Open-Ended Problems: A Future Chemical Engineering Education Approach. J. Patrick Abulencia and Louis Theodore.

10

Economics and Finance

This chapter is concerned with process economics and finance. As with all the chapters in Part II, there are several sections: overview, several technical topics, illustrative open-ended problems, and open-ended problems. The purpose of the first section is to introduce the reader to the subject of economics and finance. As one might suppose, a comprehensive treatment is not provided although several technical topics are also included. The next section contains three open-ended problems; the authors' solutions (there may be other solutions) are also provided. The final section contains 43 problems; *no* solutions are provided here.

10.1 Overview

This overview section is concerned with—as can be noted from its title—economics and finance. As one might suppose, it was not possible to address all topics directly or indirectly related to economics and finance. However, additional details may be obtained from either the references provided at the end of this Overview section and/or at the end of the chapter.

Note: Those readers already familiar with the details associated with this subject may choose to bypass this Overview.

An understanding of the economics and finances involved in chemical engineering applications is important in making decisions at both the engineering and management levels. Every chemical engineer should be able to execute an economic evaluation, or the equivalent, of a proposed project. If the project is not profitable, it should obviously not be pursued, and the earlier such a project can be identified, the fewer resources will be wasted.

The fundamental purpose of any process plant is to convert one or more feeds into products of greater value. In order to predict whether a new process will be economically feasible, it is necessary to estimate the costs of feeds, the value of products, the capital investment required to build the plant, and the cost of operating the plant.

Capital costs are usually estimated once a fairly detailed material balance, flow sheet and equipment list are worked out. The flow sheet used at this stage is referred to as a Process Flow Diagram, or PFD (see next Chapter on Plant Design). It is necessary to know key dimensions of major pieces of equipment, but it is not necessary to have a complete, detailed design of every item in the plant. Environmental control systems located within the main processing plant, such as an electrostatic precipitator, must also be included. The costs of auxiliary, or "off-site", systems are often added in using rules-of-thumb rather than engineering calculations. These systems include cooling towers, steam boiler plants, in-plant roads, shipping and storage facilities, and perhaps some of the aforementioned environmental control systems, such as air and wastewater treatment facilities.

Operating costs can also be estimated once a preliminary flowsheet and material balance have been developed. The largest costs are usually those for feed materials and for utilities (electricity, steam, fuel, etc.). Waste treatment costs are occasionally a major factor in overall plant operations. The costs for labor, plant maintenance, insurance and property taxes are also included; but these are often estimated using common rules-of-thumb rather than detailed engineering calculations. Likewise, common rule-of-thumb factors are usually used for such hard-to-calculate overhead costs as sales promotion, workmen's compensation, accident management, public relations, employee morale, etc.

The overall economics of a plant venture are determined using *present-worth* or *discounted-cash-flow* methods that take into account the time value of money, income taxes, and other factors. Often a simpler method, a *payout time*, can be used for preliminary estimations. In general, investment in a new plant or modification to an existing one must have a simple payoff (increased annual revenue or decreased annual operating costs, before taxes) of three years or less to be economically attractive.

Before the cost of a unit or process or facility can be evaluated, the various factors contributing to the cost must be recognized. As noted above, there are two major contributing factors: capital costs and operating costs; these are discussed in the next two sections. Once the total cost of the facility has been estimated, the engineer must determine whether or not the project will be profitable. This may involve converting all cost contributions to an annualized basis, a method favored by one of the authors that is discussed in the following subsections. If more than one project proposal is under study, this method provides a basis for comparing alternate proposals and for choosing the best proposal. Project optimization is the subject of a later section, where a brief description of a perturbation analysis is presented.

Detailed cost estimates are beyond the scope of this section and chapter. Such procedures are capable of producing accuracies in the neighborhood of ±5%; however, such estimates generally require many months of engineering work. This section is primarily designed to give the reader a basis for a *preliminary cost analysis* only, with an expected accuracy of approximately ±20%. See also Chapter 11 – Plant Design and Chapter 13 – Project Management for additional detail.

The reader should note that the material for this chapter was adapted primarily from the following four sources:

1. T. Shen, Y. Choi, and L. Theodore, *EPA Manual Hazardous Waste Incineration*, USEPA/APTI, RTP, NC, 1985[1].
2. L. Theodore and K. Neuser, *Engineering Economics and Finance*, A Theodore Tutorial, Theodore Tutorials, East Williston, NY, originally published by the USEPA/APTI, RTP, 1997 [2].
3. L. Theodore and E. Moy, *Hazardous Waste Incineration*, USEPA/APTI, RTP, NC, 1992[3].
4. J. Santoleri, J. Reynolds and L. Theodore, *Introduction to Hazardous Waste Incineration*, 2nd edition, John Wiley & Sons, Hoboken, NY, 2009[4].

The remaining five Sections in this chapter include:

1. Capital Costs
2. Operating Costs

3. Project Evaluation
4. Perturbation Studies in Optimization
5. Principles of Accounting.

10.2 Capital Costs

Equipment cost is a function of many system variables, one of the most significant of which is capacity. There are other important variables that vary with the cost of equipment or process. Preliminary estimates are often made from simple cost-capacity relationships that are valid when the other variables are assumed constant or confined to narrow ranges of values; these relationships can be represented by approximate linear (on log-log coordinates) cost equipment, equation of the form [5]

$$C = \alpha\, q^{\beta} \tag{10.1}$$

where C = cost
q = some measure of equipment capacity
α, β = empirical "constants" that depend mainly on equipment type

It should be emphasized that this procedure is suitable for rough estimation only; actual estimates from vendors are more preferable. Only major pieces of equipment are included in this analysis; small peripheral equipment such as pumps and compressors may not be included. Similar methods for estimating costs are available in the literature [5]. If greater accuracy is needed, however, actual quotes from vendors should be used.

Again, the equipment cost estimation model just described is useful for a very preliminary estimation. If more accurate values are needed and old price data is available, the use of an indexing method may be better, although a bit more time consuming. The method consists of adjusting earlier cost data to present values using factors that correct for inflation. A number of such indices are available; some of the most commonly used are the Chemical Engineering Fabricated Equipment Cost Index (FECI), the Chemical Engineering Plant Cost Index, and the Marshall and Swift (M&S) Equipment Cost Index, all three of which are available in the magazine *Chemical Engineering*.

The usual technique for determining the *capital costs* (i.e., total capital costs, which include equipment design, purchase, and installation) for a facility is based on the *factored method* of establishing direct and indirect installation costs as a function of the known equipment costs. This is basically a *modified Lang method*, whereby cost factors are applied to known equipment costs [6,7].

The first step is to obtain directly from vendors (or, if less accuracy is acceptable, from one of the estimation techniques previously discussed) the purchase prices of the primary and auxiliary equipment. The total base prices designated by X, which should include instrumentation, control, taxes, freight costs, etc., serves as the basis for estimating the direct and indirect installation costs (ICF). The installation costs are obtained by multiplying X by the cost factors, which can be adjusted to more closely model the proposed system by using adjustment factors that may be available in order to take into account for the complexity and sensitivity of the system[6–8].

The second step is to estimate the *direct installation cost* by summing all the cost factors involved in the direct installation costs, which can include piping, insulation, foundation, and supports, etc. The sum of these factors is designated as the DCF (*direct installation cost factor*). The direct installation costs are then the product of the DCF and X.

Once the direct and indirect installation costs have been calculated, the total *capital cost* (TCC) may be evaluated as

$$\mathrm{TCC} = \mathrm{X} + (\mathrm{DCF})(\mathrm{X}) + (\mathrm{ICF})(\mathrm{X}) \tag{10.2}$$

This cost is then converted to *annualized* capital costs with the use of the *capital recovery factor* (CRF), which is described in a later section. The *annualized capital cost* (ACC) is the product of the CRF and TCC and represents the total installed equipment cost distributed over the lifetime of the facility.

10.3 Operating Costs

Operating costs can vary from site to site, plant to plant, and equipment to equipment, since these costs, in part, reflect local conditions, e.g., staffing practices, labor, and utility costs. Operating costs, like capital costs, may also be separated into two categories: direct and indirect costs. *Direct* costs are those that cover material and labor and are directly involved in operating the facility. These can include labor, materials, maintenance labor and maintenance supplies, replacement parts, waste (e.g., residues) disposal fees, utilities, and laboratory costs. *Indirect* costs are those operating costs associated with, but not directly involved in, operating the unit or facility in question; costs such as overhead (e.g., building-land leasing and office supplies), administrative fees, local property taxes, and insurance fees fall into this category [9,10].

The major direct operating costs are usually those associated with labor and materials. *Material* costs usually involve the cost of chemicals needed for the operation of the system(s). *Labor* costs differ greatly, depending on whether or not the costs are located on-site or off-site and the degree of controls and/or instrumentation. Typically, there are three working shifts per day plus the standby shift used for rotation on a weekly basis, with one supervisor per shift. On the other hand, it may be manned by a single operator for only one third or one half of each shift; usually only an operator, supervisor, and site manager are necessary to run a facility. The cost of *utilities* generally consists of that for electricity, water, fuel, compressed air, and steam. The annual costs are estimates and can be described as a percentage of the capital equipment costs. Typical life expectancies can be found in the literature. Laboratory costs (if applicable) depend on the number of samples tested and the extent of these tests; these costs may be estimated as 10-20% of the operating labor costs.

The indirect operating costs consist of overhead, local property tax, insurance, administration, less any credits. The overhead can comprise payroll, fringe benefits, social security, unemployment insurance, and other compensation that is indirectly paid to the plant personnel. This cost can be estimated as 70-90% of the operating labor, supervision, and maintenance costs [11,12]. Local property costs may be estimated as 2% of the TCC.

The total operating costs is the sum of the direct operating costs and the indirect operating costs less any credits that may be recovered (e.g., the value of recovered by-products such as steam). Unlike capital costs, operating costs are usually calculated on an annual basis.

10.4 Project Evaluation

Although this section primarily deals with a plant or process, it may be applied to equipment and/or other economic issues. In comparing alternate processes or different options of a particular process from an economic point of view, it is recommended that the total capital cost be converted to an annual basis by distributing it over the projected lifetime of the facility. The sum of both the annualized capital costs (ACC) and the annual operating costs (AOC) is known as the total annualized cost (TAC) of the facility. The economic merit of the proposed facility, process or scheme can be examined once the total annual cost is available. Alternate facilities, processes, or options may also be compared. Note, a small flaw in this procedure is the assumption that the operating costs remain constant throughout the lifetime of the facility. However, since the analysis is geared to comparing different alternatives, the changes with time is often uniform among the various alternatives, resulting in little loss of accuracy.

The conversion of the total capital cost to an annualized basis involves an economic parameter known as the capital recovery factory (CRF) an approach routinely employed by one of the authors in the past. These factors can be found in any standard economics text [13–15] or can be calculated directly from

$$CRF = \frac{i(1+i)^n}{(n+i)^n - 1} \tag{10.3}$$

where i = annual interest rate (expressed as a fraction)

n = projected lifetime of the system (years)

The CRF calculated from Equation (10.3) is a positive, fractional number. The ACC is computed by multiplying the TCC by the CRF. The annualized capital cost reflects the cost associated in recovering the initial capital outlay over the depreciable life of the system.

Investment and operating costs can be accounted for in other ways, such as the popular aforementioned *present worth* analysis. However, the capital recover method is preferred because of its simplicity and versatility. This is especially true when comparing systems having different depreciable lives. There are usually other considerations in such decisions besides the economics, but if all the other factors are equal, the proposal with the lowest total annualized cost should be the most attractive.

10.5 Perturbation Studies in Optimization

Once a particular process scheme (or project) has been selected, it is common practice to optimize the process from a capital cost and O&M (operation and maintenance) standpoint. There are many optimization procedures available, most of them too detailed for meaningful application to some studies. These sophisticated optimization techniques, some of which are routinely used in the design of conventional chemical and petrochemical plants invariably involve computer calculations. Occasionally employed by one of the authors, the use of these techniques in many chemical engineering applications is usually not warranted.

One simple optimization procedure that is recommended is the perturbation study (see also Chapter 2). This involves a systematic change (or perturbation) of variables, one by one, in an attempt to locate the optimum design from a cost and operation viewpoint. To be practical, this often means that the chemical engineer must limit the number of variables by assigning constant values to those process variables that are known beforehand to play an insignificant role. Reasonable guesses and simple or short-cut mathematical methods can further simplify the procedure. Much information can be gathered from this type of study since it usually identifies those variables that significantly impact on the overall performance of the process and also helps identify the major contributors to the total annualized cost.

10.6 Principles of Accounting

Accounting is the science of recording business transactions in a systematic manner. Financial statements are both the basis for and the result of management decisions; practicing chemical engineers are rarely involved. Such statements can tell a manager or a chemical engineer a great deal about a company, provided that one can interpret the information correctly.

Accounting has also been defined by accountants as the language of business. The different departments of management use it to communicate within a broad context of financial and cost terms. The chemical engineer who does not take the trouble to learn the language of accountancy denies him/herself the most important means available for communicating with top management. He/she may be thought by them to lack business acumen. Some chemical engineers have only themselves to blame for their lowly status within the company hierarchy since they seem determined to hide themselves from business realities behind the screen of their specialized technical expertise. However, more and more chemical engineers are becoming involved in decisions that are business related. In addition to understanding the principles of accountancy and obtaining a working knowledge of its practical techniques, chemical engineers should be aware of possible inaccuracies of accounting information in the same way that he/she allows for errors in any technical information data.

A detailed and expanded treatment of economics and finance is available in the following two references:

1. L. Theodore and K. Neuser, *Engineering Economics and Finance*, A Theodore Tutorial, Theodore Tutorials, East Williston, NY, originally published by the USEPA/APTI, RTP, NC, 1997 [2].
2. L. Theodore, *Chemical Engineering: The Essential Reference*, McGraw-Hill, New York City, NY, 2014 [16].

10.7 Illustrative Open-Ended Problems

This and the last section provide open-ended problems. However, solutions *are* provided for the three problems in this section in order for the reader to hopefully obtain a better understanding of these problems which differ from the traditional problems/illustrative examples. The first problem is relatively straightforward while the third (and last problem) is somewhat more difficult and/or complex. Note that solutions are not provided for the 43 open-ended problems in the next section.

Problem 1: To what does the term "due diligence process" refer? How would this process reveal any environmental liabilities a corporation may have?

Solution: As defined by law, the term "due diligence" refers to "such measure of prudence, activity, or assiduity, as is properly to be expected from, and ordinarily exercised by, a reasonable and prudent man under the particular circumstances; not measured by any absolute standard, but depending on the relative facts of the special case."

If, for example, a corporation is seeking a loan from a bank to purchase a piece of property to expand its operations, the bank would be required by FDIC regulations to include checks for any liabilities associated with the property or with the corporation seeking the loan. This check is required in order to be sure that neither the borrower nor the property has any potential liabilities which could make the bank responsible for any liabilities.

Problem 2: An investor may invest $60,000 in either Option A or Option B. The return on the investment for each option is given in Table 10.1 below. The investor wished to earn the highest rate of return possible. What is the present value of each option? Select various end-of-year discounting rates.

Table 10.1 Return on Investment for Investment Options A and B

Year	**Annual Income Option A**	**Annual Income Option B**
1	\$10,000	\$10,000
2	\$15,000	\$10,000
3	\$10,000	\$15,000
4	\$10,000	\$15,000
5	\$15,000	\$10,000
Total	\$60,000	\$60,000

Solution: One approach is to apply the *present value* formula.

$$PV = (AI)\frac{1.0}{(1.0+i)^n} \tag{10.4}$$

where PV = present value of annual income for period n in \$, AI = annual income in \$, i = annual interest factor or discount rate on a fractional bases, and n = number of annualized periods.

Select a discount rate of 0.10 (10%). For option A, year one, the present value of the income is calculated as follows:

$$\text{PV} = \$10,000\frac{1.0}{(1.0+0.10)^1} = \$9091$$

For Option A, year two, the present value of the income is:

$$\text{PV} = \$15,000\frac{1.0}{(1.0+0.10)^2} = \$12,397$$

The results for both options for the 5 years are given in the Table 10.2. It can be seen that Option A yields a higher present value than Option B (\$45,145 versus \$45,079). Option A is marginally the better investment even though both options earn the same total undiscounted income.

Table 10.2 Return on Investment for Investment Options A and B Expressed in Present Value Terms. Present Value Calculated Results

Year	Annual Income Option A	Present Value Option A	Annual Income Option B	Present Value Option B
1	$10,000	$9,091	$10,000	$9,091
2	$15,000	$12,397	$10,000	$8,264
3	$10,000	$7,513	$15,000	$11,270
4	$10,000	$6,830	$15,000	$10,245
5	$15,000	$9,314	$10,000	$6,209
Total	$60,000	$45,145	$60,000	$45,079

The above calculational procedure can now be extended to include other discount rates. The analysis of these calculations is left as an exercise for the reader.

Problem 3: Plans are underway to construct and operate a commercial waste treatment facility in Dumpsville in the state of Egabrag. The company is still undecided as to whether to install a liquid injection or rotary kiln incinerator at the waste site. The liquid injection unit is less expensive to purchase and operate than a comparable rotary kiln system. However, projected waste treatment income from the rotary kiln unit is higher since it will handle a larger quantity and different varieties of waste.

Based on economic and financial data provided below in Table 10.3, select the incinerator that will yield the higher annual profit

Table 10.3 Costs/Credits for Liquid Injection and Rotary Kiln Incinerators

Costs/Credits	Liquid Injection	Rotary Kiln
Capital ($)	2,625,000	2,975,000
Installation ($)	1,575,000	1,700,000
Operation ($/yr)	400,000	550,000
Maintenance ($/yr)	650,000	775,000
Income ($/yr)	2,000,000	2,500,000

Calculations should be based on interest rates in the 2 – 18% range and process lifetime of 8 – 15 years for the both incinerators [2-4].

Solution: The solution for $i = 0.12$ (12%) and $n = 12$ follows

1. Calculate the capital recovery factor, CRF.

$$\begin{aligned} CRF &= i/[1 - (1+i)^{-n}] \\ &= 0.12/[1 - (1+0.12)^{-12}] \\ &= 0.1614 \end{aligned}$$

2. Determine the annual capital and installation costs for the liquid injection (LI) unit.

$$\begin{aligned} \text{LI costs} &= (\text{Capital} + \text{Installation})(\text{CRF}) \\ &= (2625000 + 1575000)(0.1614) \\ &= \$677{,}880 / \text{yr} \end{aligned}$$

3. Determine the annual capital and installation costs for the rotary kiln (RK) unit.

$$\begin{aligned} \text{RK costs} &= (\text{Capital} + \text{Installation})(\text{CRF}) \\ &= (2975000 + 1700000)(0.1614) \\ &= \$754{,}545 / \text{yr} \end{aligned}$$

4. Complete the following (see Table 10.4) which provides a comparison of the costs and credits for both incinerators.

Table 10.4 Cost Comparison for Problem 3

	Liquid Injection	**Rotary Kiln**
Total Installed ($/yr)	678 ,000	755,000
Operation ($/yr)	400,000	550,000
Maintenance ($/yr)	650,000	775,000
Total annual cost ($/yr)	1,728,000	2,080,000
Income credit ($/yr)	2,000,000	2,500,000

5. Calculate the profit for each unit on an annualized basis.
   The profit is the difference between the total annual cost and the income credit.
   LI (profit) = 2,000,000 – 1,728,000 = $272,000 /yr
   RK (profit) = 2,500,000 – 2,080,000 = $420,000 /yr

A rotary kiln incinerator should be selected based on the above economic analysis.

10.8 Open-Ended Problems

This last section of the chapter contains open-ended problems as they relate to economics and finance. No detailed and/or specific solution is provided; that task is left to the reader, noting that each problem has either a unique solution or a number of solutions or (in some cases) no solution at all. These are characteristics of open-ended problems described earlier.

There are comments associated with some, but not all, of the problems. The comments are included to assist the reader while attempting to solve the problems. However, it is recommended that the solution to each problem should initially be attempted *without* the assistance of the comments.

There are 43 open-ended problems in this section. As stated above, if difficulty is encountered in solving any particular problem, the reader should next refer to the comment, if any is provided with the problem. The reader should also note that the more difficult problems are generally located at or near the end of the section.

1. Describe the early history associated with economics and finance.
2. Discuss the recent advances in economics and finance.
3. From an insurance perspective, why is it in a corporation's best interest to be ethically conscious?
4. The Securities and Exchange Commission (SEC) requires corporations to disclose their liabilities for accounting purposes. What happens to a corporation if it fails to properly report a liability?
5. Select a refereed, published economics and finance article from the literature and provide a review.
6. Provide some normal everyday domestic applications involving the general topics of economics and finance.
7. Develop an original problem that would be suitable as an illustrative example in a book on economics and finance.
8. Prepare a list of the various books which have been written on economics. Select the three best and justify your answer. Also select the three weakest books and, once again, justify your answer.

9. Prepare a list of the various books which have been written on finance. Select the three best and justify your answer. Also select the three weakest books and, once again, justify your answer.
10. Define and describe single interest in layman terms.
11. Define and describe compound interest in layman terms.
12. Define and describe present worth in layman terms.
13. Define and describe depreciation (straight line sinking fund) in layman terms.
14. Define and describe the capital recover factor (CRF) in layman terms.
15. Define and describe perpetual life in layman terms.
16. Define and describe break-even point in layman terms.
17. Define and describe rate of return in layman terms.
18. Define and describe bonds in layman terms.
19. Define and describe deferred investments in layman terms.
20. Define and describe amortization in layman terms.
21. Detail the role a journal plays in a company's economic and finance dealings.
22. Explain why the practicing chemical engineer should familiarize him/herself with the economics and finance details of their company.
23. Briefly discuss the various methods that industry employs in performing economic evaluations.
24. List and describe some intangible assets at the domestic level.
25. List and describe some intangible assets at the industrial level.
26. Compare and discuss the difference of comparing alternate proposals based on total cost or present worth.
27. What criteria should be employed in choosing between new and existing equipment?
28. Describe the relationship between depreciation and appraisal value.
29. Explain why break-even point calculations are often important in economic analysis.
30. Explain the difficulties that can arise in appraising a home for sale purposes.
31. Due to government cutbacks in funding, regulatory-driven programs for most federal agencies are feeling the pinch. With fewer and fewer enforcement personnel, many feel that

corporate behavior will take a turn for the worse. The traditional sources of pressure on corporations to perform in a responsible manner have come from federal and state regulatory agencies. However, with governmental cuts in funding, the role of these regulators is being diminished. It would be reasonable to expect, then, an increase in these activities by corporations. However, such has not been the case because of the increasingly important role of other entities whose impacts on the performance of corporations may be even more significant. These entities have come to be known as "surrogate regulators". Who and what are these entities? [2].

32. Why are banks interested in determining the potential liability of corporations that seek to borrow money from them?
33. The cost for an outside group to maintaining the air-conditioning equipment for your company's laboratory is under consideration. Discuss the advantages (and disadvantages) of accepting this offer.
34. Consider the following reaction:

$$aA \leftrightharpoons bB$$

Component A is 1¢/ton while B is worth $\$10^6$/ng. Qualitatively describe how the conversion of A to B could be maximized if:

1. a=1, b=10 and the reaction is exothermic
2. a=1, b=10 and the reaction is endothermic
3. a=10, b=1 and the reaction is exothermic
4. a=10, b=1 and the reaction is endothermic

Comment: See also Chapters 3 and 8.

35. Which of the three major classes of reactors has the greatest OM&I problems from an economic perspective. Justify your answer. Comment: See also Chapter 8.
36. Set up a chart, figure and/or equations based solely on capital and operating costs that would allow a chemical engineer responsible for purchasing equipment to select the most economical choice.
37. There are a host of topics that reside under the economic and finance umbrella. List these topics in terms of importance. Justify your answer.

Table 10.6 Air Pollution Initial Equipment Data, Problem 39.

	ESP	VS	BH
Total capital cost	\$17.5/acfm	\$14.0/acfm	\$16.0/acfm
Operating cost	\$0.30/acfmyr	\$0.35/acfmyr	\$0.40/acfmyr
Maintenance costs	\$120,000/yr	\$150,000/yr	\$130,000/yr

38. Prior to being processed in an absorber, a 20,000 acfm stream of particulate contaminated air is to be treated using one of three devices: an electrostatic precipitator (ESP), a venturi scrubber (VS), or a baghouse (BH). The following data were obtained for Theodore Consultants from a reliable vendor. Which air pollution control device should be selected for this operation?
    Perform the calculations based on equipment lifetime and interest in the 10 – 15 year range and 4 – 10% range, respectively [2].
39. As part of an energy conservation project, Abulencia Airlines has decided to reduce their planes speed from 530 mi/hr to 500 mi/hr. Estimate the annual reduction in gasoline used. Also estimate the annual savings.
    Comment: This will require a literature search to obtain gasoline usage vs. speed data as well as gasoline cost information.
40. It is desired to determine whether to use 1-inch-thick or 2-inches-thick insulation for a steam pipe. Theodore Consultants have determined that the following economic data need to be provided in order to perform a meaningful analysis.
    - cost of heat loss w/o insulation
    - cost of each insulation and the corresponding heat loss
    - interest rate
    - insulation lifetime
    - depreciation
    - salvage value

    Outline the details of the calculation.
41. A vendor has provided a total installed capital cost estimate for a particulate-ladened flue gas generated at a waste incineration facility of 25.36 \$/acfm. A baghouse is to be installed for particulate control at the site employing Teflon felt bags, each with an area of 12 ft^2 (\$75.00 per bag) at an air-to-cloth

ratio (acfm/ft^2) of 5.81 to 1. The total pressure drop across the system is 16.5 inches of water (in H_20), including 3 in H_2O for the baghouse. The following economic factors exist at the time of purchase: the gas flow rate (at 350°F) is 70,000 acfm, the overall fan efficiency E_f = 60% (350°F), and the operating time is 6,240 hours/year. Electrical power costs 0.15\$/kW·h. Yearly maintenance cost is \$50,000 per year plus replacing 25% of the bags each year. In addition, there is no salvage value for the bags at the end of useful life.

Assuming that there are no fuel requirements for the incineration of the waste, determine the installed capital, operating, and maintenance costs for the proposed facility on an annualized basis for a faculty lifetime in the 10 – 20 year range with corresponding interest rate in the 5 – 10% range [2]. Comment on the results.

42. Plans are underway to construct and operate some type of a mass transfer unit that will serve to purify a product stream from a chemical reactor. The company is still undecided as to whether to install an extraction unit or a distillation column. The extraction unit is less expensive to purchase and operate than a comparable distillation system, primarily because of energy costs. However, projected income from the distillation unit is higher since it will handle a larger quantity of process liquid and provide a purer product.
Based on the economic and financial data provided below, select the mass transfer unit that will yield the higher annual profit. Select income (\$/yr) for the extraction and

Table 10.7 Equipment Cost Data, Problem 42.

Costs/Credits	Extraction	Distillation
Mass Transfer Unit (\$)	750,000	800,000
Peripherals (\$)	1,875,000	2,175,000
Total Capital (\$)	2,625,000	2,975,000
Installation (\$)	1,575,000	1,700,000
Operation (\$/yr)	400,00	550,000
Maintenance (\$/yr)	650,000	775,000
Income (\$/yr)	-	-

distillation unit in the 2 – 3 million dollar range and 2.4 – 4.0 million dollar range, respectively. The time value of money is 12% and both units have a process lifetime of 12 years [2].

43. Fourteen years ago, a 1200 kW steam electric plant was constructed at a cost of $2,200 per kW. Annual operating expenses had been $310,000 to produce the annual demand of 5,400,000 kW·h. It is estimated that the annual operating expenses and current demand will continue. The original estimate of a 20-year life with a 5% salvage value at that time is still expected to apply.

    The company is contemplating the replacement of the old steam plant with a new diesel plant. The old plant can be sold now for $750,000, while the new diesel plant will cost $2,450 per kW to construct. The diesel plant will have a life of 25 years with a salvage value of 10% at the end of that time and will cost $230,000 annually to operate. Annual taxes and insurance are estimated to be 2.3% of the first cost of either plant. Using several interest rates in the 1 – 10% range, determine whether the company is financially justified in replacing the old steam plant now [2].

    Comment on the results.

References

1. T. Shen, Y. Choi and L. Theodore, EPA Manual *Hazardous Waste Incineration*, USEPA/APTI, RTP, NC, 1985.
2. L. Theodore and K. Neuser, *Engineering Economics and finance*, A Theodore Tutorial, Theodore Tutorials, East Williston, NY, originally published by the USEPA/APTI, RTP, 1997.
3. L. Theodore and E. Moy, *Hazardous Waste Incineration*, USEPA/APTI, RTP, NC, 1992.
4. J. Santoleri, J. Reynolds and L. Theodore, *Introduction to Hazardous Waste Incineration*, 2nd edition, John Wiley & Sons, Hoboken, NY, 2009.
5. R. McCormick and R. DeRoiser, *Capital and O&M Cost Relationships for Hazardous Waste Incinerators*, Acurex Corp., Cincinnati, OH, EPA report, date unknown.
6. R. Neveril, *Capital and Operating Costs of Selected Air Pollution Control Sytstems*, Gard, Inc., Niles, IL, EPA Report 450/5-80-002, Dec., 1978.
7. W. Vatavuk and R. Neveril, *Factors for Estimating Capital and Operating Costs*, Chem. Eng., 157-162, New York City, NY, Nov. 3, 1980.

8. G. Vogel and E. Martin, *Hazardous Waste Incineration Part I—Equipment Sizes and Integrated-Facility Costs*, Chem. Eng., 143-146, New York City, NY, Sept. 5, 1983.
9. G. Vogel and E. Martin, *Hazardous Waste Incineration Part 2—Estimating Costs of Equipment and Accessories*, Chem. Eng., 75-78, New York City, NY, Oct. 17, 1983.
10. G. Vogel and E. Martin, *Hazardous Waste Incineration Part 3—Estimating Capital Costs of Facility Components*, Chem. Eng., 87-90, New York City, NY, Nov. 28, 1983.
11. G. Ulrich, *A Guide to Chemical Engineering Process Design and Economics*, John Wiley & Sons, Hoboken, NJ, 1984.
12. G. Vogel and E. Martin, *Hazardous Waste Incineration Part 4—Estimating Operating Costs*, Chem. Eng., 97-100, New York City, NY, Jan. 9, 1984.
13. E. DeGarmo, J. Canada, and W. Sullivan, *Engineering Economy*, 6th ed., Macmillan, New York City, NY, 1979.
14. C. Hodgman, S. Selby, and R. Weast, ed., *CRC Standard Mathematical Tables*, 12th ed., Chemical Rubber Company, Cleveland, OH, 1961 (presently CRC Press, Boca Raton, FL).
15. T. Tielenberg, *Environmental and Natural Resource Economics*, Scott, Foreman, and Company, Glenview, IL, 1984.
16. L. Theodore, *Chemical Engineering: The Essential Reference*, McGraw-Hill, New York City, NY, 2014.