Appendix One

Study Questions and Problems

CHAPTER ONE

Questions

1.1 What is energy management? Is energy conservation the same as energy efficiency in an effective energy management program?

1.2 Why is there an increasing interest in energy management?

1.3 In the concept of energy management, distinguish between an energy management steering committee and an energy management technical committee. Should they be combined into one committee or not?

1.4 In your opinion, what is the single most important ingredient for a successful energy management program?

1.5 You have recently been hired as a consultant to develop an energy cost accounting system for a medium-sized job shop plant involved in metal working. Discuss your approach to this project. State some of your first activities.

1.6 Discuss the relationship between a good energy accounting system and an effective energy management program.

Problems

1.1 For your university or organization, list some energy management projects that might be good "first ones," or early selections.

1.2 Again for your university or organization, assume you are starting a program and are defining goals. What are some potential first-year goals?

1.3 If you were a member of the upper level management in charge of implementing an energy management program at your university or organization, what actions would you take to reward participating individuals and to reinforce commitment to energy management?

1.4 Perform the following energy conversions and calculations:

a) A spherical balloon with a diameter of ten feet is filled with natural gas. How much energy is contained in that quantity of natural gas?

b) How many Btu are in 200 therms of natural gas? How many Btu in 500 gallons of #2 fuel oil?

c) An oil tanker is carrying 20,000 barrels of #2 fuel oil. If each gallon of fuel oil will generate 550 kWh of electric energy in a power plant, how many kWh can be generated from the oil in the tanker?

d) How much coal is required at a power plant with a heat rate of 10,000 Btu/kWh to run a 6 kW electric resistance heater constantly for 1 week (168 hours)?

e) A large city has a population which is served by a single electric utility which burns coal to generate electrical energy. If there are 500,000 utility customers using an average of 12,000 kWh per year, how many tons of coal must be burned in the power plants if the heat rate is 10,500 Btu/kWh?

f) Consider an electric water heater with a 4500 watt heating element. Assuming that the water heater is 98% efficient, how long will it take to heat 50 gallons of water from 70 degrees F to 140 degrees F?

1.5 A person takes a shower for ten minutes. The water flow rate is 3 gallons per minute, and the temperature of the shower water is 110 degrees F. Assuming that cold water is at 65 degrees F, and that hot water from a 70% efficient gas water heater is at 140 degrees F, how many cubic feet of natural gas does it take to provide the hot water for the shower?

1.6 An office building uses 1 million kWh of electric energy and 3000 gallons of Number 2 fuel oil per year. The building has 45,000 square feet of conditioned space. Determine the Energy Use Index (EUI) and compare it to the average EUI of an office building.

1.7 The office building in Problem 1.6 pays $65,000 a year for electric energy and $3300 a year for fuel oil. Determine the Energy Cost Index (ECI) for the building and compare it to the ECI for an average building.

1.8 As a new energy manager, you have been asked to predict the energy consumption for electricity for next month (February). Assuming consumption is dependent on units produced, that 1000 units will be produced in February, and that the following data are representative, determine your estimate for February.

Last year	Units produced	Consumption (kWh)
January	600	600
February	1500	1200
March	1000	800
April	800	1000
May	2000	1100
June (vacation)	100	700
July	1300	1000
August	1700	1100
September	300	800
October	1400	900
November	1100	900
December (1-week shutdown)	200	650
January	1900	1200

1.9 For the same data as given in Problem 1.8, what is the fixed energy consumption (at zero production, how much energy is consumed and for what is that energy used)?

1.10 At the Gator Products Company, fuel switching caused an increase in electric consumption as follows:

	Expected energy consumption	Actual energy consumption after switching fuel
Electric/cooling degree days	75×10^6 Btu	80×10^6 Btu
Electric/units of production	100×10^6 Btu	115×10^6 Btu

The base year cost of electricity is $\$15.00/10^6$ Btu, while this year's cost is $\$18.00/10^6$ Btu. Determine the cost of fuel switching, assuming there were 2000 cooling degree days and 1000 units produced in each year.

CHAPTER TWO

Questions

2.1 Which performance measure should be used in setting up an audit procedure for a series of buildings: Btu/ft^2/year or Btu/year? Discuss the reasons for your decision.

2.2 Sketch a graph similar to Figure 2-3 for electric energy consumption for a building in your geographic location.

2.3 What information does the Bin Weather Data provide that the HDD and CDD data does not? Can you obtain HDD from Bin Weather Data? Explain.

2.4 Discuss some of the advantages and disadvantages of using a portable computer to prompt the auditor for the data needed in a facility audit.

2.5 Describe a representative energy management team for a county school system. For a city government. For a newspaper.

Problems

2.1 Select a building and perform some of the initial audit steps so that you can become familiar with the basic audit process. Collect energy cost data for the building for one year, plot that data, and analyze it. Collect data on the building layout, operating hours and equipment contained in the building. Note preliminary areas for EMO's, and determine which EMO is most likely to produce the greatest savings.

2.2 Compute the number of heating degree days associated with the following weather data.

Time Period	Temperature
Midnight - 4:00 AM	20 F
4:00 AM - 7:00 AM	15 F
7:00 AM - 10:00 AM	18 F
10:00 AM - Noon	22 F
Noon - 5:00 PM	30 F
5:00 PM - 8:00 PM	25 F
8:00 PM - Midnight	21 F

2.3 Select a specific type of manufacturing plant (e.g. metal furniture, plastic injection molding, laser medical devices, electronic circuit boards, etc.) and describe the kinds of equipment that would likely be found in such a plant. List the audit data that would need to be collected for each piece of equipment. What particular safety aspects should be considered when touring that plant? Would any special safety equipment or protection be required?

2.4 Section 2.1.2 provided a list of energy audit equipment that should be used. However, this list only specified the major items that might be needed. In addition, there are a number of smaller items

such as hand tools that should also be carried. Make a list of these other items, and give an example of the need for each item. How can these smaller items be conveniently carried to the audit? Will any of these items require periodic maintenance or repair? If so, how would you recommend that an audit team keep track of the need for this attention to the operating condition of the audit equipment?

2.5 Section 2.2 discussed the point of making an inspection visit to a facility at several different times to get information on when certain pieces of equipment need to be turned on and when they are unneeded. Using your school classroom or office building as a specific example, list some of the unnecessary uses of lights, air conditioners, and other pieces of equipment. How would you recommend that some of these uses that are not necessary be avoided? Should a person be given the responsibility of checking for this unneeded use? What kinds of automated equipment could be used to eliminate or reduce this unneeded use?

2.6 An outlying building has a 25 kW company-owned transformer that is connected all the time. A call to a local electrical contractor indicates that the core losses from comparable transformers are approximately 3% of rated capacity. Assuming that the electrical costs are ten cents per kWh and $10.00/kW/month of peak demand, that the average building use is ten hours/month, and that the average month has 720 hours, estimate the annual cost savings from installing a switch that would energize the transformer only when the building was being used.

CHAPTER THREE

Questions

3.1 Recently, there has been a trend across the country for utilities to charge more for demand but keep consumption billing about the same (or even reduce the charges). Discuss why this may be occurring.

3.2 Discuss why demand control during peaking months may be more profitable than during nonpeaking months. How might a ratchet clause affect this?

3.3 Discuss ways a manufacturing company might prepare for natural gas curtailments to minimize their impacts.

3.4 Discuss why some managers have failed to analyze and understand their energy rate schedules.

3.5 Do you think a company should periodically analyze its energy rate schedules to see if a change is in order? Explain.

3.6 Discuss why a utility does not pay as much (buy-back rates) for electricity generated by cogeneration, wind, and solar as it charges its customers for the electricity it generates.

3.7 Discuss the advantages and disadvantages of a time-of-day electric rate to residential customers. Examine the time-of-use rate shown in Figure 3-6. What actions could a residential customer on this time-of-day rate take to reduce his on-peak use of electricity?

Problems

3.1 In working with Ajax Manufacturing Company, you find six large exhaust fans running constantly to exhaust general plant air (not localized heavy pollution). They are each powered by 30-hp electric motors with loads of 27 kW each. You find they can be turned off periodically with no adverse effects. You place them on a central timer so that each one is turned off for 10 minutes each hour. At any time, one of the fans is off, and the other five are running. The fans operate 10 h/day, 250 days/year. Assuming the company is on the rate schedule given in Figure 3-10, what is the total dollar savings per year to the company? The company is on service level 3 (distribution service). Neglect any ratchet clauses. (There will be significant heating savings since conditioned air is being exhausted, but ignore that for now.)

3.2 A large manufacturing company in southern Arizona is on the rate schedule shown in Figure 3-10 (service level 5, secondary service). Their peak demand history for last year is shown below. They have found a way to reduce their demand in the off-peak season by 100 kW, but the peak season demand will be the same (i.e., the demand in each month of November through May would be reduced by 100 kW). Assuming they are on the 65% ratchet clause specified in Figure 3-10, what is their dollar savings? Assume the high month was July of the previous year at 1150 kW. If the demand reduction of 100 kW occurred in the peak season, what would be the dollar savings (i.e., the demand in June through October would be reduced by 100 kW)?

Month	Demand (kW)	Month	Demand
Jan.	495	July	1100
Feb.	550	Aug.	1000
March	580	Sept.	900
April	600	Oct.	600
May	610	Nov.	500
June	900	Dec.	515

3.3 In the data for Problem 3.2, how many months would be ratcheted, and how much would the ratchet cost the company above normal billing?

3.4 In working with a company, you find they have averaged 65% power factor over the past year. They are on the rate schedule shown in Figure 3-10 and have averaged 1000 kW/month. Neglecting any ratchet clause and assuming their demand and power factor is constant each month, calculate the savings for correcting to 80% power factor. How much capacitance (in kVARs) would be necessary to obtain this correction? Assume they are on transmission service, PLY (level 1).

3.5 A company has contacted you regarding their rate schedule. They are on the rate schedule shown in Figure 3-10, service level 5 (secondary service), but are near transmission lines and so can accept

service at a higher level (service level 1) if they buy their own transformers. Assuming they consume 300,000 kWh/month and are billed for 1000 kW each month, how much could they save by owning their own transformers. Ignore any charges other than demand and energy.

3.6 In working with a brick manufacturer, you find for gas billing that they were placed on an industrial (priority 3) schedule (see Figure 3-12) some time ago. Business and inventories are such that they could switch to a priority 4 schedule without many problems. What is the savings? They consume 7000 Mcf of gas per month for process needs and essentially none for heating.

3.7 Calculate the electric bill for a customer with a January consumption of 140,000 kWh, a peak 15-minute demand during January of 500 kW, and a power factor of 80%, under the electrical schedule of the example in Section 3.6. Assume that the fuel adjustment is $0.01/kWh.

3.8 Compare the following residential time-of-use electric rate with the rate shown in Figure 3-6.

Customer charge: $8.22/month

Energy charge:
On-peak energy $0.123/kWh
Off-peak energy $0.0489/kWh

On-peak hours:
Summer: Noon to 9:00 pm
May 15th to October 15th
(Including weekends)
Winter: 7 am to 11 am; 6 pm to 10 pm
January 2nd to February 28th
(Excluding weekends)

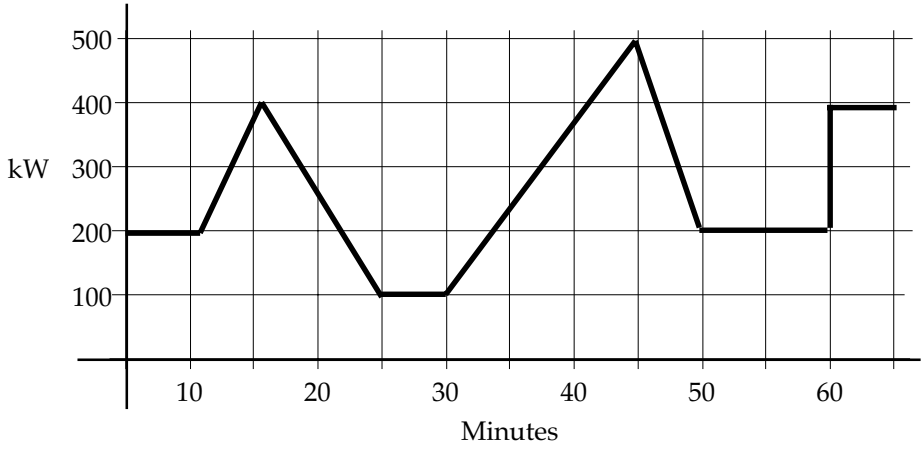
Off-peak hours:
All other hours

This rate charges less for electricity used during off-peak hours—about 80% of the hours in a year—than it does for electricity used during on-peak hours.

Sample time-of-day electric rate.
(Courtesy Gainesville Regional Utilities, FL)

3.9 A small facility has 20 kW of incandescent lights and a 25 kW motor that has a power factor of 80%. What is the power factor of the combined load? If they added a second motor that was identical to the one they are presently using, what would their power factor be?

3.10 A utility charges for demand based on a 30 minute synchronous averaging period. For the load curve shown below for Jones Industries, what is their billing demand and how many kWh did they use in that period?



3.11 The A1 Best Company has a steam demand of 6,500 lb/hour and a consumption of 350,000 lbs during the month of January. Based on the hypothetical steam rate in Figure 3-13, determine their steam consumption cost for the month.

3.12 A1 Best also purchases chilled water with the rate schedule of Figure 3-13. During the month of July, their chilled water demand was

485 tons, and their consumption was 250,000 ton-hours. What was their monthly cost? What was their Btuh (Btu/hour) equivalent for the average chilled water demand?

CHAPTER FOUR

Questions

4.1 The early part of the chapter refers to avoided energy costs. Why is this term more correct than reduced energy costs?

4.2 Why would a company require a higher rate of return for energy management projects than for other projects? If you don't understand the answer to this question, then you will have a difficult time defending your projects against these arguments.

4.3 How would you defend the use of an economic performance measure that did not include the time value of money?

4.4 Which are more important in the budget decisions for a state — economic criteria or non-economic criteria? Under what circumstances does one group of criteria predominate?

4.5 Should the equivalent uniform annual cost method be the only method used in comparing projects of unequal service lives?

4.6 What are some good sources for inflation rate projections?

Problems

4.1 The Orange and Blue Plastics Company is considering an energy management investment which will save 2500 kWh of electric energy per year at $0.08/kWh. Maintenance will cost $50.00 per year, and the company's discount rate is 12%. How much can they spend on the purchase price for this project and still have a Simple Payback Period of two years? Using this figure as the cost, what is the return on investment (ROI), and the Benefit-Cost Ratio (BCR)? Assume a life of 5 years for the project.

4.2 A new employee has just started to work for Orange and Blue Plastics, and she is debating whether to purchase a manufactured home or rent an apartment. After looking at apartments and manufactured homes, she decides to buy one of the manufactured homes. The Standard Model is the basic model that costs $20,000 and has insulation and appliances that have an expected utility cost of $150/month. The Deluxe Model is the energy efficient model that has more insulation and better appliances, and it costs $22,000. However, the Deluxe Model has expected utility costs of only $120/month. If she can get a 10% loan for 10 years to pay back the entire amount for either home, which model should she buy to have the lowest total monthly payment including the loan and the utility bill?

4.3 The A1 Best Company uses a 10 hp motor 16 hours per day, 5 days per week, 50 weeks per year in its flexible work cell. This motor is 85% efficient, and it is near the end of its useful life. The company is considering buying a new high efficiency motor (91% efficient) to replace the old one instead of buying a standard efficiency motor (86.4% efficient). The high efficiency motor costs $70 more than the standard model, and should have a 15 year life. The company pays $7.00/kW per month and $0.06/kWh. The company has set a discount rate of 10% for their use in comparing projects. Determine the SPP, ROI and BCR for this project. The company's discount rate is 10%.

4.4 Craft Precision, Incorporated must repair their main air conditioning system, and they are considering two alternatives.

(1) purchase a new compressor for $20,000 that will have a future salvage value of $2000 at the end of its 15 year life; or

(2) purchase two high efficiency heat pumps for $28,000 that will have a future salvage value of $3000 at the end of their 15 year useful life.

The new compressor will save the company $6500 per year in electricity costs, and the heat pumps will save $8500 per year. The company's discount rate is 12%. Using the BCR measure, which project should the company select? Is the answer the same if Life Cycle Costs are used to compare the projects?

4.5 There are a number of energy-related problems that can be solved using the principles of economic analysis. Apply your knowledge of these economic principles to answer the following questions.

a) Estimates of our use of coal have been made that say we have a 500 years' supply at our present consumption rate. How long will this supply of coal last if we increase our consumption at a rate of 7% per year? Why don't we need to know what our present consumption is to solve this problem?

b) Some energy economists have said that it is not very important to have an extremely accurate value for the supply of a particular energy source. What can you say to support this view?

c) A community has a 100 MW electric power plant, and their use of electricity is growing at a rate of 10% per year. When will they need a second 100 MW plant? If a new power plant costs one million dollars per MW, how much money (in today's dollars) must the community spend on building new power plants over the next 35 years?

4.6 A church has a gymnasium with sixteen 500 Watt incandescent ceiling lights. An equivalent amount of light could be produced by sixteen 250 Watt PAR (parabolic aluminized reflector) ceiling lamps. The difference in price is $10.50 per lamp, with no difference in labor. The gymnasium is used 9 months each year. How many hours per week must the gymnasium be used in order to justify the cost difference of a 1-year payback? Assume that the rate schedule used is that of Problem 3.8, that gymnasium lights do contribute to the peak demand (which averages 400 kW), and that the church consumes enough electricity that much of the bill comes from the lowest cost block in the table.

4.7 Find the equivalent present worth of the following 6-year project using the depreciation schedule in Table 4-1: purchase and installation cost, $100,000; maintenance per year, $10,000; energy saving per year, $45,000; salvage value, $20,000. Assume that the minimum attractive rate of return is 12%/year. Assume that the corpo-

rate tax rate is 34%, and that the equipment has a 5-year life for tax purposes. What is the after-tax ROR or IRR for this project?

4.8 Calculate the constant dollar, after-tax ROR or IRR for Problem 4-7, if the inflation rate is 6%.

4.9 Find the equivalent constant dollar after-tax present worth of the following 6-year project using the depreciation schedule in Table 4-6: purchase and installation cost, $100,000; maintenance per year, $10,000, increasing at 5%/year; energy saving per year, $45,000, increasing at 8%/year; salvage value, $20,000, increasing at 6%/year; and the Consumer Price Index (CPI) projected to increase at 6%/year. Assume that the minimum attractive constant dollar rate of return is 12%/year. Assume that the corporate tax rate is 34%, and that the equipment has a 5-year life for tax purposes. What is the constant dollar, after-tax ROR or IRR for this project?

CHAPTER FIVE

Questions

5.1 How does lighting affect worker productivity?

5.2 What factors are important in selecting a lamp for a manufacturing plant in which color rendition and finely-detailed tasks are important?

5.3 What factors affect the amount of light reaching the work plane?

5.4 How would you convince the management of a facility to switch to group relamping when they have a large number of relatively new lamps that have been installed through spot relamping?

5.5 Why wouldn't you automatically specify the lamp with the greatest efficacy for every application?

Problems

5.1 When performing an energy survey, you find twelve 2-lamp F40T12 security lighting fixtures turned on during daylight hours

(averaging 12 hours/day). The lamps draw 40 Watts each, the ballasts draw 12 Watts each, and the lights are currently left on 24 hr/day. How much can you save by installing a photocell? What is the payback period of this investment? Costs: energy use = $0.055/kWh; power demand = $7.00/kW; lamps = $1.00 each; photocell = $85 installed.

5.2 You count 120 4-lamp F40T12 troffers that contain 34 Watt lamps and two ballasts. How much can you save by installing:

a. 3 - F40T10 lamps (at $15/fixture)?
b. 3 - F32T8 lamps and an electronic ballast (at $40/fixture)?

Assume the same energy costs given in Problem 5-1. What is the simple payback period and what is the return on investment for each alternative? The lights are on 876 hours per year, and the life of the lighting system is 7 years.

5.3 You see 25 exit signs with two 20-Watt incandescent lamps each. How much can you save by replacing the two 20-Watt bulbs with a 7-Watt CFL? The 20-Watt incandescent lamps have a 2500 hour lifespan and cost $3.00 each. The 7-Watt CFLs have a 12,000 hour lifespan and cost $5.00 each and require the use of a $15 retrofit kit. Assume the same energy costs given in Problem 5-1.

5.4 An old train station is converted to a community college center, and a train still passes by in the middle of the night. There are eighty-two 75-Watt A19 lamps in surface-mounted wall fixtures surrounding the building, and they are turned on about 12 hours per day. The lamps cost $0.40 each and last for about one week before failure. How can this problem be solved, and how much money can you save in the process? Assume electricity costs 8 cents per kWh.

5.5 During a lighting survey you discover thirty-six 250-Watt mercury vapor cobrahead streetlights operating 4300 hours per year on photocells. How much can you save by replacing these fixtures with 70-Watt HPS cutoff luminaires? There is no demand charge, and energy costs $0.055 per kWh.

5.6 You find a factory floor that is illuminated by eighty-four 400-Watt mercury vapor downlights. This facility operates two shifts per day

for a total of 18 hours, five days per week. What is the savings from retrofitting the facility with eighty 250-Watt high pressure sodium (HPS) downlights? Assume that the lights are contributing to the facility's peak demand, and that the rates given in Problem 5-1 apply. What will happen to the lighting levels?

5.7 An office complex has average ambient lighting levels of 27 footcandles with four-lamp F40T12 40-Watt 2'×4' recessed troffers. They receive a bid to convert each fixture to two centered F32T8 lamps with a specular reflector designed for the fixture and an electronic ballast with a ballast factor of 1.1 for $39 per fixture. What will happen to the lighting levels throughout the space and directly under the fixtures? Will this retrofit be cost-effective? This lighting is used on-peak, and electric costs are $6.50 per kW and $0.05 per kWh. What is your recommendation?

5.8 An exterior loading dock in Chicago uses F40T12 40-Watt lamps in enclosed fixtures. They are considering a move to use 34-Watt lamps. What is your advice?

5.9 A turn-of-the-century power generating station uses 1500-Watt incandescent lamps in pendant mounted fixtures to achieve lighting levels of about 18 footcandles in an instrumentation room. They plan on installing a dropped ceiling with a 2'×4' grid. How would you recommend they proceed with lighting changes. What will be the savings if they have a cost of 6 cents per kWh?

5.10 A meat-packing facility uses 100-Watt A19 lamps in jarlights next to the entrance doors. These lamps cost $0.50 each and last for 750 hours. What would be the life-cycle savings of using 13-Watt compact fluorescent lamps in the same fixtures? The CFLs cost $15.00 each, and last 12,000 hours. The lights are used on-peak, 8,760 hours per year, and electricity costs 8 cents per kWh. The MARR of the facility is 15%.

5.11 A retail shop uses a 1000-Watt mercury vapor floodlight on the corner of the building to illuminate the parking lot. Some of this light shines out into the roadway. What problems can you anticipate from the light trespass off the lot? How would you recommend improving the lighting? How much can you save with a

better lighting source and design? Use electric costs from Problem 5-7, and assume the light does not contribute to the shop's peak load.

5.12 A commercial pool uses four 300-Watt quartz-halogen floodlights. What are the energy, power, and relamping savings from using two 250-Watt HPS floodlights? What will happen to the lighting levels? The lights do contribute to the facility's peak load, and the electric rates are those of Problem 5-7.

5.13 You notice that the exterior lighting around a manufacturing plant is frequently left on during the day. You are told that this is due to safety-related issues. Timers or failed photocells would not provide lighting during dark overcast days. What is the solution?

5.14 A manufacturing facility uses F96T12HO lamps to illuminate the production area. Lamps are replaced as they burn out. These fixtures are about 15 years old and seem to have a high rate of lamp and ballast failure. How can you solve these problems?

CHAPTER SIX

Questions

6.1 You are performing an energy audit in the winter on a school with a dual-duct HVAC system. In one room, you note that the temperature is 55 degrees F although the thermostat is set at 70 degrees. Explain how this discrepancy could be caused by each of the following: (a) dampers, (b) grilles, (c) fans, (d) filters or ductwork, (e) the boiler, or (f) the control system.

6.2 What factors other than those discussed in the text should be considered in determining the heating and cooling requirements for a building?

6.3 In a split-system air conditioner, the compressor unit is outside and the evaporator unit is inside. The two units are connected with refrigerant lines. Which one of the lines should be insulated? Why?

6.4 A refrigerant-to-water heat exchanger is sometimes added to an air conditioner to provide hot water using the waste heat from the compressor unit. Where is this heat exchanger connected, and what is its effect on the efficiency of the air conditioner?

6.5 A friend of yours says he bought a heat pump that is 200% efficient. Is this possible? Explain.

Problems

6.1 Estimate the total heating load caused by a work force of 22 people including 6 overhead personnel, primarily sitting during the day; 4 maintenance personnel and supervisors; and 12 people doing heavy labor. Assume that everyone works the same 8-hour day.

6.2 If the HVAC system that removes the heat in Problem 6.1 has a COP of 2.0 and runs continuously, how many kW will this load contribute to the electrical peak if the peak usually occurs during the working day? Assume that the motors in the HVAC system are outside the conditioned area and do not contribute to the cooling load.

6.3 Answer Problem 6.2 under the assumption that 8 of the 12 people doing heavy labor and 2 foremen-maintenance personnel come to work when the others are leaving and that 3000 Watts of extra lighting are required for the night shift.

6.4 A heated building has six 8×10 inch window panes missing on the windward side. The wind speed has been measured at 900 ft/min, and the location has 6000 heating degree days/year. (a) Calculate the total number of Btu lost through these windows per year. (b) If the heat is supplied by a boiler, and the heat generation and transmission efficiency is 60%, estimate the cost of leaving the windows broken if gas costs \$0.50/therm.

6.5 You have measured the ventilation in a large truck bay and have found that you are using 12,000 cfm. An analysis shows that only 8000 cfm are required. Measurements at the fans give the total electrical consumption of the ventilation system as 16.0 kW at current

cfm rates. You are currently ventilating this area 16 hours each day, 250 days each year, including the times of peak electrical usage. Your monthly electric rates are $.045/kWh and $12.00/kW of demand. Assuming that your power factor is 90% and that your marginal electrical costs are at the least expensive rates, what is the amount of annual savings that you can expect by the proposed reduction in ventilation rates?

6.6 After implementing the improvements suggested in Problem 6.5, you decide to analyze the value of having the second shift come in just as the first shift is leaving, thereby reducing the amount of time that ventilation is needed by 1 hour each day. How much annual savings do you expect this measure to achieve?

6.7 Suppose the HVAC system in Problem 6.2 needs to be replaced. Compare the cost of running the present system with the cost of a new system with a COP of 3.0. The more efficient system costs $100 more than a replacement that has the old efficiency. Using the SPP method of analysis, which system would you recommend? If the life of the HVAC system is ten years, what is the ROI for the additional cost of the more efficient system? If the company's investment rate is 10%, what is the discounted Benefit/Cost Ratio for this investment? Assume electricity costs 8¢ per kWh, and the HVAC system operates the equivalent of 2000 hours per year at full load.

6.8 ACE Industries has a plant in Nebraska (40° N latitude) with a building that has three, 5×10 foot windows facing South. The windows are single pane glass, one-eighth inch thick. The building is air conditioned with a unit that has an EER = 8.0, and the plant pays $0.08 per kWh for electricity. The plant manager is considering installing interior shades for each of these three windows. The shades would give the windows shading coefficients of about 0.2, and would cost about $150 per window. Would you recommend that the plant manager authorize the investment decision?

6.9 A window air conditioner is rated at 5000 Btu/hour, 115 volts, 7.5 amps. Assuming that the power factor has been corrected to 100%, what is its SEER? How many kWh are used if the unit runs 2000 hours each year at full load? What is the annual cost of operation if electric energy costs 7.5 cents per kWh? How many kWh would be saved if the unit had an SEER of 9.1? How much money would be

saved? Compute three economic performance measures to show whether this more efficient unit is a cost-effective investment. The low efficiency unit costs $200, the higher efficiency unit $250, and each unit lasts ten years. Use a MARR of 15%.

6.10 On an energy audit visit to the Orange and Blue Plastics Company, the chiller plant was inspected. Readings on the monitoring gauges showed that chilled water was being sent out of the plant at 44°F and being returned at 53°F. The flow rate was 6000 gallons of water per minute. How many tons of chilling capacity was the plant supplying?

CHAPTER SEVEN

Questions

7.1 What chemical processes make up a flame? Take one gas, say CH4, and show as many reaction steps as you can. Include all necessary components and the formation of free radicals in your explanation.

7.2 What are NO_X, and SO_X, and how are they formed in a boiler?

7.3 What concentration of CO is poisonous to humans? How can this answer change the desirability of excess air?

7.4 In Section 7.3.2, a series of questions were asked to illustrate the uncertainties associated with burning any new fuel. Make a list of 10 such questions that should be asked when deciding whether to use the industrial waste most prevalent in your area as a fuel.

7.5 Many of the basic costs given in the example of Section 7.3.3 are subject to change. How do you (a) estimate the range of parameter values, (b) express the resulting economic evaluation in ways that are clear to the public, and (c) incorporate the range of values into your decision-making process?

7.6 What could go wrong with the waste-fired boiler proposal in Section 7.3.3, and what additional data do you need at this time to prevent these problems?

7.7 What is a reasonable value for the minimum rate of return which would make a waste-fired boiler attractive?

Problems

7.1 A refinery gas available as a fuel has the following dry chemical composition, by volume [1]:

CO_2:	3.3%	C_2H_6:	19.8%
CO:	1.5%	C_3H_8:	38.1%
H_2:	5.6%	C_4H_{10}	0.8%
CH_4:	30.9%		

(a) Determine the heating value in Btu/ft^3 and in Btu/lb.
(b) Assuming that 15% excess air is supplied for complete combustion, determine the total amount of combustion air needed for each cubic foot of this gas.

7.2 For the gas in Problem 7.1, assuming that 15% excess air is needed for complete combustion, determine the flue gas composition (a) by volume and (b) by weight.

7.3 A particular Utah coal has the following proximate and ultimate analyses:

Proximate analysis		Ultimate analysis	
Component	Weight (%)	Component	Weight (%)
Moisture	4.3	Moisture	4.3
Volatile matter	37.2	Carbon	72.2
Fixed carbon	51.8	Hydrogen	5.1
Ash	6.7	Sulfur	1.1
Total: 100.0		Nitrogen	1.6
		Oxygen	9.0
Heating value: 12,990 Btu/lb		Ash	6.7
		Total 100.0	

(a) Determine the amount of air needed for combustion, assuming complete mixing.
(b) Calculate the flue gas composition by weight, assuming that 25% excess combustion air is supplied and that standard air (relative humidity, 60%; temperature, 80°F) is used.
(c) Assuming that the boiler produces 3 million Btu/h for 4000 hours each year and that the flue gas temperature is 750°F, determine the annual amount and cost of coal used where the delivered coal cost is $60.00/ton.

7.4 Suppose that a reputable firm has been advertising a new burner system that would enable the boiler in Section 7.1.2 to operate at 8% excess air before CO was detected in the flue gas. Why would this system be worth examining? Quantify your answer.

7.5 In Table 7.5, a waste-burning boiler was described. Assume the capacity of this boiler is 28,000 lb/h. Suppose that these figures are 5 years old, that your company is contemplating the purchase of such a boiler, and that it is planned to save twice the energy amounts and have twice the capacity of the given boiler. The energy cost has been inflating at 10% per year, base construction costs have been inflating at 6%/year, the basic inflation rate of the economy has been 5%, and without inflation the cost of constructing a unit is R.73 multiplied by the cost of the existing unit, where R is the ratio between the capacity of the proposed unit and the capacity of the present unit. The tax rate of the company is 34%. The unit is subject to the 5-year depreciation schedule shown in Table 4-6. What is the after-tax present worth of the first 5 years of cash flows associated with this investment if the company uses a constant-dollar after-tax rate of return of 8% on this kind of investment?

7.6 The choice of an optimum combination of boiler sizes in the garbage-coal situation is not usually easy. Suppose that health conditions limit the time that garbage, even dried, can be stored to 1 month. Use the initial costs given in the accompanying table, and assume that the municipality and your company have supplies and needs for energy, respectively, as given in the table labeled "data" for Problem 7.6. Suppose that all the other costs for this problem are the same as in Section 7.3.3. What is the optimum choice now?

Costs for Problem 7.6

Capacity, 750 psi	Initial costs: trash-fired boiler	Initial costs: coal-fired boiler
50,000 lb/h	—	$1,800,000
100,000	—	3,500,000
150,000	$6,250,000	5,100,000
200,000	8,640,000	6,900,000
250,000	10,870,000	8,900,000
300,000	13,000,000	11,000,000

Data for Problem 7.6

Month	Garbage needed (tons)	Garbage available (tons)
January	23,000	13,500
February	23,000	13,500
March	21,600	16,500
April	19,500	18,000
May	14,100	18,900
June	9,500	19,500
July	7,600	22,500
August	9,500	21,000
September	10,800	21,000
October	13,500	18,000
November	18,400	15,000
December	24,300	18,600

Constituent	Percent by volume	Btu/ft^3 of mixture
CH_4	86.4	788.9 (= .864 × 913.2)
C_2H_6	8.4	150.1
C_3H_8	1.5	38.9
C_4H_{10}	1.1	37.1
N_2	.5	—
CO_2	2.1	—
		Total Btu/ft^3: 1015.0

Questions

8.1 Conceivably, most of the heat in the flue gas should be recoverable. What are the practical considerations that limit the amount of heat recovery?

8.2 What are some ways suggested by Figure 8-2 for improving the efficiency of that boiler system?

8.3 In Problem 8.4 in the following section, it is unlikely that the pressure of the entire steam system will be 350 psig because of steam drops. Does this make the use of Grashof's formula invalid if 350 psig is used for P1?

8.4 If cogeneration produces both electric power and process heat so efficiently, why don't you see more cogeneration facilities in operation?

8.5 A citrus processing plant uses gas heat to dry pulp for cattle feed. Would this be a possible application for cogeneration?

Problems

8.1 An audit of a 600-psi steam distribution system shows 50 wisps (estimated at 25 lb/h each), 10 moderate leaks (estimated at 100 lb/h each), and 2 leaks estimated at 750 lb/h each. The boiler efficiency is 85%, the ambient temperature is 75°F, and the fuel is coal, at $65.00/ton and 14,500 Btu/lb. The steam system operates continuously throughout the year. How much do these leaks cost per year in lost fuel?

8.2 Superheated steam enters a heat exchanger at 1400°F and 500 psia and leaves as water at 300°F and 120 psia. How much heat is exchanged per pound of entering steam?

8.3 What would be the potential annual savings in the example of Sec-

tion 8.1.4 if the amount of boiler blowdown could be decreased to an average rate of 3000 lb/h, assuming that it remained at 400°F? How much additional heat would be available from the 3000 lb/h of blowdown water for use in heating the incoming makeup water? Assume 100% of the heat could be used. Calculate the combined cost saving of these two measures using a fuel cost of $65.00/ton for 14,200-Btu/lb coal.

8.4 Suppose that you are preparing to estimate the cost of steam leaks in a 350-psig steam system . The source of the steam is 14,200-Btu/lb coal at $70.00/ton, and the efficiency of the boiler plant is 70 percent. Hole diameters are classified as 1/16, 1/8, 1/4, 3/8 and 1/2 in. Develop a table showing the size of the orifice, the number of pounds of steam lost per hour, the cost per month, and the cost for an average heating season of 7 months.

8.5 A citrus processor needs 500 cubic feet per minute of 200°F air to dry citrus pulp for a small production process to produce a specialized cattle feed. The air is heated in a steam coil unit that is fed with 50-psig steam. How many pounds of steam per hour does the dryer take?

8.6 A 300 foot long steam pipe carries saturated steam at 95-psig. The pipe is not well insulated, and has a heat loss of about 50,000 Btu per hour. The plant Industrial Engineer suggests that the pipe insulation be increased so that the heat loss would be only 5,000 Btu per hour. If this change is made, how many pounds per hour of steam does this EMO save?

8.7 Tastee Orange Juice Company has a large boiler that has a 450 ft^2 exposed surface that is at 225°F. This boiler discharges flue gas at 400°F, and has an exposed surface for the stack of 150 ft^2. Calculate the heat loss from the boiler for these two sources.

8.8 In Section 8.4.2 two methods were given to estimate the energy lost and cost of steam leaks. What is the relationship of the wisp, moderate leak, and severe leak as defined by Waterland to the hole sizes found from Equation 8-3 for 600 psig steam? In other words, find the hole sizes that correspond to the wisp, moderate leak and severe leak.

Questions

9.1 In the section on demand control, the discussion said that some loads must be recovered (i.e., run later) and some not. Give an example of a load that must be fully recovered, one that does not need any recovery, and one that may need partial recovery.

9.2 What uses of computers in energy management can you think of that are not discussed in this chapter?

9.3 You have just finished auditing a large supermarket that operates 16 hours per day. The supermarket has substantial glass exposure to the outside and substantial lighting for display purposes. Outside lights are used for parking and security. Forgetting any change of light sources, what control schemes would you recommend?

9.4 Someone once said that improperly maintained timers can cost more energy than they save. Section 9.2.2 discuss several examples of this problem. What other possibilities can you come up with?

9.5 Discuss examples of loads whose start-stop times can be optimized as in Figure 9-2(d).

Problems

9.1 Ugly Duckling Manufacturing Company has a series of 12 exhaust fans over its diagnostic laboratories. Presently, the fans run 24 hours per day, exhausting 600 cfm each. The fans are run by 2-hp motors with load factors of 0.8 and efficiencies of 80%. Assuming the plant operates 24 hours per day, 365 days/year in an area of 5000°F heating degree days and 2000°F cooling degree days per year, how much will be saved by duty-cycling the fans such that each is off 10 minutes/hour on a rotating basis? At any time, two fans are off and 10 are running. The plant pays \$.05/kWh and \$5.00/kW for its electricity and \$5.00/10^6 Btu for its gas. The heating plant efficiency is .80, and the cooling COP is 2.5. Assume that the company only approves EMO projects with a two year or less

simple payback period. How much will they be willing to spend for a control system to duty-cycle the fans?

9.2 Profits, Inc. has a present policy of leaving all of its office lights on for the cleaning crew at night. The plant closes at 6:00 pm and the cleaning crew works from 6:00 - 10:00 pm. After a careful analysis, the company finds it can turn off 1000 fluorescent lamps (40 W each) at closing time. The remaining 400 lamps leave enough light for the cleaning crew. Assuming the company works 5 days/week, 52 weeks/year, what is the savings for turning these lamps off an extra 4 hours/day? The company pays $.06/kWh and $6.00/kW for electricity. Peaking hours for demand are 1:00-3:00 pm. Assume there is one ballast for every two lamps and the ballast adds 15% to the load of the lamps. What type of control system would you recommend for turning off the 1000 lamps? (Manual or automatic? Timers? Other sensor?)

9.3 In problem 9.2, assume that the plant manager has checked on the lighting situation and discovered that the cleaning crew does not always remember to turn the remaining lights off when they leave. In the past year, the lights have been left on overnight (8 hours) an average of twice a month. One of the times the lights were left on over a weekend (56 hours). How much did it cost the company in extra charges not to have the lights on some kind of control system? What type of control system would you recommend and why?

9.4 Therms, Inc. has a large electric heat-treating furnace that takes considerable time to warm up. However, a careful analysis shows the furnace could be turned back from a normal temperature of 1800°F to 800°F, 20 hours/week and be heated back up in time for production. If the ambient temperature is 70°F, the composite R value of the walls and roof is 12, and the total surface area is 1000 ft^2, what is the savings in Btu for this setback? (Heat loss equations are given in Chapter 11.). How could this furnace setback be accomplished?

9.5 Obtain bin data for your region, and calculate the savings in Btu for a nighttime setback of 15°F from 65 to 50°F, 8 hours per day (midnight to 8:00 am).

9.6 Petro Treatments has its security lights on timers. The company figures an average operating time of 1 hour per day can be saved by using photocell controls. The company has 100 mercury vapor lamps of 1000 Watts each, and the lamp ballast increases the electric load by 15%. If the company pays $.06/kWh, what is the savings? Assume there is no demand savings. The photocell controls cost $10.00 apiece and each lamp must have its own photocell. It will cost the company an average of $15.00 per lamp to install the photocells. Determine the simple payback period for this EMO. Would you recommend it to the company?

9.7 CKT Manufacturing Company has an office area with a number of windows. The offices are presently lighted with 100 40-Watt fluorescent lamps. The lights are on about 3000 hours each year, and CKT pays $0.08 per kWh for electricity. After measuring the lighting levels throughout the office area for several months, you have determined that 70% of the lighting energy could be saved if the company installed a lighting system with photosensors and dimmable electronic ballasts and utilized daylighting whenever possible. The new lighting system using 32 Watt T-8 lamps and electronic ballasts together with the photosensors would cost about $2500. Would you recommend this change? Explain the basis for your answer.

CHAPTER TEN

Questions

10.1 What routine preventive maintenance tasks should be performed for a residential gas furnace? Do you think they are performed very often? If not, why not?

10.2 What criteria should be used in determining priorities of repair maintenance projects? How would you weight these criteria?

10.3 With two other people, walk through a church or some building with systems in need of repair, and list specific repair jobs. Then

make a list of criteria to be used in weighting these jobs, and weigh each job against each criterion. Then multiply the criteria weights by the job weights to get a weight for each job. Does the resulting ranking make sense? If not, find some way to improve this system.

10.4 What are the training needs and costs of maintenance personnel?

10.5 Why is safety training especially important for maintenance personnel?

Problems

10.1 In determining how often to change filters, an inclined tube manometer is installed across a filter. Conditions have been observed as follows:

Week	Manometer reading	Filter condition
1	.4 in water	Clean
2	.6	Clean
3	.7	A bit dirty
4	.8	A bit dirty
5	.8	A bit dirty
6-9	.9	Dirty
10-13	1.0	Dirty
14-18	1.1	Dirty
19-23	1.2	Very Dirty
24	1.3	Plugged up: changed

Based on this table, give a range of times for possible intervals for changing filters.

10.2 You have been keeping careful records on the amount of time taken to clean air filters in a large HVAC system. The time taken to clean 35 filter banks was an average of 18 min/filter bank and was calculated over several days with three different people-one fast, one slow, and one average. Additional time that must be taken into

account includes personal time of 20 minutes every 4 hours. Setup time was not included. Calculate the standard time for filter cleaning, assuming that fatigue and miscellaneous delay have been included in the observed times.

10.3 Your company has suffered from high employee turnover and production losses, both attributed to poor maintenance (the work area was uncomfortable, and machines also broke down). Eight people left last year, six of them probably because of employee comfort. You estimate training costs as $10,000/person. In addition, you had one 3-week problem that probably would have been a 1-week problem if it had been caught in time. Each week cost approximately $10,000. All these might have been prevented if you had a good maintenance staff. Assuming that each maintenance person costs $25,000 plus $15,000 in overhead per year, how many people could you have hired for the money you lost?

10.4 A recent analysis of your boiler showed that you have 15% excess combustion air. Discussion with the local gas company has revealed that you could use 5% combustion air if your controls were maintained better. This represents a calculated efficiency improvement of 2.3%. How large an annual gas bill is needed before adding a maintenance person for the boiler alone is justified if this person would cost $40,000/year?

10.5 Your steam distribution system is old and has many leaks. Presently, steam is being generated by a coal-fired boiler, and your coal bill for the boiler is $600,000/year. A careful energy audit estimated that you were losing 15% of the generated steam through leaks and that this could be reduced to 2%. What annual amount would this be worth, considering energy costs only?

10.6 Group relamping is a maintenance procedure recommended in Chapter Five. Using data from Chapter Five, construct a graph which plots maintenance costs per hour and relamping interval expressed as a percentage of the lamps rated life against the total relamping cost. Can you construct such a graph that will provide the answer to the question of whether group relamping is cost-effective for a particular company?

Questions

11.1 Give examples of heat transfer by radiation, conduction, and convection.

11.2 Infrared heaters heat by radiation. Why are they recommended for large open areas or areas with a lot of air infiltration?

11.3 Discuss whether insulation actually stops heat loss or only slows it down.

11.4 Demonstrate why the R value of a metal tank itself is usually ignored and the surface resistance Rs is used.

11.5 If it is necessary to calculate an effective insulation thickness for pipes, why isn't it necessary to do the same for cylindrical tanks?

11.6 Discuss why the concept of thermal equilibrium is important.

Problems

11.1 A metal tank made out of mild steel is 4 feet in diameter, 6 feet long, and holds water at 180°F. What is the heat loss per year in Btu? The tank holds hot water all the time and is on a stand so all sides are exposed to ambient conditions at 80°F. If the boiler supplying this hot water is 79% efficient and uses natural gas costing $\$5.00/10^6$ Btu, what is the cost of this heat loss? Assume there is no air movement around the tank.

11.2 Ace Manufacturing has an uninsulated condensate return tank holding pressurized condensate at 20 psig saturated. The tank is 2.5 feet in diameter and 4 feet long. Management is considering adding 2 inches of aluminum-jacketed fiberglass at an installed cost of $\$.60/ft^2$. The steam is generated by a boiler which is 78% efficient and consumes No. 2 fuel oil at $\$7.00/10^6$ Btu. Energy costs will remain constant over the economic life of the insulation of 5 years. Assume that the tank is on a stand, and that the facility MARR =

15%. Ambient temperature is 70°F. Use Rs = .42 for the uninsulated tank. The tank is utilized 8000 hours/year. Calculate the present worth of the proposed investment.

11.3 Your plant has 500 ft of uninsulated hot water lines carrying water at 180°F. The pipes are 4 inches in nominal diameter. You decide to insulate these with 2-inch calcium silicate snap-on insulation at $\$1.00/ft^2$ installed cost. What is the savings in dollars and Btu if the boiler supplying the hot water consumes natural gas at $\$6.00/10^6$ Btu and is 80 percent efficient? Ambient air is 80°F, and the lines are active 8760 hours/year.

11.4 Given a wall constructed as shown in Figure 11-6, what is the cost of heat loss and heat gain per ft^2 for a year? Heating degree days are 4000°F days, while cooling degree days are 2000°F days. Heating is by gas with a unit efficiency of .7. Gas costs $\$6.00/10^6$ Btu. Cooling is by electricity at \$.06/kWh (ignore demand costs), and the cooling plant has a 2.5 seasonal COP.

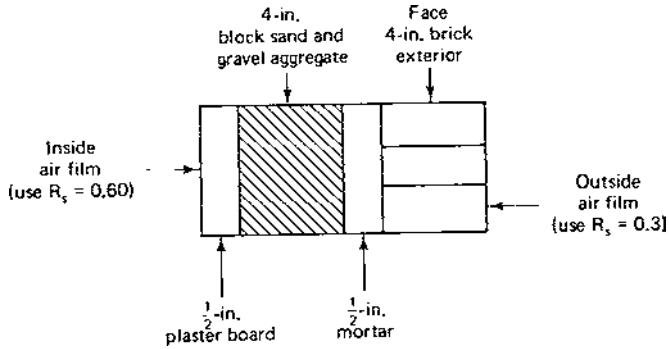


Figure 11-6

11.5 A 6-inch pipe carries chilled water at 40°F in an atmosphere with a temperature of 90°F and a dew point of 85°F. How much fiberglass insulation with a Kraft paper jacket is necessary to prevent condensation on the pipes?

11.6 A building consists of four walls that are each 8 feet high and 20 feet long. The wall is constructed of 4 inches of corkboard, with 1 inch of plaster on the outside and 1/2 inch of gypsum board on the

inside. Three of the walls have 6×4 foot, single-pane windows with R = 0.7. The fourth wall has a 6×4 window and a 3×7 foot door made out of one inch thick softwood. The roof is constructed of 3/4 inch plywood with asphalt roll roofing over it. What is the R value of one of the walls with just a window? What is the R value of the wall with the window and the door? What is the R value of the roof? If the inside temperature of the building is regulated to 78 degrees F by an air conditioner operating with a thermostat. The air conditioner has an SEER = 8.0. If the outside temperature is 95 degrees F for one hour, how many Btus must that air conditioner remove in order to keep the inside temperature at 78 degrees F? How many kWh of electric energy will be used in that one hour period by the air conditioner?

11.7 Repeat Problem 11.6 with the single-pane windows replaced with double-paned windows having an R value of 1.1.

11.8 While performing an energy audit at Ace Manufacturing Company you find that their boiler has an end cap of mild steel that is not insulated. The end cap is six feet in diameter and two feet long. You measure the temperature of the end cap as 250°F. If the temperature in the boiler room averages 90°F, the boiler is used 8760 hours per year, and fuel for the boiler is $6.00 per million Btu, how many dollars per year can be saved by insulating the end cap? What kind of insulation would you select? If that insulation cost $300 to install, what is the simple payback period for this EMO? Assume the boiler efficiency is 80%.

11.9 Assume the tank in problem 11.1 is a hot water tank that is heated with an electrical resistance element. If this were a hot water tank for a residence, it would probably come with an insulation level of R-5. A friend says that the way to save money on hot water heating is to put a timer or switch on the tank, and to turn it off when it is not being used. Another friend says that the best thing to do is to put another layer of insulation on the tank and not turn it off and on. What is the most cost effective solution? Assume that there are four of you in the residence, and that you use an average of 20 gallons of hot water each per day. Assume that you set the water temperature in the tank to 140 degrees F, and that the water coming

into the tank is 70 degrees F. You have talked to an electrician, and she says that she will install a timer on your hot water heater for $50, or she will install an R-19 water heater jacket around your present water heater for $25. Assume that the timer can result in saving three-fourths of the energy lost from the water heater when it is not being used. If electric energy costs $.08 per kWh, what is the most cost effective choice to make between these two alternatives?

CHAPTER TWELVE

Questions

12.1 Give an example of how the design of the layout of a manufacturing operation could influence the energy consumed by the facility.

12.2 Flagging Industries has a purchasing manager who says it is always cheaper to have a motor rewound than to buy a new one. How would you convince the purchasing manager that this is not always the best decision for the company?

12.3 JumpStart Manufacturing Company has a production line that is mechanized, and the drive motors are manually switched off and on to control the speed of the line. Motors and drives usually last about six months. Can you think of a process improvement for this operation?

12.4 Tiger City Bakeries has a large oven whose excess heat is presently being vented outside. What uses for this waste heat can you think of for the bakery?

12.5 Reducing waste streams often has a benefit of improved process energy efficiency. Give at least one example of a waste stream in a manufacturing plant that could be reduced or eliminated, and would have an energy efficiency benefit.

Problems

12.1 Florida Electric Company offers financial incentives for large customers to replace their old electric motors with new, high efficiency

motors. Crown Jewels Corporation, a large customer of FEC, has a 20-year-old 100-hp motor that they think is on its last legs, and they are considering replacing it. The motor has a load factor of 0.6. Their old motor is 91% efficient, and the new motor would be 95% efficient. FEC offers two different choices for incentives: either a $6/hp (for the size motor considered) incentive or a $150/kW (kW saved) incentive. If Crown Jewels buys the new motor, which one of these incentives should they ask for?

12.2 During an energy audit at Orange and Blue Plastics Company you saw a 100-hp electric motor that had the following information on the nameplate: 460 volts; 114 amps; three phase; 95% efficient. What is the power factor of this motor? (Hint-See Eq. 6-11 in Chapter Six)

12.3 Ruff Metal Company has just experienced the failure of a 20-hp motor on a waste-water pump that runs about 3000 hours a year. Using the data in Table 12-1, determine whether Ruff should purchase the high efficiency model or the standard model motor. Find the SPP, ROI and B/C ratio, assuming the new motor will last for 15 years, and the company's investment rate is 15%. The demand charge is $7.00 per kW per month, and the energy charge is $0.05 per kWh.

12.4 A rule of thumb for an air compressor is that only 10% of the energy the air compressor uses is transferred into the compressed air. The remaining 90% becomes waste heat. If you have seen a 50-hp air compressor on an audit of a facility, but you do not have any measurements of air flow rates or temperatures, how would you estimate the amount of waste heat that could be recovered for use in heating wash water for metal parts? Assume the efficiency of the motor is 91.5%.

12.5 Orange and Blue Plastics has a 150-hp fire pump that must be tested each month to insure its availability for emergency use. The motor is 93% efficient, and must be run for 30 minutes to check its operation. The facility pays $7.00/kW for its demand charge and $.05/kWh for energy. During your energy audit visit to Orange and Blue, you were told that they check out the fire pump during the day (which is their peak time), once a month. You suggest that they pay one of the maintenance persons an extra $50 a month to

come in one evening a month to start up the fire pump and run it for 30 minutes. How much would this save Orange and Blue Plastics on their annual electric costs?

12.6 Our "rules of thumb" for the load of a motor and air conditioner have implicit assumptions on their efficiencies. What is the implied efficiency of a motor if we say its load is 1 kW per hp? What is the implied COP of an air conditioner that has a load of 1 kW per ton?

12.7 During an audit trip to a wood products company, you note that they have a 50-hp motor driving the dust collection system. You are told that the motor is not a high efficiency model, and that it is only 10 years old. The dust collection system operates about 6000 hours each year. Even though the motor is expected to last another five years, you think that the company might be better off replacing the motor with a new high-efficiency model. Provide an analysis to show whether this is a cost-effective suggestion.

CHAPTER THIRTEEN

Questions

13.1 What is a selective surface? How and why does it affect the efficiency of a solar collector?

13.2 Why would phase change materials be popular for thermal storage in solar applications where space is limited?

13.3 Describe the refuse stream of a typical university. State its probable Btu content.

13.4 What renewable energy source is most popular today? Why?

13.5 Discuss some hindrances facing wider-spread utilization of solar energy in industry.

13.6 Is water in short supply in your area? What measures are being taken to insure the adequacy of the water supply?

Problems

13.1 In designing a solar thermal system for space heating, it is determined that water will be used as a storage medium. If the water temperature can vary from 80°F up to 140°F, how many gallons of water would be required to store 1×10^6 Btu?

13.2 In designing a system for photovoltaics, cells producing 0.5 volts and 1 ampere are to be used. The need is for a small dc water pump drawing 12 volts and 3 amperes. Design the necessary array but neglect any voltage-regulating or storage devices.

13.3 A once-through water cooling system exists for a 100-hp air compressor. The flow rate is 3 gal/min . Water enters the compressor at 65°F and leaves at 105°F. If water and sewage cost $\$1.50/10^3$ gallons and energy costs $\$5.00/10^6$ Btu, calculate the annual water savings (gallons and dollars) and annual energy savings (10^6 Btu and dollars) if the water could be used as boiler makeup water. Assume the water cools to 90°F before it can be used and flows 8760 hours/year. Assume a boiler efficiency of 70%.

13.4 A large furniture plant develops 10 tons of sawdust (6000 Btu/ton) per day that is presently hauled to the landfill for disposal at a cost of $10/ton. The sawdust could be burned in a boiler to develop steam for plant use. The steam is presently supplied by a natural gas boiler operating at 78% efficiency. Natural gas costs $\$5.00/10^6$ Btu . Sawdust handling and in-process storage costs for the proposed system would be $3.00/ton. Maintenance of the equipment will cost an estimated $10,000/year. What is the net annual savings if the sawdust is burned? The plant operates 250 days/year.

13.5 Design an energy-efficient facility (location on site, layout, building envelope, etc.) for an existing factory whose operation is familiar to you. Do not be constrained by the existing facility.

13.6 At 40°N latitude, how many square feet of solar collectors would be required to produce each month the energy content of a) one barrel of crude oil? b) one ton of coal? c) one therm of natural gas? Assume a 70% efficiency of the solar heating system.

13.7 Using Table 13.1, determine whether Portland, OR, New Orleans, LA, or Boston, MA have the greatest amount of solar energy per square foot of collector surface? Assume each collector is mounted at the optimum tilt angle for that location.

13.8 A family car typically consumes about 70 million Btu per year in fuel. How many gallons of gasoline is this? Using the maximum Btu contents shown in Table 13-15, how many pounds of corn cobs would it take to equal the Btus needed to run the car for one year? How many pounds of rice hulls? Of dirty solvents?

13.9 Determine the power outputs in Watts per square foot for a good wind site and an outstanding wind site as defined in Section 13.5.

13.10 How much difference—in percent—is there between these two sites?