# CH402 Chemical Engineering Process Design

Class Notes L14

Cost Estimation & Capital Investments

WPR1 Corrections Due Friday 14 Feb 2359
(Bonus, Point value = 40% of cut)

Download and open "Cost and Evaluation Spreadsheet"

## L14 Learning Objectives

- 1. Relate the I/O analysis from Lesson 13 to the different cash flows in a process.
- 2. Calculate the different types of cash flow in a chemical process (Figure 6-1).
- 3. Calculate equipment costs using capacity scaling factors.

#### **Definitions:**

Working capital, nonmanufacturing and manufacturing fixed costs, direct and indirect costs, total capital investment, gross profit, purchased equipment costs, operating labor costs, utility costs, depreciation, annual total product costs, cumulative cash position, cost capacity scaling factors

## Known Vinyl Chloride Routes

5 processes

$$C_2H_2 + HCI \longrightarrow C_2H_3CI \qquad A$$

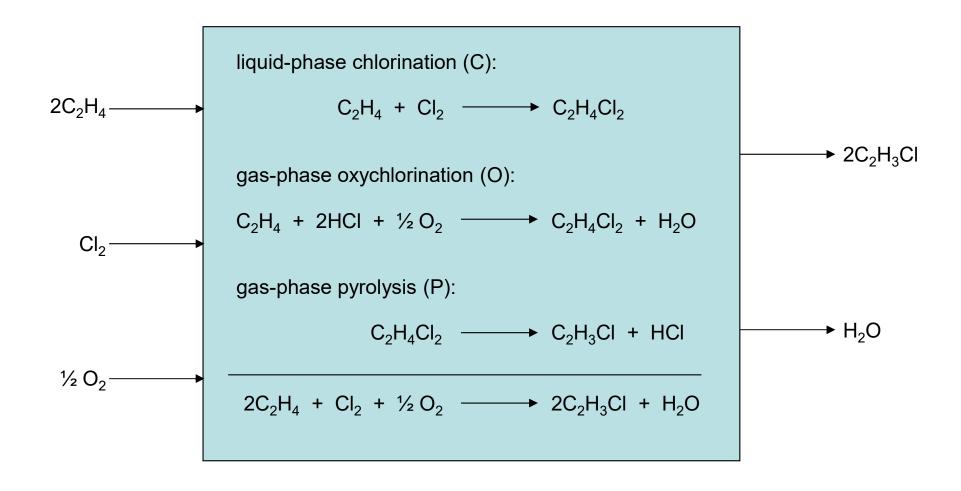
$$C_2H_4 + CI_2 \longrightarrow C_2H_3CI + HCI \qquad C$$

$$C_2H_4 + CI_2 \longrightarrow C_2H_3CI + HCI \qquad C-P$$

$$C_2H_4 + HCI + \frac{1}{2}O_2 \longrightarrow C_2H_3CI + H_2O \qquad O-P$$

$$2C_2H_4 + CI_2 + \frac{1}{2}O_2 \longrightarrow 2C_2H_3CI + H_2O \qquad C-O-P$$

## Input/Output Structure - Route 5 – "COP"



The I/O diagram allows us to assessment the overall economics of the process.

## Economic Analysis Based on I/O Structure

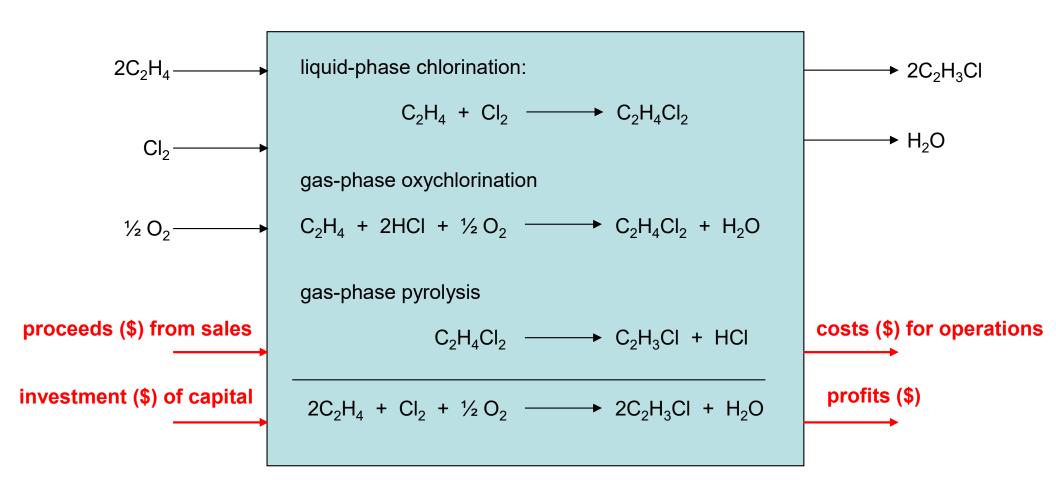
|    | Α                             | В               | С              | D             | E          | F          | G           | Н      |
|----|-------------------------------|-----------------|----------------|---------------|------------|------------|-------------|--------|
| 1  | Example 4-                    | 2. Compare prod | luct and raw m | aterial value | s based or | 1kg of vin | yl chloride |        |
| 2  |                               |                 |                |               |            |            |             |        |
| 3  |                               |                 |                |               | Reactio    | n Path, kg | /kg VC      |        |
| 4  | Species                       | MW, kg/kgmol    | Price, \$/kg   | 1             | 2          | 3          | 4           | 5      |
| 5  | Cl <sub>2</sub>               | 70.9            | 0.03           |               | 1.13       | 1.13       |             | 0.57   |
| 6  | HCI                           | 36.5            | 0.22           | 0.58          | 0.58       | 0.58       | 0.58        |        |
| 7  | C <sub>2</sub> H <sub>2</sub> | 26.0            | 1.39           | 0.42          |            |            |             |        |
| 8  | C <sub>2</sub> H <sub>4</sub> | 28.1            | 0.45           |               | 0.45       | 0.45       | 0.45        | 0.45   |
| 9  | $C_2H_3CI$                    | 62.5            | 0.45           | 1.00          | 1.00       | 1.00       | 1.00        | 1.00   |
| 10 | O <sub>2</sub>                | 32.0            | 0.04           |               |            |            | 0.26        | 0.13   |
| 11 |                               |                 |                |               |            |            |             |        |
| 12 | product val                   | ue              |                | \$0.45        | \$0.58     | \$0.58     | \$0.45      | \$0.45 |
| 13 | reactant co                   | st              |                | \$0.71        | \$0.24     | \$0.24     | \$0.34      | \$0.22 |
| 14 | excess valu                   | ie              |                | -\$0.26       | \$0.34     | \$0.34     | \$0.11      | \$0.23 |

I/O diagram for process 5 is shown in slide 6.

The bottom line represents \$ per kg of product. If we know the kg/year, then we know the annual cash flow.

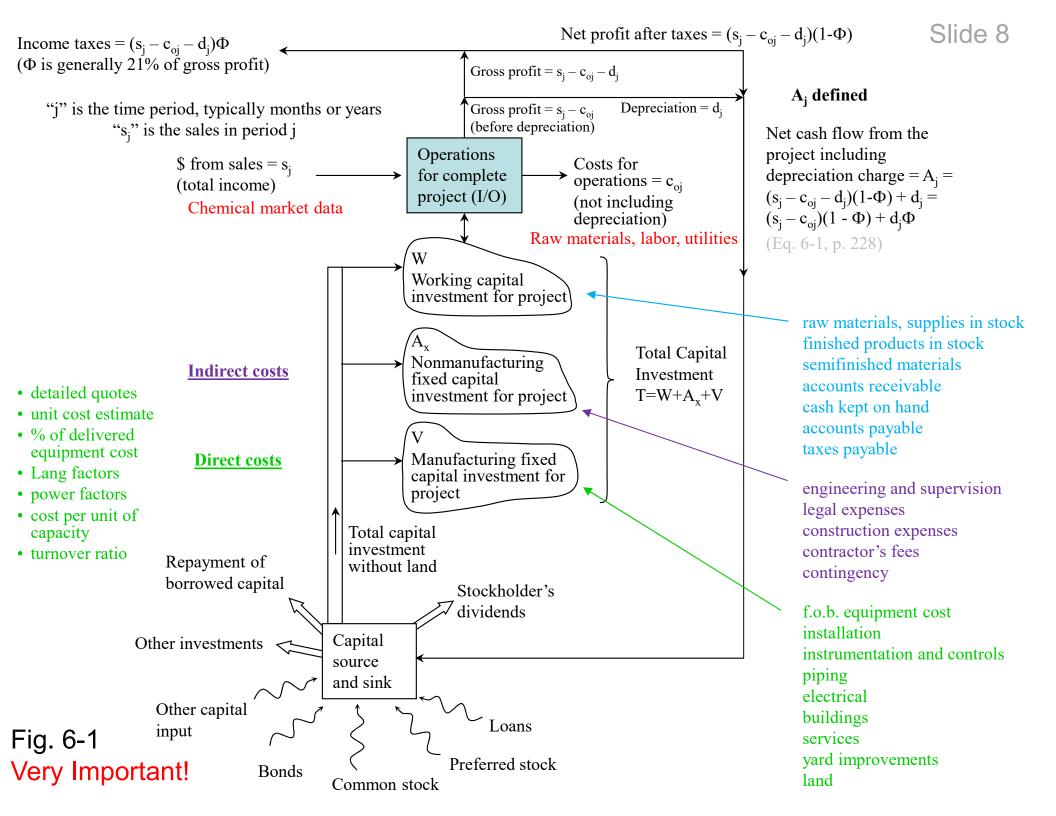
## Input/Output Diagram - Route 5 - COP

Decision Makers (company, government, army, etc.) are concerned with cash flows.



## **Evaluation of Industrial Processes**

- Economic depends on cost of process, cost of process flows, and cash flows to and from process.
- Equipment needs to be designed, sized, and costed.
- Preliminary cash flow patterns must be created from future cash flows and analyzed.
- Future cash flows are functionally related to chemical flow rates through market values.
- Future cash flows must account for (1) interest, (2) depreciation, and (3) taxes.







## ■ Gost and Evaluation Spreadsheet \*







🧝 SiriusXM - For You 🐞 Home - Welcome -... 🚱 New Tab 🙀 Astrometry,net 🧱 Personal-Use Math... 🔥 GoogleDrive

### CH402 Chemical Engineering Process Design

USMA Chemical Engineering AY23-2 Professor Andrew Biaglow (BH441, x4080) C1R2 & D1S2 hours, BH331

Web site last modified 10 January 2023

#### USMA CHEMIC

Program Mission Program Objectiv Student Outcome

#### COURSE ADMIN

Schedule

Welcome Email

Standing Instructions for Students (SIS)

Section Marcher Duties & Rotation

Registrar

SharePoint Directory

Roster C1R2-Hour

Roster D1S2-Hour

Seating Chart C1R2-Hour

Seating Chart D1S2-Hour

FE Reference Handbook v10.2 (2022)

FE Calculator Policy

Cover Sheet

#### COST INDICES

CE Plant Cost Index

ENR Skilled Labor Index

Nelson-Farrar Refinery Index

Nelson-Farrar Chemical Cost Index

#### SPREADSHEETS

Cost & Evaluation Spreadsheet

Agitator Design Spreadsheet

Pneumatic Conveyor Design Spreadsheet

#### CAPSTONE DESIGN PROJECT

Project Handout

Project Grading Rubric

Database Activation

Safety Design Checklist

Assignments and Groups

Guidance for IPR1

Guidance for IPR2

#### SAFETY AND ENVIRONMENTAL

Chemical Safety & Hazard Investigation Board Registry of Toxic Effects of Chem. Subst.

Nat. Inst. for Occ. Health & Safety

Safety Data Sheets

#### OTHER USEFUL RESOURCES

Online Unit Converter

Unit Glossary

Unit Dictionary

Nominal Pipe Size Charts

NIST WebBook

USMA Library

Perry's Chemical Engineer's Handbook

ChemExper (Structure and Properties)

#### CAPSTONE PR

Encyclopedia of Encyclopedia of Encyclopedia of

USMA Research

European Patent

Japanese Patent § US Patent Search

Access Engineeri

Google Scholar

SciFinder

Knovel

#### USEFUL JOUR

American Chemi

Chemical Engine

Chemical Engine

Chemical Process

EngineerLive

#### USEFUL eBOO

Chemical Process Rules of Thumb

Chemical Process

Pipeline Rules of

Troubleshooting

## Cost Components of Capital Investments

FEE Reference Handbook, v10.4, pp. 257 (263/502)

| ESTIMATION OF CAPITAL INVESTMI       | ENT BY PERO              | CENTAGE OF      | DELIVERED     | EQUIPMENT     | METHOD     |                        |            |
|--------------------------------------|--------------------------|-----------------|---------------|---------------|------------|------------------------|------------|
| (See Table 6-9)                      |                          |                 |               |               |            |                        |            |
| The fractions in the cells below are | e approxima              | tions applic    | able to typic | cal chemical  | processing |                        |            |
| plants. These values may differ de   | epending on 1            | nany factors    | such as locat | tion, process | type, etc. |                        |            |
| Required user input                  | Default                  |                 | Subtotal      |               | Result     |                        |            |
| Required, from a linked sheet or     |                          | anually         |               | Notes & con   | nments     |                        |            |
| Project Identifier: Illustration 101 | Fraction                 | of delivered    | equipment     | User: copy    | Calculated |                        |            |
| •                                    | Solid-                   | Solid-fluid     | Fluid         | from values   |            |                        |            |
|                                      | processing               | processing      | processing    | at left or    | million \$ |                        |            |
|                                      | plant                    | plant           | plant         | insert        |            |                        |            |
|                                      | Direct                   | Costs           |               |               |            |                        |            |
| Purchased equipment, E'              |                          |                 |               |               | 1.000      |                        |            |
| Delivery, fraction of E'             | 0.10                     | 0.10            | 0.10          | 0.10          | 0.100      |                        |            |
| Subtotal: delivered equipment        |                          |                 |               |               | 1.100      |                        |            |
| Purchased equipment installation     | 0.45                     | 0.39            | 0.47          | 0.47          | 0.517      |                        |            |
| Instrumentation&Controls(installed)  | 0.18                     | 0.26            | 0.36          | 0.36          | 0.396      |                        |            |
| Piping (installed)                   | 0.16                     | 0.31            | 0.68          | 0.68          | 0.748      |                        |            |
| Electrical systems (installed)       | 0.10                     | 0.10            | 0.11          | 0.11          | 0.121      |                        |            |
| Buildings (including services)       | 0.25                     | 0.29            | 0.18          | 0.18          | 0.198      |                        |            |
| Yard improvements                    | 0.15                     | 0.12            | 0.10          | 0.10          | 0.110      |                        |            |
| Service facilities (installed)       | 0.40                     | 0.55            | 0.70          | 0.70          | 0.770      |                        |            |
| Total direct costs                   | 1.69                     | 2.02            | 2.60          | 2.60          | 3.960      |                        |            |
|                                      |                          |                 |               |               |            |                        |            |
|                                      | ndirect Cos              |                 |               |               |            |                        |            |
| Engineering and supervision          | 0.33                     | 0.32            | 0.33          | 0.33          | 0.363      |                        |            |
| Construction expenses                | 0.39                     | 0.34            | 0.41          | 0.41          | 0.451      |                        |            |
| Legal expenses                       | 0.04                     | 0.04            | 0.04          | 0.04          | 0.044      |                        |            |
| Contractor's fee                     | 0.17                     | 0.19            | 0.22          | 0.22          | 0.242      |                        |            |
| Contingency                          | 0.35                     | 0.37            | 0.44          | 0.44          | 0.484      |                        |            |
| Total indirect costs                 | 1.28                     | 1.26            | 1.44          | 1.44          | 1.584      |                        |            |
| Fire                                 | d capital inv            | rootment /F/    | <b>~!</b> \   |               | 5.544      | Sent to <b>'Eval</b> u | ation' and |
| Fixe                                 | <b>'Year-0 \$'</b> , the | ere adjusted as |               |               |            |                        |            |
| Working capital (WC)                 | 0.70                     | 0.75            | 0.89          | 0.89          | 0.979      | described belo         | )W         |
|                                      |                          |                 |               |               |            |                        |            |
| Tota                                 |                          |                 |               |               |            |                        |            |

#### Raw Materials and Labor

#### ANNUAL RAW MATERIAL COSTS AND PRODUCTS VALUES

| Process Identifier | r: Illustratio | n 101      |              |                      |
|--------------------|----------------|------------|--------------|----------------------|
| Required user inp  | out            | Notes & co | mments       |                      |
| Default, may be o  | changed        |            |              |                      |
| RESULT             |                |            |              |                      |
| Products, C        | Coproducts     | and Bypro  | oducts       |                      |
| Name of            | Price,         | Annual     | Annual       | explained in         |
| Material           | \$/kg          | Amount,    | value of     | further in           |
|                    |                | million    | product,     |                      |
|                    |                | kg/y       | million \$/y | slide 13             |
| Main               | 1.60           | 30.000     | 48.00        |                      |
| Byproduct          | 0.25           | 12.000     | 3.00         |                      |
|                    |                |            | 0.00         |                      |
|                    |                |            | 0.00         |                      |
|                    |                |            | 0.00         |                      |
|                    |                |            | 0.00         |                      |
| Total annual       | value of pro   | ducts =    | 51.00        | Sent to 'Evaluation' |

**Raw Materials** 

Annual

Amount,

million

kg/y

20.000

12.000

13.000

Annual raw

materials

cost,

million \$/y

9.00

3.00

0.65 0.00 0.00 0.00

12.65

Price,

\$/kg

0.45

0.25

0.05

Name of

Material

1

2

3

and 'Year-0 \$'

ANNUAL OPERATING LABOR COSTS Process Identifier: Illustration 101

Notes & comments Required user input

Default, may be changed RESULT.

| ILEGGEI       |             |              |              |
|---------------|-------------|--------------|--------------|
| (             | Operating I | ₋abor        |              |
| Number of     | Shifts per  | Operator     | Annual       |
| operators per | day**       | rate, \$/h # | operating    |
| shift*        |             |              | labor cost,  |
|               |             |              | million \$/y |
| 3.0           | વ           | 33.67        | 0.885        |

\*See Tables 6-13 and Fig. 6-9.

\*\*Default = 3 for continuous process.

Enter appropriate value for batch operation.

\*To obtain current, local value enter (latest local

ENR skilled labor indet)/6067 =

explained further in slide 12

Sent to 'Annual TPC'

Table 6-13 Typical Labor Reuizements for Process Equipment

| Type of equipment        | Workers/u    | nit/shift     | # units |     |
|--------------------------|--------------|---------------|---------|-----|
| Blowers and Compressors  | 0.1-0.2      | 0.15          | 4       | 0.6 |
| Centrifugal separator    | 0.25-0.50    | 0.37          | 0       | 0.0 |
| Crystallizer, mechanical | 0.16         | 0.16          | 0       | 0.0 |
| Dryer, rotary            | 0.5          | 0.5           | 0       | 0.0 |
| Dryer, spray             | 1.0          | 1             | 0       | 0.0 |
| Dryer tray               | 0.5          | 0.5           | 0       | 0.0 |
| Eyaporator               | 0.25         | 0.25          | 0       | 0.0 |
| Filter, vacuum           | 0.125-0.25   | 0.131         | 0       | 0.0 |
| Filter, plate and frame  | 1.0          | 1             | 0       | 0.0 |
| Filter, rotary and belt  | 0.1          | 0.1           | 0       | 0.0 |
| Heat exchangers          | 0.1          | 0.1           | 2       | 0.2 |
| Process vessels, towers  | 0.2-0.5      | 0.35          | 2       | 0.7 |
| Reactor, batch           | 1.0          | 1             | 1       | 1.0 |
| Reactor, continuous      | 0.5          | 0.5           | 1_      | 0.5 |
| Total number             | er of worker | s per shift = | :       | 3.0 |

Sent to sheet

'Annual TPC'

COST INDICES

Total annual cost of raw materials =

CF Plant Cost Index ENR Skilled Labor Index

Nelson-Farrar Refinery Index

Nelson-Farrar Chemical Cost Index

## **ENR Skilled Labor Index**

|   | ENR'S SKILLED LABOR INDEX (1990-2025) |       |       |       |       |       |       |       |       |       |       |                   |
|---|---------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------------------|
| YEAR  | JAN                                   | FEB   | MAR   | APR   | MAY   | JUN   | JUL   | AUG   | SEP   | ост   | NOV   | DEC               |
| 2025  | 11870                                 | 11997 | )     |       |       |       |       |       |       |       |       |                   |
| 2024  | 11709                                 | 116/5 | 11675 | 11682 | 11687 | 11703 | 11703 | 11751 | 11805 | 11805 | 11805 | 11811             |
| 2023  | 11332                                 | 11332 | 11400 | 11445 | 11663 | 11674 | 11686 | 11686 | 11686 | 11698 | 11698 | 11698             |
| 2022  | 11056                                 | 11112 | 11112 | 11114 | 11155 | 11178 | 11200 | 11223 | 11246 | 11269 | 11292 | 11314             |
| 2021  | 10775                                 | 10797 | 10800 | 10805 | 10805 | 10815 | 10826 | 10848 | 10880 | 10978 | 11000 | 11055             |
| 2020  | 10626                                 | 10626 | 10626 | 10626 | 10626 | 10637 | 10658 | 10679 | 10690 | 10701 | 10722 | 10744             |
| 2019  | 10431                                 | 10436 | 10441 | 10441 | 10441 | 10483 | 10525 | 10527 | 10527 | 10548 | 10569 | 10622             |
| 2018  | 10224                                 | 10254 | 10275 | 10277 | 10277 | 10277 | 10277 | 10297 | 10349 | 10380 | 10380 | 10411             |
| 2017  | 1011                                  | 10021 | 10021 | 10061 | 10061 | 10061 | 10090 | 10133 | 10158 | 10168 | 10106 | 10046             |
| 2016  | 9705                                  | 9732  | 9771  | 9809  | 9809  | 9878  | 9888  | 9898  | 9898  | 9927  | Fntr  | y for labor i     |
| 2015  | 9465                                  | 9468  | 9475  | 9529  | 9474  | 9551  | 9563  | 9570  | 9618  | 9653  |       | , 101 10001 II    |
| 2014  | 9188                                  | 9192  | 9225  | 9265  | 9294  | 9295  | 9306  | 9309  | 9341  | 9387  | 4.1.5 |                   |
| COURSE ADMIN                                      | 9010                                  | 9028  | 9028  | 9028  | 9029  | 9047  | 9051  | 9058  | 9062  | 9129  | 1119  | 77                |
| Schedule  | 8809                                  | 8820  | 8848  | 8848  | 8848  | 8851  | 8879  | 8963  | 8966  | 8973  |       | $\frac{1.9}{1.9}$ |
| Welcome Email                                     | 8644                                  | 8644  | 8644  | 8652  | 8652  | 8711  | 8725  | 8748  | 8763  | 8773  | 606   | :7                |
| Standing Instructions for Students (SIS)          | 8356                                  | 8391  | 8391  | 8391  | 8437  | 8449  | 8494  | 8499  | 8517  | 8593  | 000   | ) /               |
| Section Marcher Duties & Rotation                 | 8112                                  | 8112  | 8112  | 8112  | 8171  | 8191  | 8200  | 8240  | 8251  | 8255  | 8255  | 8356              |
| Registrar Canvas                                  | 7796                                  | 7796  | 7796  | 7803  | 7818  | 7818  | 7846  | 7861  | 7975  | 8103  | 8105  | 8107              |
| Roster B1T2-Hour                                  | 7459                                  | 7459  | 7464  | 7466  | 7579  | 7579  | 7590  | 7644  | 7701  | 7718  | 7793  | 7796              |
| Roster D1S2-Hour                                  | 7201                                  | 7207  | 7209  | 7213  | 7213  | 7213  | 7218  | 7224  | 7266  | 7416  | 7450  | 7459              |
| Seating Chart B1T2-Hour                           | 6912                                  | 6926  | 6926  | 6926  | 6972  | 6981  | 6997  | 7065  | 7157  | 7164  | 7199  | 7199              |
| Seating Chart D1S2-Hour                           | 6644                                  | 6660  | 6672  | 6672  | 6672  | 6698  | 6717  | 6728  | 6838  | 6874  | 6878  | 6912              |
| FE Reference Handbook v10.4 (2024)<br>Cover Sheet | 6366                                  | 6393  | 6411  | 6421  | 6426  | 6487  | 6515  | 6553  | 6569  | 6596  | 6604  | 6616              |
| CHEMCAD License Server                            | 6097                                  | 6097  | 6109  | 6109  | 6148  | 6166  | 6242  | 6264  | 6291  | 6306  | 6333  | 6338              |
| CHEMCAD Installation Fix                          | 5874                                  | 5874  | 5874  | 5892  | 5906  | 5948  | 5978  | 5984  | 6052  | 6065  | 6065  | 6067              |
|   | 5641                                  | 5650  | 5676  | 5676  | 5714  | 5735  | 5750  | 5764  | 5770  | 5812  | 5817  | <del>507</del> 3  |
| COST INDICES CE Plant Cost Index                  | 5474                                  | 5474  | 5474  | 5489  | 5495  | 5521  | 5548  | 5548  | 5589  | 5596  | 5605  | 5635              |
| ENR Skilled Labor Index                           | 5294                                  | 5314  | 5317  | 5317  | 5317  | 5345  | 5369  | 5387  | 5416  | 5463  | 5471  | 5473              |
| Nelson-Farrar Refinery Index                      | 5177                                  | 5177  | 5179  | 5182  | 5203  | 5203  | 5231  | 5263  | 5267  | 5280  | 5288  | 5294              |
| Nelson-Farrar Chemical Cost Index                 | 5016                                  | 5020  | 5020  | 5028  | 5039  | 5060  | 5075  | 5123  | 5133  | 5160  | 5164  | 5177              |
|   | 4881                                  | 4892  | 4894  | 4903  | 4909  | 4909  | 4945  | 4967  | 4982  | 4998  | 5017  | 5016              |
| SPREADSHEETS Cost & Evaluation Spreadsheet        | 4766                                  | 4764  | 4764  | 4776  | 4782  | 4806  | 4816  | 4835  | 4865  | 4878  | 4878  | 4880              |
| Piping Design Spreadsheet                         | 4653                                  | 4653  | 4665  | 4665  | 4665  | 4662  | 4720  | 4720  | 4749  | 4757  | 4762  | 4766              |
| Agitator Design Spreadsheet                       | 4539                                  | 4529  | 4536  | 4542  | 4553  | 4558  | 4593  | 4627  | 4639  | 4642  | 4551  | 4653              |
| Pneumatic Conveyor Design Spreadsheet             | 4389                                  | 4387  | 4387  | 4390  | 4421  | 4440  | 4475  | 4493  | 4504  | 4520  | 4539  | 4539              |
| 1990  | 4242                                  | 4242  | 4248  | 4250  | 4267  | 4308  | 4310  | 4332  | 4372  | 4374  | 4387  | 4389              |
|   |                                       |       |       |       |       |       |       |       |       |       |       |                   |

Notes:

Index value in "Colorful" worksheet is **bold** and hightlighted in yellow

# Additional Info for Determining Operating Labor (Figure 6-9)

Example: A large automated plant produces 100,000 kg/day with 12 processing steps.

(34 employee hours per day / step) x 12 steps = 408 employee hours per day

408 employee hours per day / (8 hours / day) = 51 employees

51 employees / 3 shifts = 17 employees per shift

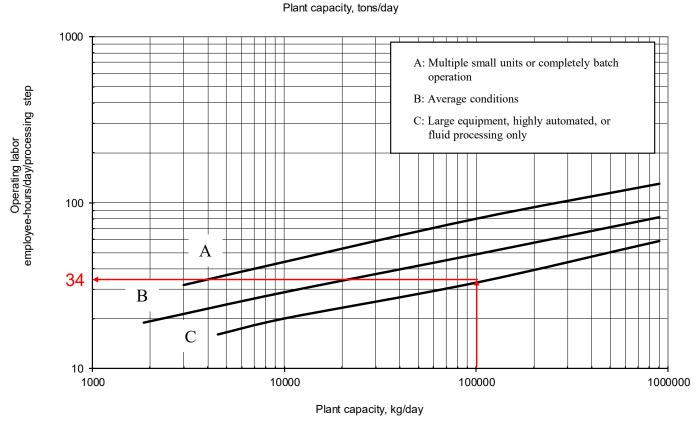


Figure 6-9 Operating Labor in the chemical process industries

## **Utility Costs**

See Table 6-14 and Table B-1 for ranges of utility unit costs and sources of information. Default values are rough averages and may be changed. Utility costs can differ widely with location.

| Process Identifier: Illustration 10 | )1      | Required use           | er input   | Notes & comments                           |   |  |  |  |  |
|-------------------------------------|---------|------------------------|--|--|---|--|--|--|--|
|                                     |         | Result                 | _  | Default, may be                            | changed                                 |  |  |  |  |
| TOTAL UTILITY COST =                |         | 2.025                  | million \$/y   |  | ,                                       |  |  |  |  |
|                                     | Sent to | sheet 'Ann             | ual TPC'   | 1  |   |  |  |  |  |
| Utility                             | Unit    | Default<br>cost units  | Annual utility<br>requirement, in<br>appropriate units | Default units<br>of utility<br>requirement | Annual utility<br>cost, million<br>\$/y |  |  |  |  |
| Air, compressed                     |         |                        |  |  |   |  |  |  |  |
| Process air                         | 0.45    | \$/100m <sup>3</sup> # |  | 100 m <sup>3*</sup> /y                     |   |  |  |  |  |
| Instrument air                      | 0.90    | \$/100m <sup>3</sup> # |  | 100 m <sup>3*</sup> /y                     |   |  |  |  |  |
| Electricity                         |         |                        |  |  |   |  |  |  |  |
| Purchased, U.S. average             | 0.045   | \$/kWh                 | 1800000  | kWh/y                                      | 0.081                                   |  |  |  |  |
| Self-generated                      | 0.05    | \$/kWh                 |  | kWh/y                                      |   |  |  |  |  |
| Fuel                                |         |                        |  |  |   |  |  |  |  |
| Coal                                | 1.66    | \$/GJ                  |  | GJ/y                                       |   |  |  |  |  |
| Fuel oil                            | 3.30    | \$/GJ                  |  | GJ/y                                       |   |  |  |  |  |
| Natural gas                         | 3.00    | \$/GJ                  | 360000   | GJ/y                                       | 1.080                                   |  |  |  |  |
| Manufactured gas                    | 12.00   |                        |  | GJ/y                                       |   |  |  |  |  |
| Refrigeration, to temperature       |         |                        |  |  |   |  |  |  |  |
| 15 °C                               | 4.00    | \$/GJ                  |  | GJ/y                                       |   |  |  |  |  |
| 5 °C                                | 5.00    | \$/GJ                  |  | GJ/y                                       |   |  |  |  |  |
| -20 °C                              | 8.00    | \$/GJ                  |  | GJ/y                                       |   |  |  |  |  |
| -50 °C                              | 14.00   | \$/GJ                  |  | GJ/y                                       |   |  |  |  |  |
| Steam, saturated                    |         |                        |  |  |   |  |  |  |  |
| 3550 kPa                            | 8.00    | \$/1000 kg             |  | 1000 kg/y                                  |   |  |  |  |  |
| 790 kPa                             | 6.00    | \$/1000 kg             | 40000  | 1000 kg/y                                  | 0.240                                   |  |  |  |  |
| Exhaust (150 kPa)                   | 2.00    | \$/1000 kg             |  | 1000 kg/y                                  |   |  |  |  |  |
| Waste water                         |         |                        |  |  |   |  |  |  |  |
| Disposal                            | 0.53    | \$/m <sup>3</sup>      |  | m³/y                                       |   |  |  |  |  |
| Treatment                           | 0.53    | \$/m <sup>3</sup>      | 400000   | m³/y                                       | 0.212                                   |  |  |  |  |
| Waste disposal                      |         |                        |  |  |   |  |  |  |  |
| Hazardous                           | 145.00  | \$/1000 kg             |  | 1000 kg/y                                  |   |  |  |  |  |
| Non-hazardous                       | 36.00   | \$/1000 kg             |  | 1000 kg/y                                  |   |  |  |  |  |
| Water                               |         |                        |  |  |   |  |  |  |  |
| Cooling                             | 0.08    | \$/ m <sup>3</sup>     | 2500000  | m³/y                                       | 0.200                                   |  |  |  |  |
| Process                             |         |                        |  |  |   |  |  |  |  |
| General                             |         | \$/m <sup>3</sup>      | 400000   | m³/y                                       | 0.212                                   |  |  |  |  |
| Distilled                           | 0.90    | \$/m <sup>3</sup>      |  | m <sup>3</sup> /y                          |   |  |  |  |  |

## Modified Accelerated Cost Recovery System (MACRS)

FEE Reference Handbook, v10.4, pp. 231-232 (257-258/502)

| 1  |         | 934      |  |          |          |          |               |         |          |        |         |          |         |        |       |       |       |       |       |       |       |
|--|---------|----------|--|----------|----------|----------|---------------|---------|----------|--------|---------|----------|---------|--------|-------|-------|-------|-------|-------|-------|-------|
| DEPRE  | CIATIO  | NC       |  |          |          |          |               |         |          |        |         |          |         |        |       |       |       |       |       |       |       |
| Default = 8  | 5-y MA  | CRS.     | Defau  | lt is in | place ir | n sheet  | s <b>'Eva</b> | luation | and "    | Year-0 | \$'.    |          |         |        |       |       |       |       |       |       |       |
| To use a   |         |          | The second secon |          |          |          |               |         |          |        | w of    |          |         |        |       |       |       |       |       |       |       |
| sheets 'Eva  |         |          |  |          |          |          |               |         |          | 1.5    |         |          |         |        |       |       |       |       |       |       |       |
| User may   | elect s | traight- | line de  | preciat  | ion and  | d period | d(d = F       | CI/per  | iod), ar | nd     |         |          |         |        |       |       |       |       |       |       |       |
| substitute the value into the depreciation row on sheets |         |          |  |          |          |          |               | aluatio | on' and  | l      |         |          |         |        |       |       |       |       |       |       |       |
| 'Year-0 \$'.   |         |          |  |          |          |          |               | III III | 1111     |        |         | 1        |         |        | 95    |       |       |       |       |       | 9     |
|  |         |          |  |          |          |          | E             | entry = | MACR     | S depr | eciatio | n as fra | ction/y | of FCI |       |       |       |       |       |       |       |
| Recovery   |         |          |  |          |          | 18       |               |         |          |        | YEAR    |          |         |        | -     |       |       |       |       |       |       |
| period   | 1       | 2        | 3  | 4        | 5        | 6        | 7             | 8       | 9        | 10     | 11      | 12       | 13      | 14     | 15    | 16    | 17    | 18    | 19    | 20    | 21    |
| 3-year   | 0.333   | 0.444    | 0.148  | 0.074    |          |          |               |         |          |        |         |          |         |        |       |       |       |       |       |       |       |
| f  | 0.200   | 0.320    | 0.192  | 0.115    | 0.115    | 0.058    | 524           | - 4     |          | 2 8    | 88      |          |         |        | 35    |       |       | 526   | 160   |       | 3 3   |
| 7-year   | 0.143   | 0.245    | 0.175  | 0.125    | 0.089    | 0.089    | 0.089         | 0.045   |          |        | 80      |          |         | 3 90   | 98    | 8     |       | 6     |       |       | 2 83  |
| 10-year  | 0.100   | 0.180    | 0.144  | 0.115    | 0.092    | 0.074    | 0.066         | 0.066   | 0.066    | 0.066  | 0.033   |          |         |        |       |       |       |       |       |       |       |
| 15-year  | 0.050   | 0.095    | 0.086  | 0.077    | 0.069    | 0.062    | 0.059         | 0.059   | 0.059    | 0.059  | 0.059   | 0.059    | 0.059   | 0.059  | 0.059 | 0.030 |       | 532   |       |       | 8 8   |
| 20-year  | 0.038   | 0.072    | 0.067  | 0.062    | 0.057    | 0.053    | 0.049         | 0.045   | 0.045    | 0.045  | 0.045   | 0.045    | 0.045   | 0.045  | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.045 | 0.022 |
|  |         |          |  |          |          |          |               |         |          |        |         |          |         |        |       |       |       |       |       |       |       |

## **Annual Total Product Cost**

| See Figure 6-7 and 6-8   |                                       | Š.                          | à                           |                             | 5             |             |
|--|---------------------------------------|-----------------------------|-----------------------------|-----------------------------|---------------|-------------|
| Default, may be changed  |                                       | Subtotal                    | Notes & co                  | omments                     |               |             |
| User input   |                                       | RESULT                      |                             |                             |               |             |
| Required, may be calculated here, in   | linked work                           | sheet, or entered n         | nanually.                   |                             |               |             |
| Project identifier: Illustration 101   |                                       |                             | 3:                          | 2                           | Q §           |             |
| Capacity   | 30                                    | 10 <sup>6</sup> kg per year |                             | 8                           | 8 - 3         |             |
| Fixed Capital Investment, FCI  | 50.114                                | million \$                  |                             | 6                           | 9 6           |             |
| Item   | Default<br>factor, user<br>may change | Basis                       | Basis cost,<br>million \$/y | Cost,<br>million \$/y       |               |             |
| Raw materials  |                                       | 8                           | 8                           | 12.650                      | 1 3           |             |
| Operating labor  |                                       | ,                           |                             | 0.885                       |               |             |
| Operating supervision  | 0.15                                  | of operating labor          | 0.885                       | 0.133                       |               |             |
| Utilities  | West .                                | ALL COMP.                   |                             | 2.025                       |               |             |
| Maintenance and repairs  | 0.06                                  | of FCI                      | 50.114                      | 3.007                       |               |             |
| Operating supplies   | 0.15                                  | of maintenance &            | 3.007                       | 0.451                       | i s           |             |
| Laboratory charges   | 0.15                                  | of operating labor          | 0.885                       | 0.133                       | 8 8           |             |
| Royalties (if not on lump-sum basis)   | 0.01                                  | of co                       | 26.674                      | 0.267                       | 9             |             |
| Catalysts and solvents   | 0                                     | 22                          |                             | 0.000                       | 8             |             |
| Varia  | able cost =                           | VACABLES IN                 | all Section 2011            | 19.550                      | Sent to 'Eval | uation' and |
| Taxes (property)   | 0.02                                  | ofFCI                       | 50.114                      | 1.002                       |               | Year-0 \$   |
| Financing (interest)   | 0                                     | ofFCI                       | 50.114                      | 0.000                       |               |             |
| Insurance  | 0.01                                  | ofFCI                       | 50.114                      | 0.501                       | 0             |             |
| Rent   | 0                                     | ofFCI                       | 50.114                      | 0.000                       |               |             |
| Depreciation   | Calculate                             | d separately                |                             |                             |               |             |
| Marian and the state of the sta |                                       |                             | Charges =                   | 1.503                       |               |             |
| Plant overhead, general  | 0.6                                   | of labor, supervisi         |                             | 2.415                       | 20            |             |
| 8  |                                       | AD-SS NOV                   | verhead =                   | 1000000                     |               |             |
|  |                                       | Manufactur                  |                             |                             | 4 8           |             |
| Administration   | 0.2                                   | of labor, supervisi         |                             | 0.805                       |               |             |
| Distribution & selling   | 0.05                                  | of co                       | 26.674                      | 1.334                       |               |             |
| Research & Development   | 0.04                                  | of co                       | 26.674                      | 1.067                       | 8 6           |             |
|  | 1                                     | General Expen               | ise =                       | 3.206                       |               |             |
| TOTAL PRODUCT COST WITH  | OUT DEP                               | RECIATION =                 | c . =                       | 26.674                      |               |             |
|  |                                       |                             | 8                           | Sent to 'Eva<br>and 'Year-0 |               |             |

## **Economic Evaluation**

|   |                                |                      | -              | and the second                          |                | WITTE SAN  | and the latest     | 476                 | - 22       |              | 90 - 2    | GC         | 0 0          |         |         |   | 10                                      |  | 20       | no                                       | 3             | 70 -          |  | 302 529 |
|---|--------------------------------|----------------------|----------------|---|----------------|------------|--------------------|---------------------|------------|--------------|-----------|------------|--------------|---------|---------|---|---|--|----------|--|---------------|---------------|--|---------|
| ECONOMIC EVALUA   | ECONOMIC EVALUATION CURRENT, I |                      |                |   |                |            | , DOLLA            | RS                  | - 8        |              | 8 1       | 8 3        | 8 8          | 2 8     | 8       |   | 8 8                                     |  | E .      | 8 8                                      |               | K             | 1  | 18 B    |
| Project identifier: Illustration 101                      |                                |                      |                |   |                | tion rate, |                    |                     | 0.02       |              |           |            |              |         |         |   |   |  |          |  |               |               |  | 45      |
| Expenditures, entries must be negative                    |                                | <u> </u>             | . 8            |   |                | ation rate |                    | y -                 | 0          |              | 3         | 3 3        |              | 1 3     | - 3     |   | 1 1                                     |  | 3 1      |  |               |               | 3  | 1 1     |
| Default values, can be changed                            | - 1                            | 9                    | 2 6            | Deliver of the last                     | and the second | , fraction | Access to the same | -                   | 0.02       |              |           | 3 3        | 3 3          | 2 8     | 8       |   | 8 8                                     |  | 8        | 8 8                                      |               |               | 1  | 35 9    |
| Required, user must supply                                |                                |                      |                |   |                | ding disci |                    |                     |            |              |           |            |              |         | 0.15    | ,   | 6 8                                     |  | 0 )      | 6 6                                      |               | 10 0          | 3  | 203 774 |
| Required, may be calculated here, in it                   | nked                           |                      |                |   |                | ounding    |                    | rate, fraci         | tion/y = n | rinëmum:     | acceptab  | le rate of | return, r    | and the | 0.14    |   |   |  |          |  |               |               |  |         |
| worksheet, or entered manually                            |                                | <u> </u>             |                | - 8                                     | Income I       | tax rate = |                    | 0.35                |            |              | 3 9       | 2 9        | Š - S        | 3       | - 8     |   | 8                                       |  | 8 3      | 8  |               |               | 3  | 8 N     |
| Comments and notes begin in column                        | S                              | 2 3                  | REQUE          | - 8                                     |                |            | 8 3                | A STATE OF          | - 3        |              | 8.——      | 8 3        | 8 3          | 2 8     | - 8     |   | 8 8                                     |  | 8 3      | 8 8                                      |               |               | 1  | 18 8    |
|   |                                |                      |                |   |                |            |                    |                     |            |              |           |            |              |         |         |   |   | _  |          |  |               |               |  | 4       |
|   | 3 3                            |                      | - 3            |   |                |            | 2 2                |                     |            |              |           | 2 - 3      | 3 3          |         | Row     |   | ENTS & NO                               | The second second  |          | 1 2                                      |               |               | 1  |         |
| Year ending at time                                       | -3                             |                      | -1             | -                                       | - 1            | 2          | 3                  | - 4                 | 5          | - 6          | 7         | - 8        | 9            | 10      | Sum     |   | 200000000000000000000000000000000000000 | of estimate,   | time -   | 2 is the first                           | inflation.    |               |  |         |
| 1. Land, 10 5 (see notes)                                 | 8 3                            | 0.00                 | 0.00           | 0.00                                    |                | Ü.         | 8 8                | 3                   |            |              | 8 1       | Q 3        |              | 0.06    | 0.00    |   |   | default is 0.  | 93       |  |               |               |  |         |
| 2. Fixed Capital Investment, 10°5                         |                                | -7.32                | -17.42         | -25.38                                  |                |            |                    |                     |            |              |           |            | _            |         |         | Time 0 is s   |   |  |          |  |               |               |  |         |
| 3. Working Capital, 10 5 (see notes)                      | 2 3                            | 8 8                  | . 3            | -8.85                                   |                | 8 3        | 8 3                | 3                   | - 3        |              | 8 3       | § 3        | 8 8          | 8.85    | 0.00    | _   |   | ime 0, (+) wh  | _        | covered.                                 |               |               |  |         |
| 4. Salvage Value, 10 %                                    |                                |                      |                |   |                |            |                    |                     |            |              |           |            |              | 0.00    | 0.00    | Salvage va  | ilue is (+) at                          | time of reco   | overy.   |  |               |               |  |         |
| 5. Total Capital Investment, 10 5                         | 8                              | -7.32                | -17.42         | -34.23                                  |                | ě i        | <u> </u>           | 2                   |            |              |           | ĝ :        | 1 1          | . 8     | -58.96  |   |   |  | - 22     |  |               |               |  |         |
| 6. Annual Investment, 10 5                                |                                |                      |                |   | 0:00           | 0.00       | 0.00               | 0.00                | 0.00       | 0.00         | 0.00      | 0.00       | 0.00         | 0.00    | 0.00    | Planned In  | vestments (                             | e.g. replace   | ments    | entered he                               | re at inflate | d value.      |  |         |
| 7. Start-up cost, 10 <sup>6</sup> \$                      | 8 8                            | 3 8                  | 8              | 8                                       | -5.01          | 1          | L west             | 1 -2                | 1          | 750          | E-SAS     | i mari     | 1            | 27715   | 8       |   | aut is 10%                              |  |          | 11                                       |               |               |  | 9       |
| 8. Operating rate, fraction of capacity                   | § §                            | 3 3                  | 8              | - 8                                     | 0,50           | 0.90       | 1.00               | 1.00                | 1.00       | 1.00         | 1.00      | 1,00       | 1.00         | 1.00    |         |   | amp-up of p                             | production.  |          |  |               |               |  |         |
| 9. Annual sales, 10°5                                     | 5K                             | 2 6                  |                | - 10                                    | 25.50          | 45.90      | 51.00              | 51.00               | 51.00      | 51.00        | 51.00     | 51.00      | 51.00        | 51,00   | 479,40  |   |   |  |          |  |               |               |  |         |
| 10, Annual Total Product Cost,                            |                                |                      |                |   | -17.93         | -25.76     | -29.45             | -30.04              | -30.64     | -31.25       | -31.88    | -32.51     | -33.17       | -33.83  | -297.45 | Operating r   | rate affects                            | only variable  | e part o | of TPC.                                  |               |               |  | T I     |
| depreciation not included 10°S                            |                                |                      |                |   |                |            |                    |                     |            |              |           |            |              |         |         | E02.000.00000   |   | 200000000000000000000000000000000000000  | 1000     | 1002-00                                  |               |               |  |         |
| 11. Annual depreciation factor, 1/y                       | 3 6                            | 3 8                  | - 3            | - 8                                     | 0.20           | 0.320      | 0.192              | 0.115               | 0.115      | 2.89         | 8         | 9 9        | 8 S          | - 3     | 50.11   | Depreciatio   | in derault is                           | 5-year MAC   | MS.      |  |               |               |  |         |
| 12. Annual depreciation, 10 S/y                           | 2 3                            | 5 3                  | 2              | - 2                                     | 10.02          | 16.04      | 9.62               | 5.77                | 5.77       |              | 40.40     | 40.40      | 47.00        |         |         | Official country  |   | 2222   |          |  |               |               |  |         |
| 13. Annual Gross Profit, 10 5                             |                                | · ·                  |                |   | -7.47          | 3.11       | 11.93              | 15.19               | 14.59      | 16.86        | 19.12     | 18.49      | 17.83        | 17.17   |         | Start costs   |   | The state of the s |          |  |               |               |  |         |
| 14. Annual Net Profit, 10 5                               | 2 1                            | 3 3                  | 2 3            | - 8                                     | -7.47          | 2.02       | 7.75               | 9.87                | 9.48       | 10.96        | 12.43     | 12.02      | 11.59        | 11.16   |         | 1.000   | tax credit to                           | aken for loss  | es.      |  |               |               |  | 3       |
| 15. Annual operating cash flow, 10 %                      |                                |                      |                | 2002                                    | 2.56           | 18.06      | 17.38              | 15.65               | 15.25      | 13.85        | 12.43     | 12.02      | 11.59        |         | 129.93  |   |   |  | 777207   | W. W |               |               |  |         |
| 16. Total annual cash flow, 10 \$                         | 0.00                           | -7.32                |                |   | 2.56           | 18.06      | 17.38              | 15,65               | 15.25      | 13.85        | 12.43     | 12.02      | 11.59        |         | 70.97   | -Annual op  | perating cas                            | h flow + Ann   | nual in  | vestment                                 |               |               |  |         |
| 17. Cumulative cash position, 10 5                        | 0.00                           | -7.32                |                | -58.96                                  | -56.41         | -38.35     | -20.98             | -5.33               | 9.92       | 23.77        | 36.20     | 48.22      | 59.81        | 70.97   |         | AND DESCRIPTION OF THE PERSON |   |  | -        | -  |               | -             | and the same of th |         |
| Profitability measures, time value of                     | money                          | NOT Incl             | uded:          | 9                                       | 3              |            | 8 8                | 3                   | - 3        |              | 8 3       | 8 3        | 8 8          |         | 8       | RESOLUTION OF THE PARTY OF THE | A 30 to 1 40 000 000 00 000             | um do NOT I  |          | recovery a                               | mounts, by    | text definiti | on.  | 3       |
| 18. Return on investment, ave. %/y                        | 13:5                           |                      |                |   |                |            |                    |                     |            |              |           |            |              |         |         | Compare w   |   | 15.0   |          |  |               |               |  |         |
| 19. Payback period, y                                     | 5.8                            |                      | 3              | - 8                                     |                | Š          | 9 4                | 8                   |            |              |           | 8 8        |              | 3       | - 3     | Compare w   | Access to the second                    | 0000000  | 3.6      | у.                                       |               |               |  |         |
| 20. Net return, 10°\$                                     | -0.80                          | at m <sub>ar</sub> - | 15.0           | %/y                                     |                |            |                    |                     |            |              |           |            |              |         |         | Compare w   | vith net retu                           | m = 0.   |          |  |               |               |  | II.     |
|   |                                |                      | - 4            |   | ***            | 9          | E 3                | 9                   | - 3        |              |           | Š )        | 8 3          |         | 1 8     |   |   |  |          |  |               |               |  | - 3     |
| Profitability measures including time                     | e value o                      | of money             | , with Al      | NNUAL E                                 | ND-OF-         | YEAR CB    | sh flows           | and disc            | ounting    | 14000        | Same of   | Survey     | S. Serenci S |         | 1 3     | NPW and I   | OCFR Includ                             | de recovery :  | amour    | its, by text o                           | lefinition.   |               |  | J.      |
| 21. Present worth factor                                  | 1.52                           | 1.32                 | 1.15           | 1.00                                    | 0.87           | 0.76       | 0.66               | 0.57                | 0.50       | 0.43         | 0.38      | 0.33       | 0.28         | 0.25    | 8       | Uses single   | e-year prese                            | ent worth fac  | tor fro  | m Table 7-3                              |               |               |  | - 3     |
| 22. Present worth of annual cash                          | 0.00                           | -9.68                | -20.03         | -34.23                                  | 2.22           | 13.65      | 11.42              | 8.95                | 7.58       | 5.99         | 4.67      | 3.93       | 3.30         | 2.76    | 0.53    | If there is n   | nore than o                             | ne sign chan   | ige in t | the annual o                             | ash flow, cl  | heck DCFR     | value separ  | rately. |
| flows 10°S  |                                | 27 Y 5 Y L           | 35.00          | 100000000000000000000000000000000000000 | 300000         | 10.00      | 77075              | 0.50                | 7.00       | 5.55         | 7.27      | 0.30       |              | ***     | 5,00    |   | generalizado                            | ocogramous-cris  | 6        |  |               |               |  |         |
| 23. Net present worth, 10 5 -                             | 0.53                           | at discou            | unt rate-      | 15.0                                    | %/y            |            |                    |                     | ` I        |              | 1         | n n        |              |         |         | Compare w   | ith net pres                            | sent worth -   | 0.       |  |               |               |  | Ť       |
| 24. Discounted cash flow rate of                          |                                | To cot 5             | CEP as         | to "Tools                               | 1 20d for      | ction "So  | hier* Co           | t tamet a           | oli ac EP  | E41 10 h     | a mada -  | O be       |              |         |         | Phile resident  | energie for                             | a a manadi   | tatal -  | neh fem in i                             | 207           |               |  |         |
| return, DCFR, %/y =                                       | 15 3                           |                      |                |   |                | be rerun : |                    |                     |            |              | e made =  | July       | 9            |         |         | Compare w   |   | n a negative   | total C  | asn now in i                             | 127.          |               |  |         |
| Iterated discount rate= 0.152                             | 100                            | anairgilly           | g cent eco     | J 35. 3011                              | es muet        | oe results | anci a uli         | arige on            | any anee   | 100          |           | W 3        | 0 8          | 3       | - 8     | Compare W   | mil (to).                               |  |          |  |               |               |  |         |
| 25. Present worth factor                                  | 1.53                           | 1.33                 | 1.15           | 1.00                                    | 0.87           | 0.75       | 0.65               | 0.57                | 0.49       | 0.43         | 0.37      | 0.32       | 0.28         | 0.24    | - 8     |   |   |  |          |  |               |               |  |         |
| 26. Present worth of annual cash                          |                                | "Williams"           | Spirit Carrie  | 100000                                  | Elisa d        |            |                    | 455655A             | 500 AUT    | 50.00        | THE PARTY |            | THEFT        |         | 12592   |   |   |  |          |  |               |               |  | - 23    |
| flows 10 <sup>6</sup> S                                   | 0.00                           | -9.71                | -20.06         | -34.23                                  | 2.22           | 13.61      | 11.37              | 8.89                | 7.52       | 5.93         | 4.62      | 3.88       | 3.25         | 2.71    | 0.00    |   |   |  |          |  |               |               |  |         |
| 12 31   | A 1                            | 2 X                  |                | 18                                      |                | 5          | 3 3                |                     | - 18       |              |           |            | <i>i</i> 3   | . 3     | 1       |   |   |  |          |  |               |               |  | - 3     |
|   |                                | 3 8                  | 111 3          | 18                                      |                | 9          | 1                  | 3                   | - 3        |              | <u> </u>  | E - 1      | 1            |         |         |   |   |  |          |  |               |               |  | - 3     |
| Profitability measures including time                     | e value o                      | of money             | , with C       | ONTINU                                  | OUS cast       | n flows a  | nd disco           | unting              | 2          | Secretary of | 8         | 82         | 83           |         | 1 3     | NPW and I   | OCFR Includ                             | de recovery a  | amour    | ts, by text o                            | lefinition.   |               |  |         |
| 27. Present worth factor                                  | 1.63                           |                      | 1.23           |   |                |            |                    | 0.61                | 0.53       | 0.46         | 0.40      | 0.35       | 0.31         | 0.27    | 1 8     | Uses 1-year   | r present w                             | orth factor fr   | rom Ta   | ble 7-5.                                 |               |               |  | - 3     |
| 28. Present worth of annual cash                          | 35555                          | 15.44.85g*           | AUCONS:        | agolijulia)                             | 19605          | 14.65      | 12.25              | 9.60                | 8 14       | 5.42         | 5.02      | 4 22       | 3.54         | 2.05    | 0.57    | Uses 1-year present worth factor from Table 7-5.  If there is more than one sign change in the annual cash flow, check DCFR value separately.   |   |  |          |  |               |               | rately.  |         |
| flows 10°S  | 1000000                        | - Professional       | 2000000        | CALL VICE                               | 200 Cm         | 14.00      | 12.20              | 5.00                | 0.15       | 0,42         | 5.02      | 7.44       | 0.34         | 2.50    | 0.57    | 57  |   |  |          |  |               |               |  |         |
| 29. Net present worth, 10 5 -                             | 0.57                           | at discou            | unt rate-      | 14.0                                    | %/y            | 100        | KS 2               | A 204               |            |              | 300       | X X        | 0            | . 2     |         | Compare with net present worth =0.  |   |  |          |  |               |               |  | T.      |
| 20 Discounted and four estand                             |                                | To col T             | OFF            | to TT and                               | 7              | ction *So  | hiera C            | t tage at           | all ac 55  | FE4 45 7     |           | 0.00       |              |         |         |   |   |  |          |  |               |               |  |         |
| 30. Discounted cash flow rate of<br>return, DCFR, %/y =   | 44.9                           |                      | TOO INC.       |   |                |            |                    | DOMESTIC CONTRACTOR |            | T            | e mage =  | u by       | 9            |         |         | "No value" results from a negative cash flow in R26.  |   |  |          |  |               |               | Ť  |         |
|   | 1991                           | unanging             | g cell SC:     | 549. SON                                | ret must       | be rerun : | anter a ch         | ange on a           | any snee   | 100          | 3 - 7     | 2          | <u>5</u>     |         | 8       | Compare with R6   |   |  |          |  |               |               | -  |         |
| Iterated discount rate = 0.141                            | 454                            | 4.42                 | 1.24           | 1.07                                    | 0.03           | 0.04       | 0.70               | 0.64                | 0.63       | 0.45         | 0.40      | 0.25       | 0.20         | 0.05    |         |   |   |  |          |  |               |               | - L  |         |
| 31. Present worth factor 32. Present worth of annual cash | 1.64                           | 1.43                 | Association in |   | 0.93           | 0.81       | 0.70               | 0.61                | 0.53       | 0.46         | 0.40      | 0.35       | 0.30         | 0.26    |         | 20.00   |   |  |          |  |               | - 9           |  |         |
| flows 10 <sup>6</sup> S                                   | 0.00                           | -10.43               | -21.55         | -36.77                                  | 2.38           | 14.62      | 12.21              | 9.55                | 8.08       | 6.37         | 4.96      | 4.17       | 3.49         | 2.92    | 0.00    |   |   |  |          |  |               |               |  |         |
| 10 A  | 2                              | 7                    |                |   | 1000000        |            |                    |                     |            | -0.000       | S)        | 1          |              |         |         |   | E 8                                     |  | E .      | E 8                                      |               | E :           | 1  | I I     |
|   | 8 8                            | š 8                  |                | - 8                                     |                | Š i        | 8 8                | ) 9                 | - 8        |              | 2         | 8 1        | 8 8          |         | - 8     |   | 3 3                                     |  | 6        | 8 8                                      |               | 6             |  |         |
|   |                                |                      |                | 1                                       |                |            |                    |                     |            |              |           |            |              |         |         |   |   |  |          |  |               |               |  |         |
| 8 <del>1 (2) (2)</del>                                    | W 0                            | Q 0                  |                | 1 5                                     | _              | 00         | 8 0                | 72                  | - 5        |              | 3         | × 7        | 0 5          |         | Y 3     |   | 20 5                                    |  | 20       | 20 5                                     |               | (i)           | 7  | 255     |

#### **Cumulative Cash Flow Position**

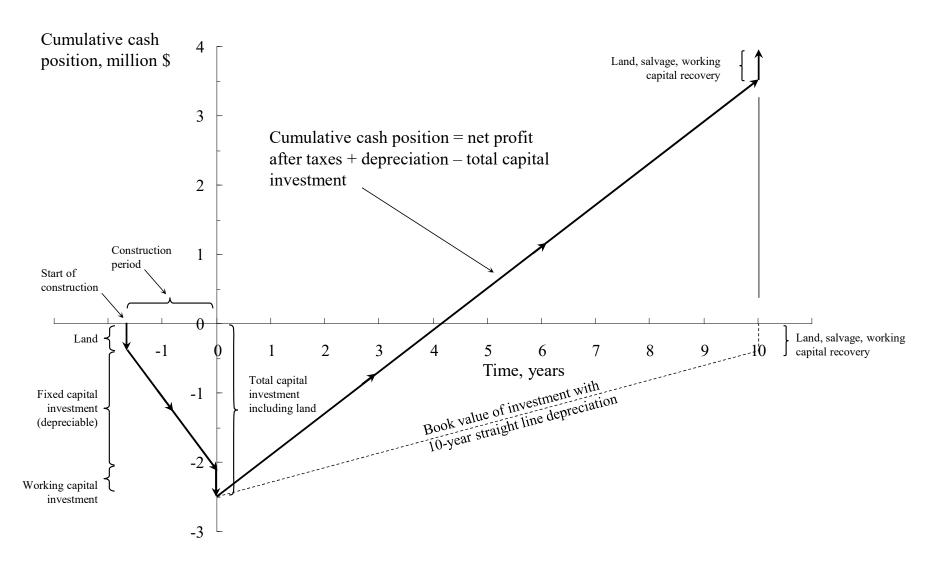


Figure 6.2 Graph of cumulative cash position showing effects of cash flow over full life cycle for a 10-year industrial operation, neglecting the time value of money

# Problem 6-1

The purchased cost of a shell-and-tube heat exchanger (floating head and carbon steel tubes) with 10 m² (not 100 m²) of heating surface was \$4200 in 1990. What was the 1990 purchased cost of a similar heat exchanger with 20 m² of heating surface if the purchased cost capacity exponent is 0.60 for surface areas ranging from 10 to 40 m²? If the purchased cost capacity exponent is 0.81 for surface areas ranging from 40 to 200 m², what was the purchased cost of a heat exchanger with 100 m² of heating surface in 2000?

This problem jumps ahead to lesson 15.

## Scaling of Equipment Costs

Cost of equipment  $a = (Cost of equipment b) \cdot X^{0.6}$ 

X is the "capacity ratio"

| Equipment  | Size Range               | Exponent |
|--|--------------------------|----------|
| Heat exchanger, shell-and-tube, floating head, (c.s.)  | 10 - 40 m <sup>2</sup>   | 0.60     |
| Heat exchanger, shell-and-tube, fixed sheet, (c.s.)    | 10 - 40 m <sup>2</sup>   | 0.44     |
| Pump, centrifugal, horizontal, cast steel (with motor) | 4 - 40 (m³/s)·(kPa)      | 0.33     |
| Reactor, glass-lined, jacketed (without drive)         | 0.2 - 2.2 m <sup>3</sup> | 0.54     |
| Tower (c.s.)   | 500 – 5,000,000 kg       | 0.62     |
| Tray, sieve  | 1 - 3 m                  | 0.86     |

#### Lesson 15

#### FEE Reference Handbook, v10.4, pp. 258 (264/502)

#### Scaling of Equipment Costs

The cost of Unit A at one capacity related to the cost of a similar Unit B with X times the capacity of Unit A is approximately  $X^n$  times the cost of Unit B.

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

Typical Exponents (n) for Equipment Cost vs. Capacity

| Equipment   | Size range  | Exponent |
|---|---|----------|
| Dryer, drum, single vacuum                                  | $10 \text{ to } 10^2 \text{ ft}^2$                      | 0.76     |
| Dryer, drum, single atmospheric                             | $10 \text{ to } 10^2 \text{ ft}^2$                      | 0.40     |
| Fan, centrifugal  | $10^3$ to $10^4$ ft <sup>3</sup> /min                   | 0.44     |
| Fan, centrifugal  | $2 \times 10^4$ to $7 \times 10^4$ ft <sup>3</sup> /mir | 1.17     |
| Heat exchanger, shell and tube, floating head, c.s.         | 100 to 400 ft <sup>2</sup>                              | 0.60     |
| Heat exchanger, shell and tube, fixed sheet, c.s.           | 100 to 400 ft <sup>2</sup>                              | 0.44     |
| Motor, squirrel cage, induction, 440 volts, explosion proof | 5 to 20 hp  | 0.69     |
| Motor, squirrel cage, induction, 440 volts, explosion proof | 20 to 200 hp  | 0.99     |
| Tray, bubble cup, c.s.                                      | 3- to 10-ft diameter                                    | 1.20     |
| Tray, sieve, c.s.   | 3- to 10-ft diameter                                    | 0.86     |

average, this table = .76

average, all equipment = .60

# Problem 6-2

Plot the 2000 purchased cost of the shell-and-tube heat exchanger outlined in Problem 6-1 as a function of surface area from 10 to 200 m<sup>2</sup>. Note that the purchased cost capacity exponent is not constant over the range of surface areas requested.

This problem also jumps ahead to lesson 15.

# Questions?