

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).

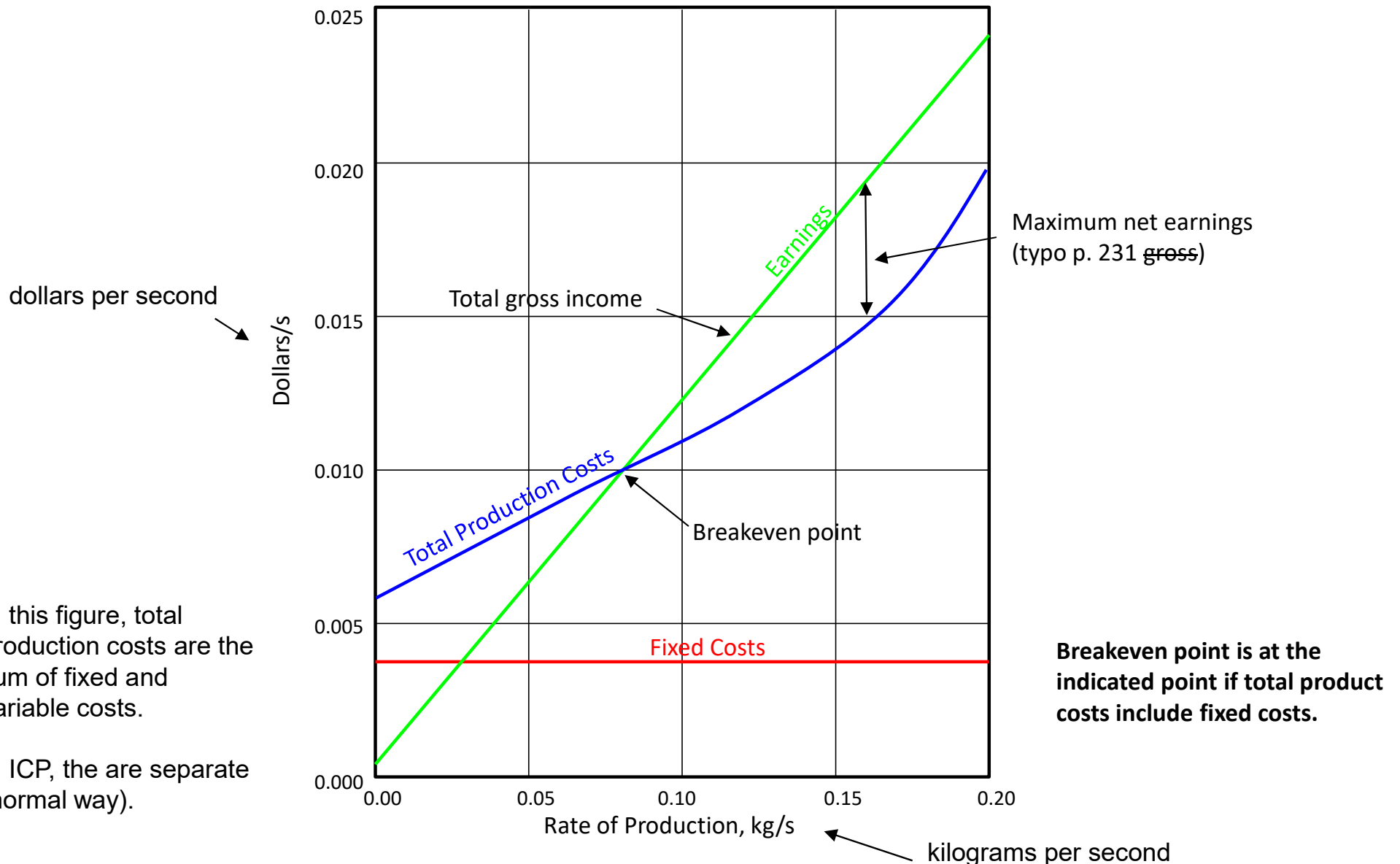
Objectives for Lesson 16:

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: $\text{gross earnings} - \text{variable costs} - \text{fixed costs}$

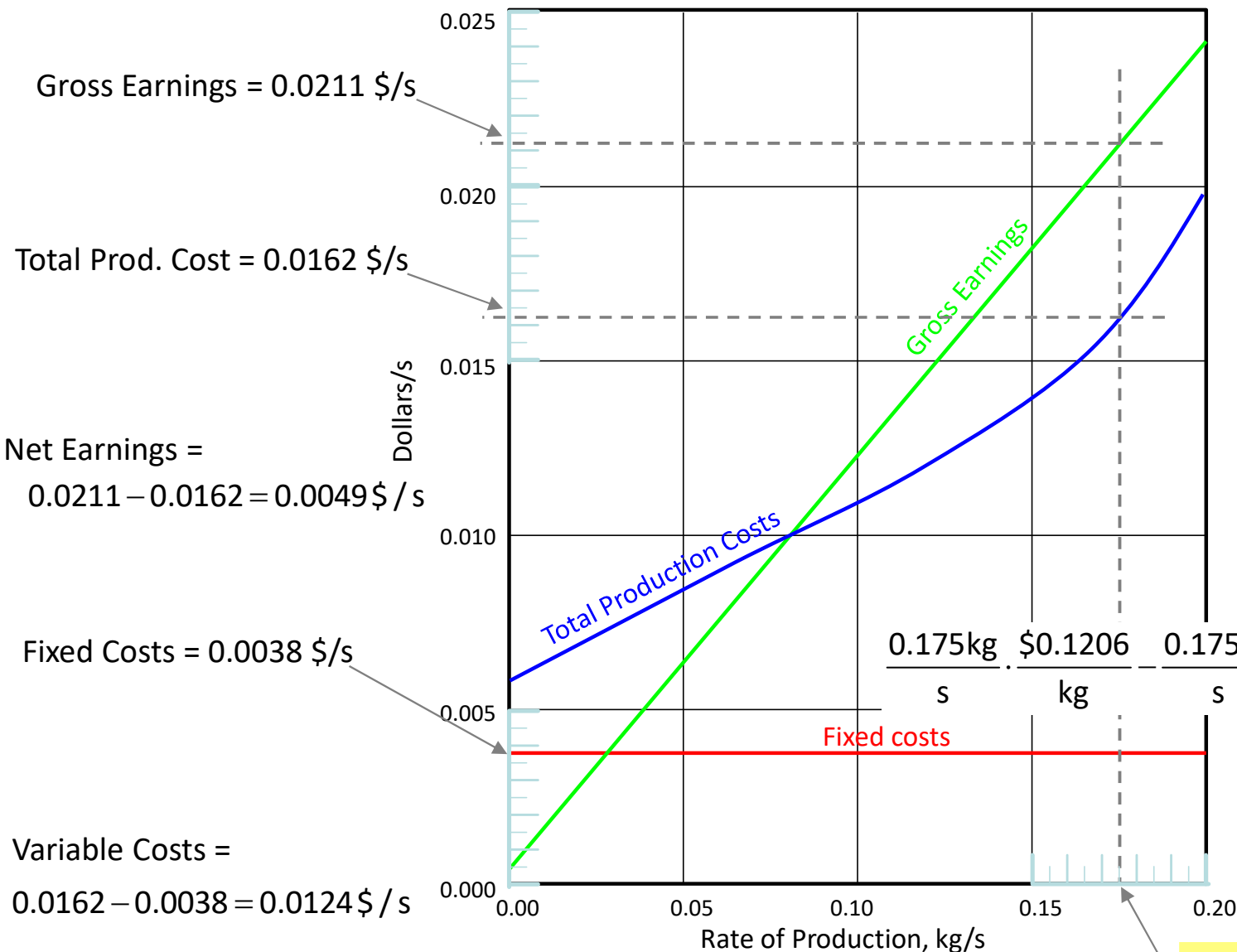
apply this equation



Break-Even Analysis – Ex1

PTW Figure 6-3; equation: $\text{gross earnings} - \text{variable costs} - \text{fixed costs}$

apply this equation



product market price x, \$/kg:

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

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

variable production cost y, \$/kg:

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

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

$$\frac{0.175 \text{ kg}}{s} \cdot \$0.1206 - \frac{0.175 \text{ kg}}{s} \cdot \$0.0709 - \$0.0038 = \$0.0049$$

Operating at a profit

Rate of production = 0.175 kg/s

Break-Even Analysis – Ex2

PTW Figure 6-3; equation: $\text{gross earnings} - \text{variable costs} - \text{fixed costs}$

apply this equation

Net Earnings =

$$0.0039 - 0.0064 = -0.0025 \$ / s$$

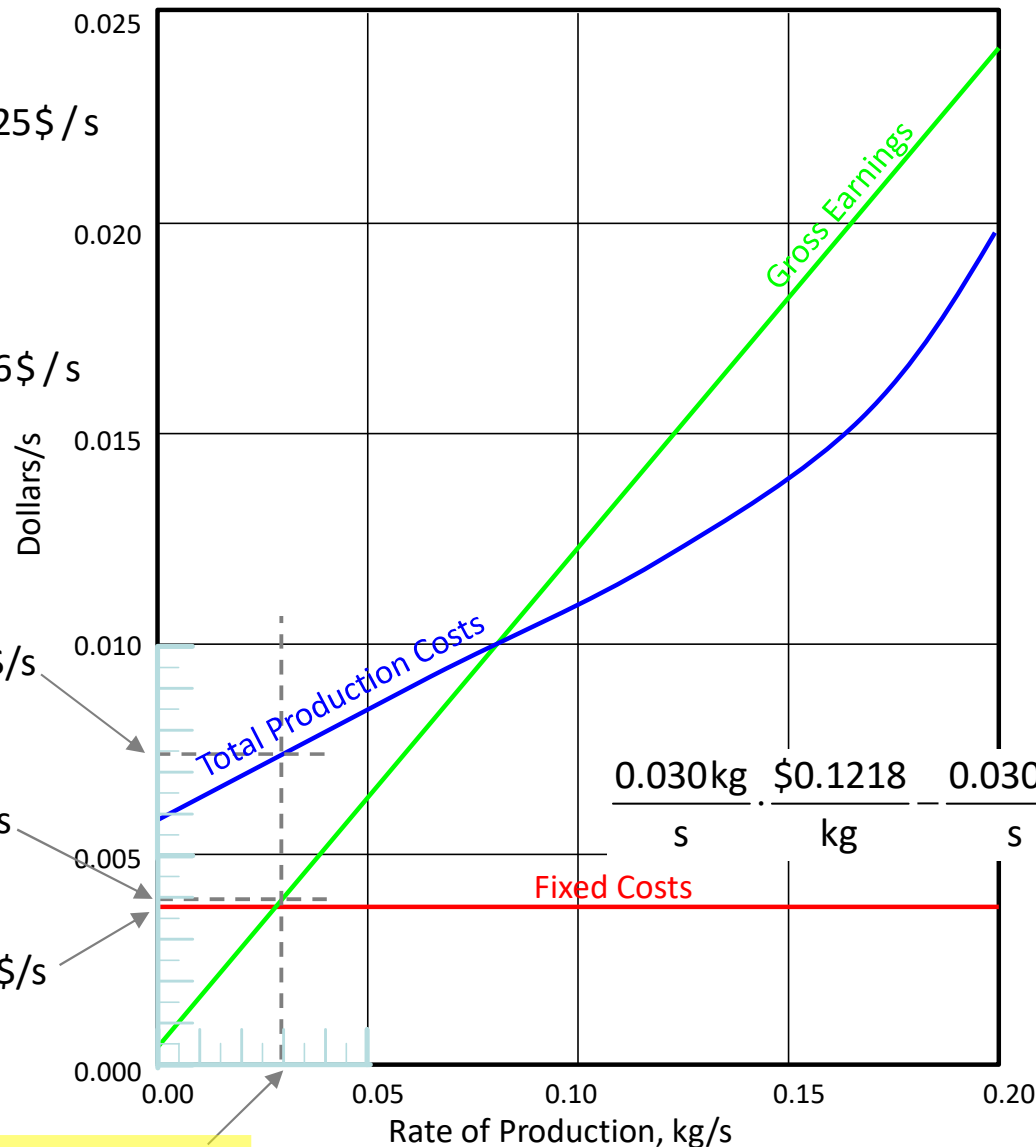
Variable Costs =

$$0.0064 - 0.0038 = 0.0026 \$ / s$$

Total Prod. Cost = 0.0064 \$/s

Gross Earnings = 0.0039 \$/s

Fixed Costs = 0.0038 \$/s



product market price x, \$/kg:

$$\frac{0.030 \text{ kg}}{s} \cdot x = \frac{\$0.0039}{s}$$

$$x = \frac{\$0.1300}{\text{kg}}$$

variable production cost y, \$/kg:

$$\frac{0.030 \text{ kg}}{s} \cdot y = \frac{\$0.0026}{s}$$

$$y = \frac{\$0.0867}{\text{kg}}$$

$$\frac{0.030 \text{ kg}}{s} \cdot \$0.1218 - \frac{0.030 \text{ kg}}{s} \cdot \$0.0867 - \frac{\$0.0038}{s} = -\frac{\$0.0025}{s}$$

Operating at loss

Rate of production = 0.030 kg/s

Break-Even Analysis – Ex3

PTW Figure 6-3; equation: $\text{gross earnings} - \text{variable costs} - \text{fixed costs}$

apply this equation

product market price x , \$/kg:

$$\frac{0.080 \text{ kg}}{s} \cdot x = \frac{\$0.0100}{s}$$

$$x = \frac{\$0.1250}{\text{kg}}$$

variable production cost y , \$/kg:

$$\frac{0.080 \text{ kg}}{s} \cdot y = \frac{\$0.0062}{s}$$

$$y = \frac{\$0.0775}{\text{kg}}$$

Net Earnings =

$$0.0100 - 0.0100 = 0.0000 \$/s$$

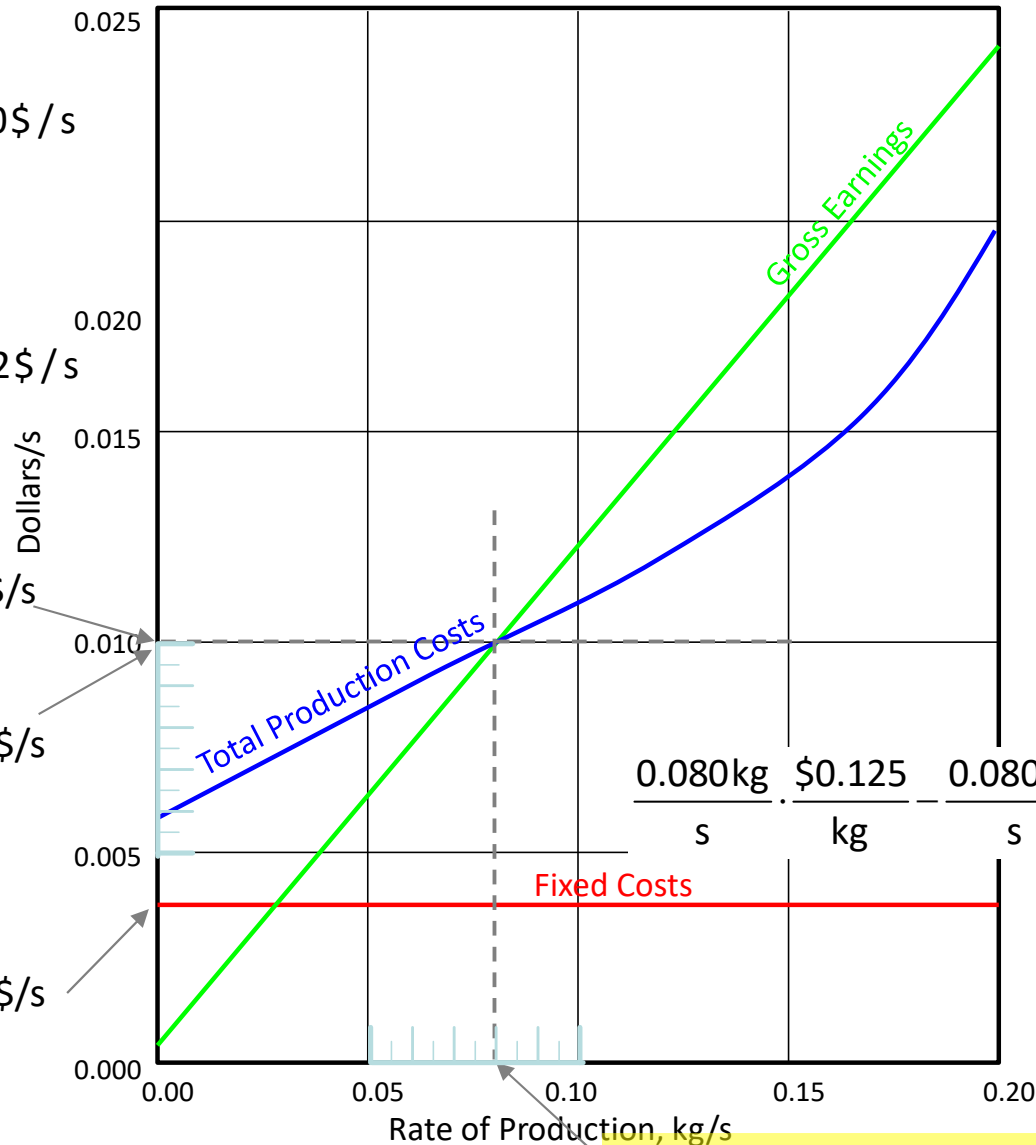
Variable Costs =

$$0.0100 - 0.0038 = 0.0062 \$/s$$

Total Prod. Cost = 0.0100 \$/s

Gross Earnings = 0.0100 \$/s

Fixed Costs = 0.0038 \$/s



$$\frac{0.080 \text{ kg}}{s} \cdot \$0.125 - \frac{0.080 \text{ kg}}{s} \cdot \$0.0062 - \$0.0038 = \frac{\$0.0000}{s}$$

"Breakeven"

Rate of production = 0.080 kg/s

Proceed to ICP1

Uses an equation from lesson 19:

PTW equation 8-1a, page 323

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

N_p = Net *annual* profit

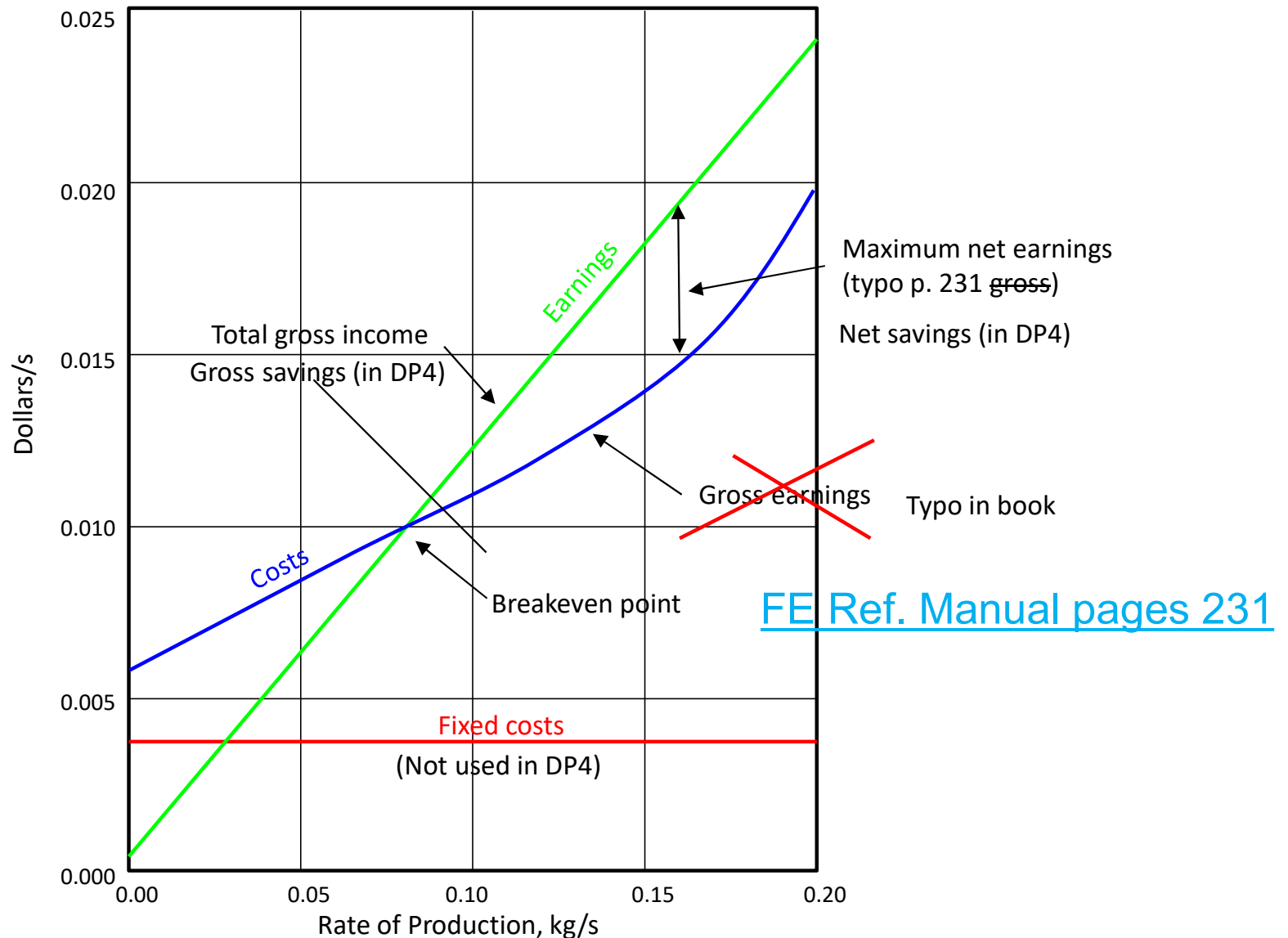
TCI = Total capital investment

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

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

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

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

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

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

File Edit View Insert Format Tools Data Window Help xICHEMCAD Type a question for help

Arial 10 B I U \$ % , +.00 -.00

Reply with Changes... End Review...

18 fx

	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								
17	<i>Indirect</i>							
18	Engineering and Supervision		4 to 20	8	7	\$32,000		
19	Construction Expenses		4 to 17	10	9	\$40,000		
20	Legal Expenses		1 to 3	2	2	\$8,000		
21	Contractor's Fee		2 to 6	2	2	\$8,000		
22	Contingency		5 to 15	8	7	\$32,000		
23								
24				109	100	\$436,000		
25								

Sheet1 Sheet2 Sheet3

Draw AutoShapes

Ready NUM

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

(New definitions for today; covered after quiz)

Ranges in FE Manual, page 150.

CostandEvaluation completed - Excel

ESTIMATION OF CAPITAL INVESTMENT BY PERCENTAGE OF DELIVERED

	A	B	C	D	E	F	G	H
1	ESTIMATION OF CAPITAL INVESTMENT BY PERCENTAGE OF DELIVERED EQUIPMENT METHOD							
2	(See Table 6-9)							
3	The fractions in the cells below are approximations applicable to typical chemical processing plants. These values may differ depending on many factors such as location, process type, etc.							
4	Required user input		Default		Subtotal		Result	
5	Required, from a linked sheet or entered manually				Notes & comments			
6	Project Identifier: Illustration 101		Fraction of delivered equipment		User: copy from values at left or insert		Calculated values, million \$	
7			Solid-processing plant	Solid-fluid processing plant	Fluid processing plant			
8								
9								
10								
11	Direct Costs							
12	Purchased equipment, E'							0.100
13	Delivery, fraction of E'		0.10	0.10	0.10	0.00		0.000
14	Subtotal: delivered equipment							0.100
15	Purchased equipment installation		0.45	0.39	0.47	0.36		0.036
16	Instrumentation & Controls (installed)		0.18	0.26	0.36	0.40		0.040
17	Piping (installed)		0.16	0.31	0.68	0.32		0.032
18	Electrical systems (installed)		0.10	0.10	0.11	0.20		0.020
19	Buildings (including services)		0.25	0.29	0.18	0.20		0.020
20	Yard improvements		0.15	0.12	0.10	0.08		0.008
21	Service facilities (installed)		0.40	0.55	0.70	0.60		0.060
22	Total direct costs		1.69	2.02	2.60	2.16		0.316
23	Indirect Costs							
24	Engineering and supervision		0.33	0.32	0.33	0.32		0.032
25	Construction expenses		0.39	0.34	0.41	0.40		0.040
26	Legal expenses		0.04	0.04	0.04	0.08		0.008
27	Contractor's fee		0.17	0.19	0.22	0.08		0.008
28	Contingency		0.35	0.37	0.44	0.32		0.032
29	Total indirect costs		1.28	1.26	1.44	1.20		0.120
30								
31	Fixed capital investment (FCI)							0.436
32	Sent to 'Evaluation' and 'Year-0 \$', there adjusted as described below							
33	Working capital (WC)		0.70	0.75	0.89	0.89		0.089
34	Total capital investment (TCI)							0.525
35								
36								
37	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							
38								
39								
40								

Instructions Capital Inv. Materials&Labor Utilities ...

Ready

$$TCI = FCI + WC$$

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

257

Use Lang factors

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

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 E page 257-258

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

ANS

Quiz 1- Problem 4

Problem: Weight:
D 6

A fixed-tube-sheet shell-and-tube heat exchanger with an area of 120 m² cost \$12,800 in 2006. What is the cost of a similar heat exchanger with an area of 300 m² 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

$$\$12,800 \cdot \left(\frac{300}{120}\right)^{0.44} \cdot \left(\frac{650.1}{548.0}\right) = \underline{\underline{\$22,725 \text{ ARS}}}$$

Grass-Roots Plant

New Definitions - Important

- 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.

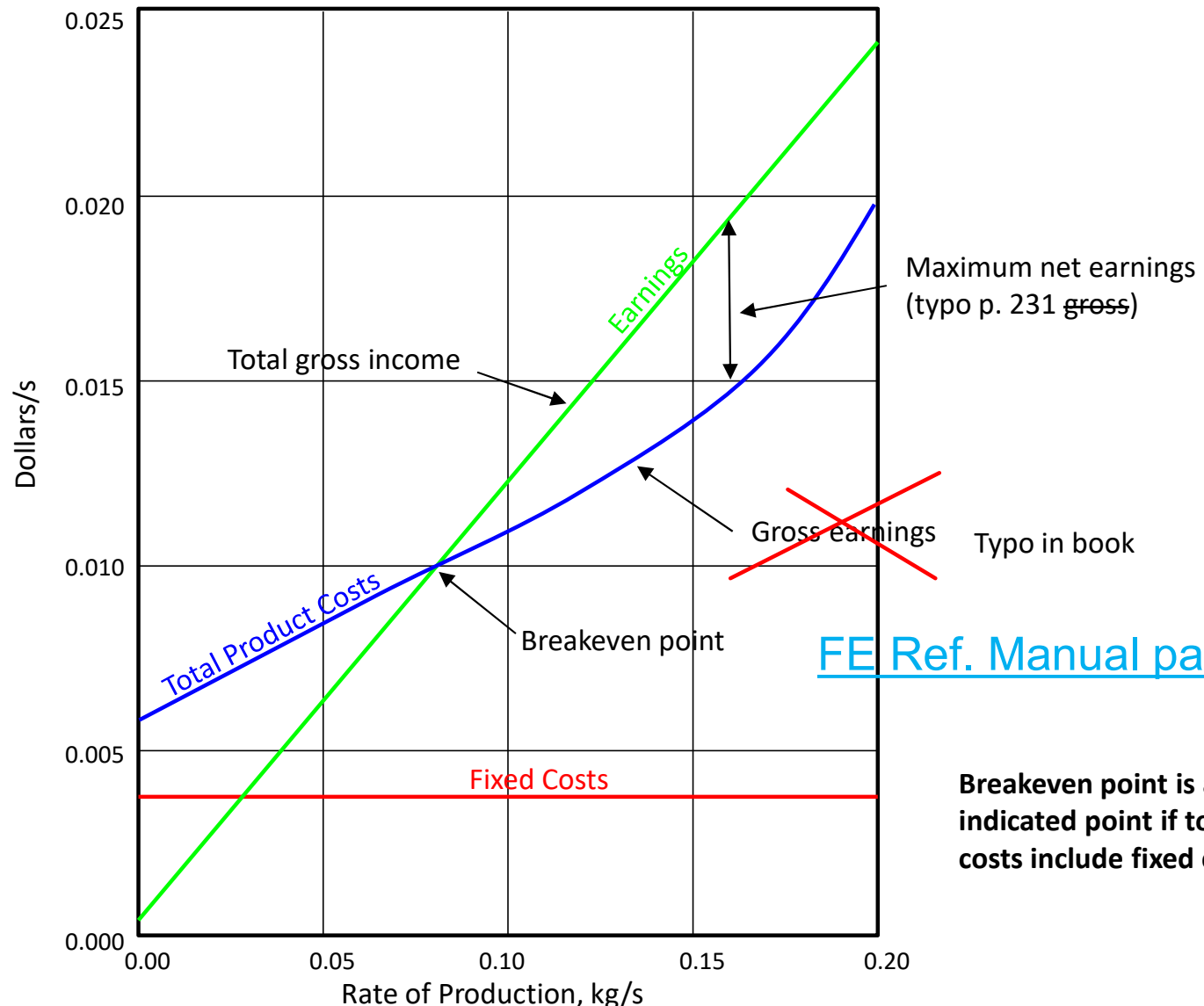
Battery Limit

- 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: $\text{gross earnings} - \text{variable costs} - \text{fixed costs}$

apply this equation



[FE Ref. Manual pages 231](#)

The authors do not state that fixed costs are included in total product costs. Normally they are not (as in ICP).

Breakeven point is at the indicated point if total product costs include fixed costs.

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

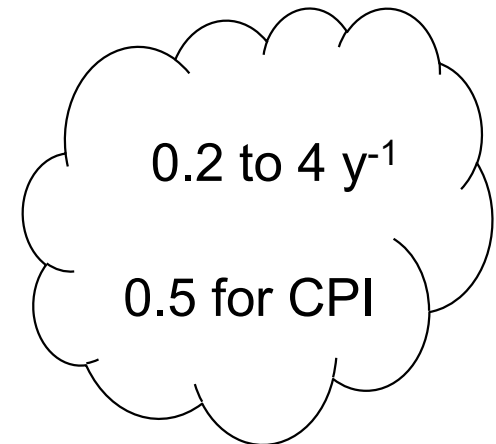
Method G: Turnover Ratio

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

Table 6-11, p. 255

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

indirect costs

direct costs

Eq. 6-10

± 20 % accuracy.

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

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?