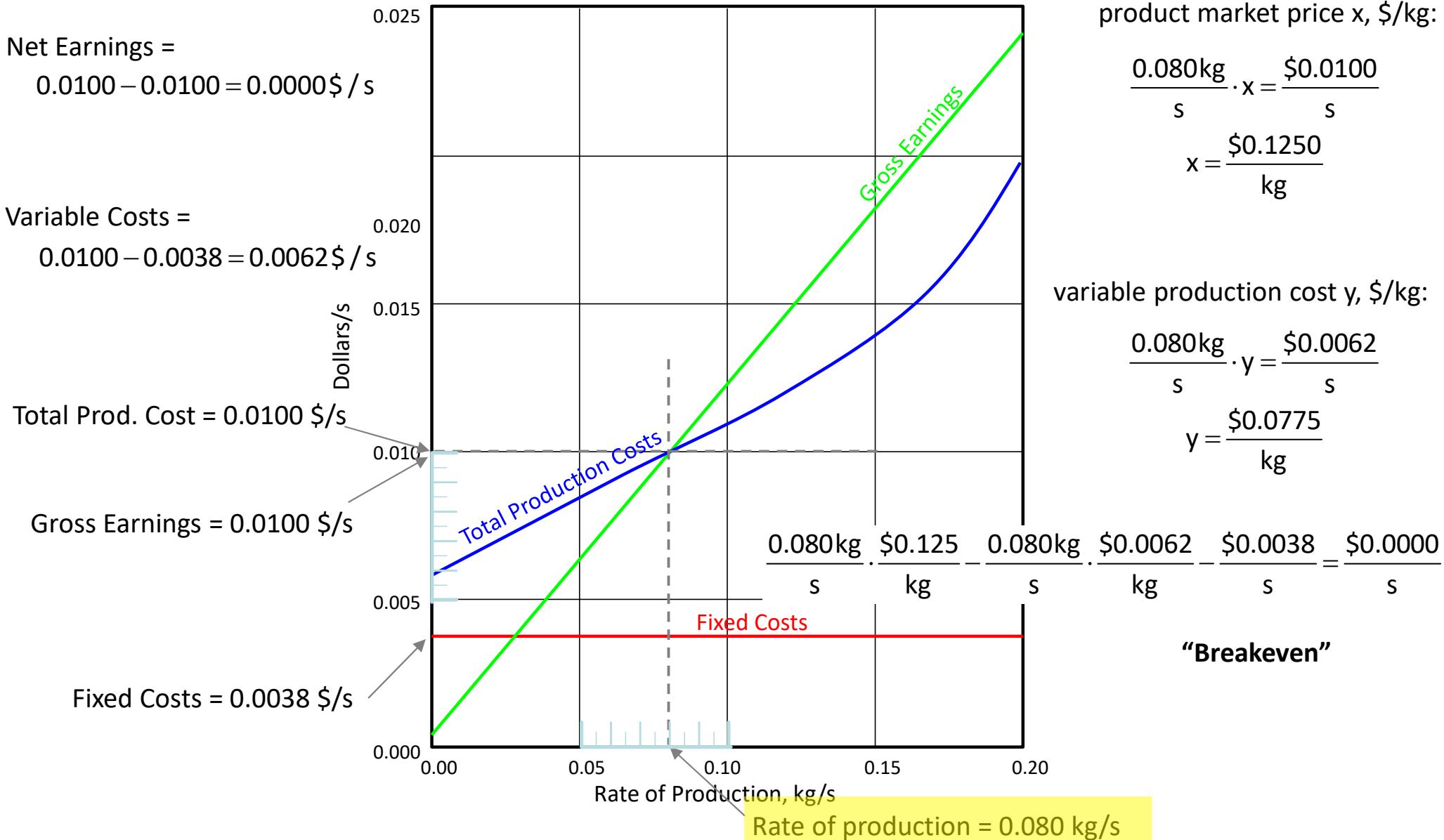
apply this equation



Break-Even Analysis – Ex3

PTW Figure 6-3; equation: gross earnings – variable costs – fixed costs

apply this equation



Proceed to ICP1

Uses an equation from lesson 19:

PTW equation 8-1a, page 323

$$\text{ROI} = \frac{N_p}{TCI}$$

N_p = Net *annual* profit

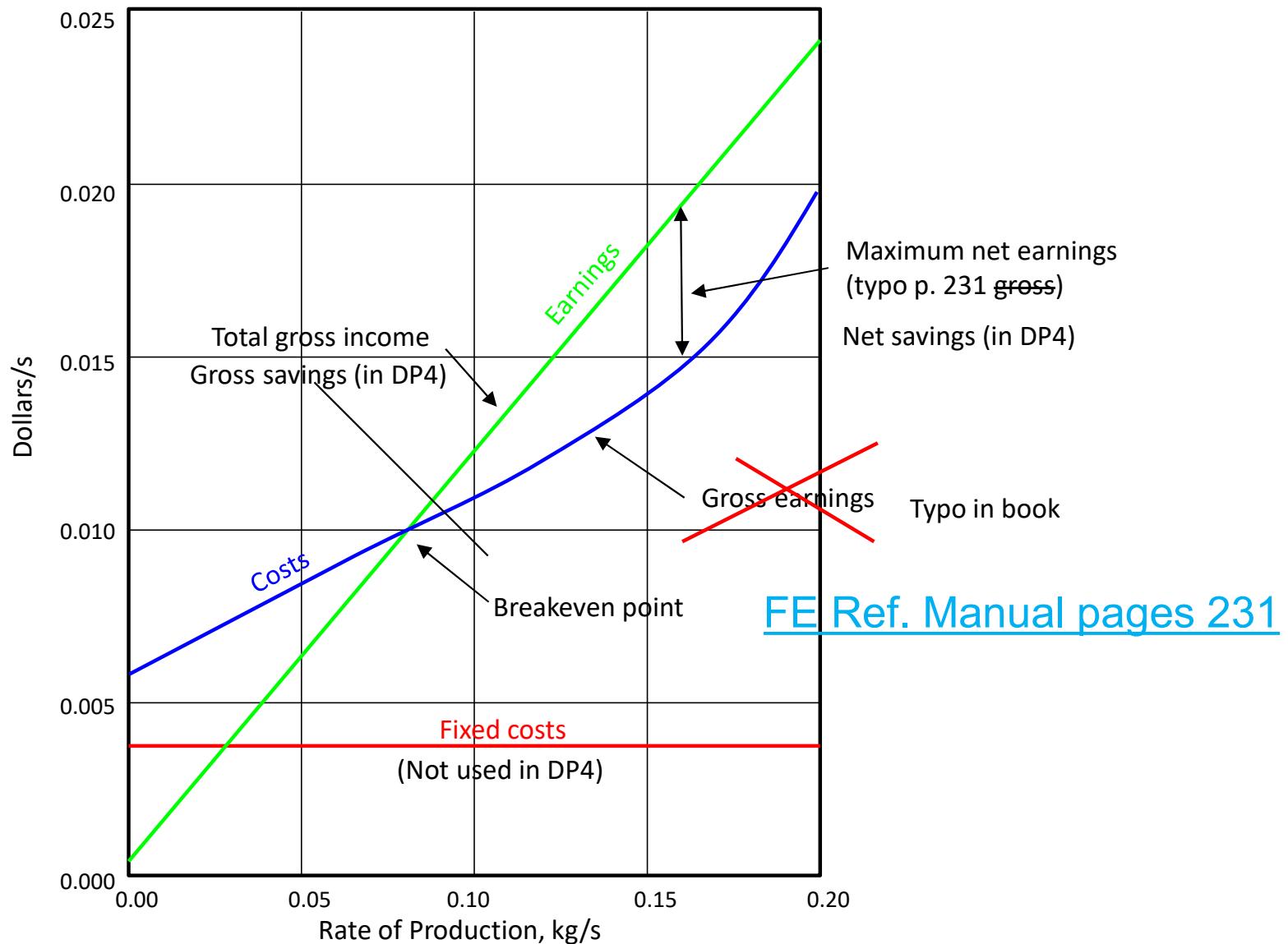
TCI = Total capital investment

Questions?

Supplemental

Break-Even Analysis

Lesson 14 reading, pages 226-232 – breakeven chart – page 231; figure 6-3; FEE p. 130



Lang Factors

Table 6-10. Revised Lang factors for estimation of fixed-capital investment (FCI) or total capital investment (TCI)

Factor × delivered-equipment cost = FCI or TCI		
Type of Plant	Lang factors	
	FCI	TCI
Solid	4.0	4.7
Solid-fluid	4.3	5.0
Fluid	5.0	6.0

H.J. Lang, Chem. Eng., 54 (10) 1947, page 117; H.J. Lang, Chem. Eng., 55 (6) 1948, page 112

Example 1: Delivered equipment cost (DEC) for a fluid processing plant is \$100,000

$$\text{FCI} = 5.0 \times \$100,000 = \$\underline{500},000 \quad \text{and} \quad \text{TCI} = 6.0 \times \$100,000 = \$\underline{600},000$$

Example 2: Purchased equipment cost for a fluid processing plant is \$100,000

$$\text{DEC} = \$100,000 + .1 \times \$100,000 = \$110,000 \quad (\text{delivery} = 10\% \text{ of PEC, slide 10})$$

$$\text{FCI} = 5.0 \times \$110,000 = \$\underline{550},000 \quad \text{and} \quad \text{TCI} = 6.0 \times \$100,000 = \$\underline{660},000$$

Example 6-1

p. 240

Make an ~~study~~ estimate of the fixed capital investment for a process plant in the purchased-equipment cost is \$100,000. Use the ranges of process-plant component cost outlined in Table 6-3, for a process plant handling both solids and fluids, with a high degree of automatic controls, and essentially outdoor operation. Do not include land.

Microsoft Excel - Example 6_1.xls

From Table 6-3

	A	B	C	D	E	F	G	H
1	Checklist for Fixed Capital Investment in a New Facility or Large Addition							
2								
3								
4	Component	% of FCI	Estimate	Estimate %	Estimated Cost			
5				(normalized)				
6	<i>Direct</i>							
7	Purchased Equipment	15 to 40	25	23	\$100,000			
8	Purchased Equipment Installation	6 to 14	9	8	\$36,000			
9	Instrumentation and Controls	2 to 12	10	9	\$40,000			
10	Piping	4 to 17	8	7	\$32,000			
11	Electrical Systems	2 to 10	5	5	\$20,000			
12	Buildings	2 to 18	5	5	\$20,000			
13	Yard Improvements	2 to 5	2	2	\$8,000			
14	Service Facilities	8 to 30	15	14	\$60,000			
15	Land	1 to 2	0	0	\$0			
16	<i>Indirect</i>							
17	Engineering and Supervision	4 to 20	8	7	\$32,000			
18	Construction Expenses	4 to 17	10	9	\$40,000			
19	Legal Expenses	1 to 3	2	2	\$8,000			
20	Contractor's Fee	2 to 6	2	2	\$8,000			
21	Contingency	5 to 15	8	7	\$32,000			
22								
23								
24			109	100	\$436,000			
25								

These tables are for grass-roots or battery-limit plants.

(New definitions for today; covered after quiz)

Ranges in FE Manual, page 150.

The screenshot shows a Microsoft Excel spreadsheet titled "CostandEvaluation completed - Excel". The spreadsheet is titled "ESTIMATION OF CAPITAL INVESTMENT BY PERCENTAGE OF DELIVERED EQUIPMENT METHOD". It includes a table for "Required user input" and a table for "Required, from a linked sheet or entered manually". The "Required user input" table has columns for "Default", "Subtotal", and "Result". The "Required, from a linked sheet or entered manually" table has columns for "Notes & comments" and "User: copy from values at left or insert" and "Calculated values, million \$". The spreadsheet then details "Direct Costs" and "Indirect Costs" across various categories. At the bottom, it calculates "Fixed capital investment (FCI)", "Working capital (WC)", and "Total capital investment (TCI)". A note at the bottom states: "The investments are made over a period of time. This is represented on the basis that startup (time 0) will be three years after the date of the estimate, that 15% of the fixed capital investment is spent in the year beginning at the time of the estimate (year ending at time -2), 35% in the second year (ending at -1), and 50% in the third year (ending at time 0). These values may be adjusted as described below."

$$TCI = FCI + WC$$

Rule of thumb:
WC is 15% of FCI
for fluids plant

Problem 6-8.

The purchased-equipment cost for a plant which produces pentaerythritol (solid-fluid processing plant) is \$300,000. The plant is to be an addition to an existing formaldehyde plant. The major part of the building cost will be for indoor construction. The contractor's fee will be 7% of the direct plant cost. All other costs are close to the average values found for typical chemical plants. On the basis of this information, estimate the total direct plant cost, the fixed capital investment, and the total capital investment.

Use Cost and Evaluation Worksheet (colorful worksheet).

Quiz 1 – Problem 1

Problem: Weight:

A 6

The delivered equipment cost for a solid-fluid processing plant is \$250,000. On average, the fixed-capital investment for the plant is most nearly 257

- (a) \$610,000
- (b) \$760,000
- (c) \$860,000
- (d) \$1,100,000

Use Lang factors, FE page 257

$$4.3 \times 250,000 = \$1,075,000 \approx \underline{\underline{\$1,100,000}}$$

ANS

Quiz 1 – Problem 2

Problem: Weight:
B 6

The delivered equipment cost for a solid-fluid processing plant is \$250,000. On average, the working capital for the plant is most nearly

- (a) \$100,000
- (b) \$180,000
- (c) \$240,000
- (d) \$310,000

Use Lang factors

257

$$(5.0 - 4.3) \cdot 250,000 = \$175,000 \approx \underline{\underline{\$180,000}}$$

ANS

Quiz 1 – Problem 3

Problem: Weight:

C 6

A six-foot stainless-steel bubble-cap tray cost \$1,850 in 1999. Estimate the cost of a similar ten-foot tray in 2020. The chemical engineering price index factors are 435.5 and 764.7 for 1999 and 2020, respectively.

- (a) \$1,800
- (b) \$3,400
- (c) \$5,000
- (d) \$6,000

Use scaling factors, ²⁵⁸ see page 257-258

$$\$1850 \cdot \left(\frac{10}{6}\right)^{1.2} \cdot \left(\frac{764.7}{435.5}\right) = \$5,996 \approx \$6000$$

ANS

Quiz 1- Problem 4

5
Problem: Weight:

D 6

A fixed-tube-sheet shell-and-tube heat exchanger with an area of 120 m^2 cost \$12,800 in 2006. What is the cost of a similar heat exchanger with an area of 300 m^2 in 2020? The chemical engineering price index factors are 548.0 and 650.1 for 2006 and 2020, respectively.

- (a) \$22,181
- (b) \$19,156
- (c) \$22,725
- (d) \$26,313

Use scaling factors ²⁵⁷

$$\$12,800 \cdot \left(\frac{300}{120}\right)^{.44} \cdot \left(\frac{650.1}{548.0}\right) = \underline{\underline{\$22,725}}$$

Grass-Roots Plant

- A complete plant including infrastructure erected on a new area or site.
- Investment includes all costs of land, site development, battery-limit facilities, and auxiliary facilities.

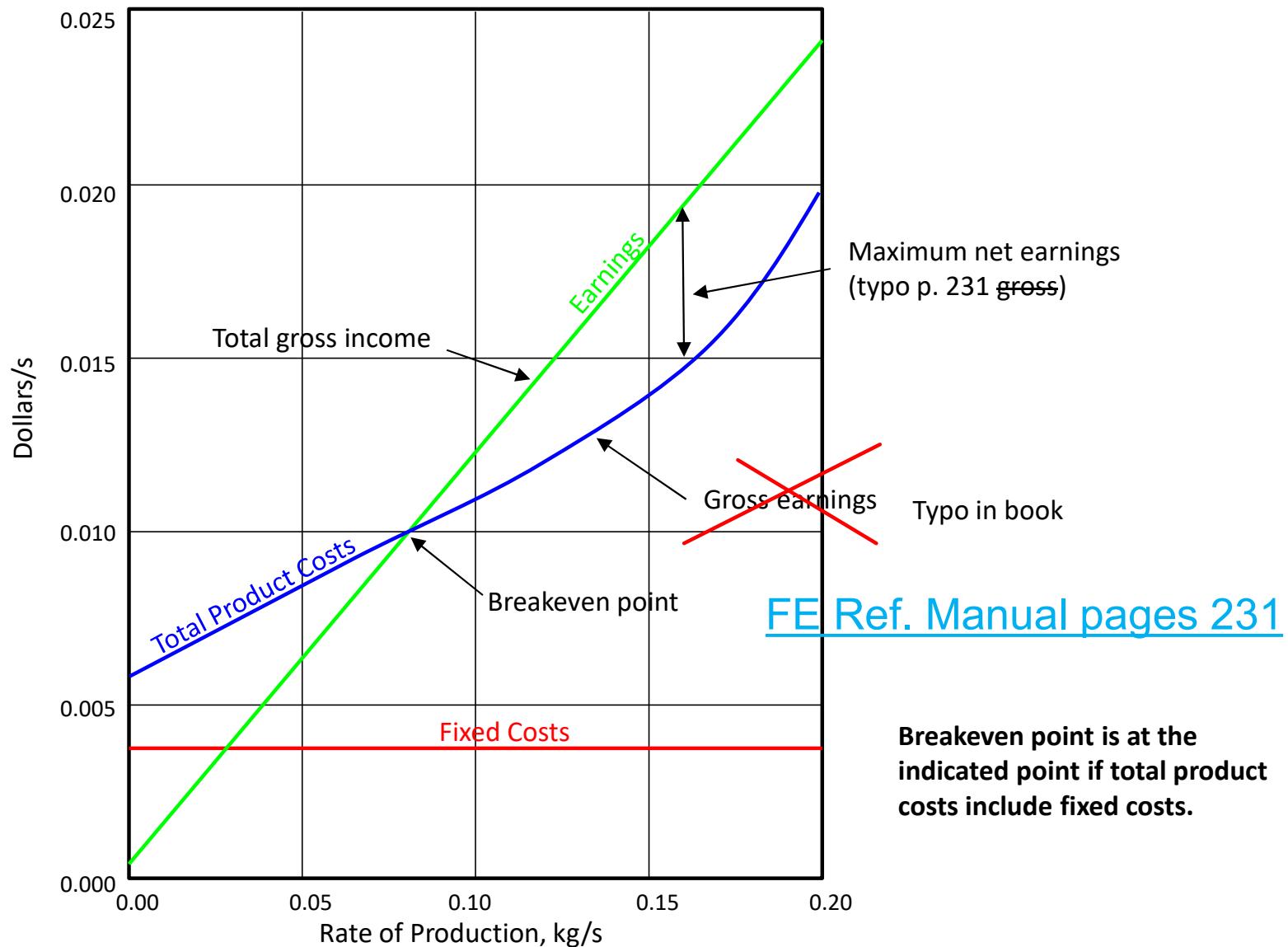
Battery Limit

- The design of most process units includes a pipe rack on one side of the unit that contains all the piping entering and exiting the unit. The battery limit is where the piping crosses the defined boundary between the unit and the area outside of the unit.
- Battery limits typically exclude storage facilities, administrative buildings, utilities, or auxiliary facilities unless otherwise specified.
- The operational principle is primarily safety but is commonly applied in process design as well. In preparing for major maintenance of a unit, it is cleared of hazardous materials and isolated from the rest of the refinery. A chief operator can go to the battery limits and determine whether all the necessary blinds have been properly installed. He or she signs off on a blind list confirming full unit isolation before work begins.

Break-Even Analysis – ICP

Figure 6-3; FEE p. 231; equation: gross earnings – variable costs – fixed costs

apply this equation



Plant Costs - Methods A-G

- A - Detailed item estimate
- B - Unit cost estimate – based on records
- C - Percentage of delivered-equipment cost
- D - Lang factors
- E - Power factors with plant/capacity ratio
- F - Cost per unit capacity
- G - Turnover ratio

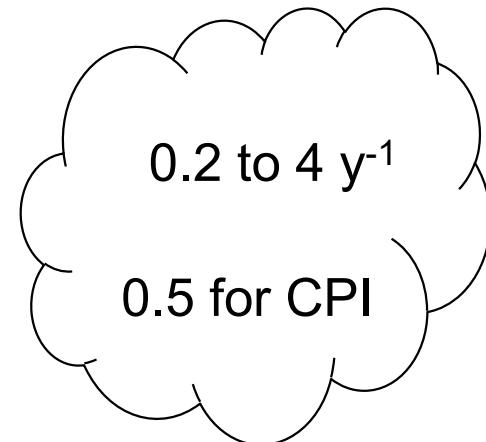
Method G: Turnover Ratio

Similar to what we have been doing for single pieces of equipment.

$$\text{Turnover Ratio} = \frac{\text{gross annual sales}}{\text{fixed capital investment}}$$

Eq. 6-11, p. 258

± 30 % accuracy.



Problem 6-9.

Estimate by the turnover ratio method the fixed-capital investment required in 2000 for a proposed sulfuric acid plant (battery-limit) which has an annual capacity of 1.3×10^8 kg/yr of 100% sulfuric acid (contact catalytic process), using the data from Table 6-11, when the selling price of sulfuric acid is \$86 per metric ton. The plant will operate 325 days/year. Repeat the calculation, using the cost capacity exponent (scaling) method with data from Table 6-11

Problem 6-9.

Estimate by the turnover ratio method the fixed-capital investment required in 2000 for a proposed sulfuric acid plant (battery-limit) which has an annual capacity of 1.3×10^8 kg/yr of 100% sulfuric acid (contact catalytic process), using the data from Table 6-11, when the selling price of sulfuric acid is \$86 per metric ton. The plant will operate 325 days/year. Repeat the calculation, using the cost capacity exponent (scaling) method with data from Table 6-11

Method E: Power Factors and Plant Capacity Ratio

Similar to what we have been doing for single pieces of equipment.

$$C_n = C \cdot f_e \cdot R^x$$

cost index ratio
0.6-0.7

Eq. 6-9, p. 254

$$C_n = f \cdot (D \cdot R^x + I)$$

indirect costs
direct costs

Table 6-11, p. 255

Eq. 6-10

± 20 % accuracy.

$$\text{Cost of Plant A} = \text{Cost of Plant B} \cdot \left(\frac{\text{Capacity of Plant A}}{\text{Capacity of Plant B}} \right)^n$$

FEE p. 258

Problem 6-10.

The total capital investment for a chemical plant is \$1 million, and the working capital is \$100,000. If the plant can produce an average of 8000 kg of final product per day during a 365-day year, what selling price in dollars per kilogram of product would be necessary to give a turnover ratio of 1.0?