Subcontractor Report

**Energy Management
Curriculum Starter Kit**

N. L. Moore, Project Manager

February 1987

**Prepared by W. C. Turner, Consultant,
for Pacific Northwest Laboratory
under Contract DE-AC06-76RLO 1830
with the U.S. Department of Energy**

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ENERGY MANAGEMENT CURRICULUM STARTER KIT

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February 1987

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for Pacific Northwest Laboratory
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the U.S. Department of Energy

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PREFACE

The Energy Management Curriculum Starter Kit was designed to help engineering educators develop and teach energy management courses. Montana State University and Oklahoma State University courses are embodied in the model curriculum given. The curricula offered at many other universities throughout the United States are also presented.

The kit was designed specifically to train engineering students to be good energy managers. Courses at both the undergraduate and postgraduate level are presented. It is hoped that professors reading this text can use this kit to design new courses. Most professors will probably start close to this model and deviate more as experience is gained.

We sincerely hope that this kit helps in the teaching of these badly needed courses. Suggestions to improve this kit are welcome and will be examined sincerely. Alternative course outlines or other suggestions will be made available by W. C. Turner as long as feasible. Inquiries or suggestions may be addressed to:

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SUMMARY

The Energy Management Curriculum Starter Kit was developed as a cooperative effort by Montana State University, Oklahoma State University, the United States Department of Energy, and Pacific Northwest Laboratory. This research first surveyed a set of existing courses and potential textbooks. Then course syllabi for an undergraduate and a graduate course in energy management were developed. The laboratory exercises were developed as a valuable part of the study; "hands-on" laboratory experience is badly needed in energy management education. An annotated bibliography of the potential textbooks was also developed.

The undergraduate model course was designed for engineering students in their junior or senior year and will require a sound engineering science basis. The graduate level class was designed to be presented at the Masters level, and the undergraduate course would be required as a prerequisite.

In addition to the model course, syllabi from numerous engineering colleges are shown. Programs at the associate-, undergraduate-, and graduate level are represented.

The researchers recommend a follow-up study in a few years to assess the maturing of energy management education and revising of the model courses. A forum for energy management educators might be needed at that time.

ACKNOWLEDGMENTS

This project could not have been completed without the help of the United States Department of Energy and Pacific Northwest Laboratory. Energy management owes them a word of thanks. Special thanks to Mr. Nick Knight, a graduate student at Montana State University.

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ENERGY MANAGEMENT CURRICULUM STARTER KIT

Course syllabi were developed for two courses in energy management. The first is an undergraduate course for the junior or senior year of an engineering study plan. The second is for a graduate-level engineering course. Also presented are several laboratory exercises for the first course and sample test questions for both. Finally, sample course materials used in various engineering colleges throughout the country are presented.

INTRODUCTION

The Energy Management Curriculum Starter Kit was developed as a cooperative effort by Montana State University, Oklahoma State University, the United States Department of Energy, and Pacific Northwest Laboratory.^(a)

This kit is designed to help engineering educators develop and teach energy management courses. Educators may completely adhere to the model, or they may vary significantly from it depending upon their personal preferences. The following materials are included in this kit:

- a model curriculum for a junior- or senior-level course with accompanying laboratories - Course objectives and a list of potential textbooks are included.
- a model curriculum for a graduate-level course - This course is designed to be more flexible than the undergraduate course.
- sample test questions that can be used with the course - The test questions are drawn from material at both the undergraduate and the graduate levels.
- an annotated bibliography of potential textbooks
- course outlines from numerous universities, including the texts used in these programs, if provided

(a) Operated by Battelle Memorial Institute for the Department of Energy under Contract DE-AC06-76RLO 1830.

- continuing education courses or adult education programs in the energy management field.

DEVELOPMENT OF THIS KIT

Two types of energy management course are found in colleges across the United States. Policy-oriented courses examine the global energy picture and a country's response. This type of course primarily concentrates on macro economics and large-scale systems modeling.

The second type trains the engineering student to be a good energy manager for organizations that must use energy to accomplish objectives. This energy manager can expect to deal with site-specific management and must employ engineering techniques for optimal energy use. A solid background in rate selection, fuel choice, waste heat recovery, demand leveling, employee motivation, and a host of other techniques is required. The courses described in this kit were designed to fill this need.

USING THE MODEL COURSES

Users of this starter kit will probably examine the Model Energy Management and Advanced Energy Management Course syllabi, then obtain copies of the potential texts. Once a primary text for the class has been chosen, instructors may use the other potential texts and listed references to strengthen specific weaknesses in their chosen text.

The course outlines shown here may be used as references for suggestions. The sequence is quite flexible and may be easily modified. Several laboratories are suggested to help the budding energy manager become familiar with the assorted equipment at his disposal and to gain firsthand experience in the occurrence of various phenomena, e.g., power factor.

Test questions from a variety of areas are listed. Questions are drawn from both the undergraduate and the graduate level.

OTHER COURSE CURRICULA

Numerous colleges and universities have shared their energy course curricula. By studying courses available in a variety of areas, engineering educators may develop a more complete program. Both undergraduate- and graduate-level courses are represented. Prerequisites are shown if they were provided by participating universities.

CONTINUING EDUCATION PROGRAMS

Several colleges have recognized the necessity for continuing education in the field of energy management. These adult programs are designed for 1) the licensed professional wanting to expand his knowledge and 2) the high school graduate training for entry-level positions in firms requiring a knowledge of the energy field. Both types of programs are represented in this kit.

MODEL ENERGY MANAGEMENT COURSE

The following outline is a possible design for a junior- to senior-level course requiring a good engineering science basis. Forty-five class periods are dedicated to the course with a laboratory exercise approximately every fourth period. If no laboratory is used or if only a few sessions are used, the material can be expanded to cover more areas or more depth in each subject.

Catalog Description

Energy Management is a study of the objectives, design, implementation, and supervision of energy management programs. The scope includes energy conservation, choice of energy sources, safety and security of fuel storage, and contingency planning with emphasis on improving profits (reducing costs) through optimal energy management. Outside speakers and field trips may be utilized. Students must have completed the following prerequisites: engineering calculus, heat transfer, and engineering economy.

Objectives

At the conclusion of the course, the student should:

- understand the basic energy situation and present and future problems
- understand the profit improvement (cost reduction) potential of energy management
- possess the necessary talents to design, implement, operate, and manage successful energy management programs.

Method of Instruction

The course is presented primarily in a lecture format with some laboratory exposure. Field trips may be utilized. Several texts are recommended, but the choice of a primary text is the instructor's prerogative. Table 1 gives one possible grading system for the course.

The Case Study is an energy management study for an industry, office building, store, church or other building or an in-depth probe into an appropriate subject. The subject must be approved.

TABLE 1. Energy Management Course--Grading System

Two Tests @ 20% each	40%
Final Exam	25%
Case Study or Research Paper	20%
Homework and Special Assignments	<u>15%</u>
	100%

The Case Study should be a complete analysis (audit of the energy profile with economic analysis and specific proposals for profit improvement). Students will work in teams of two. Table 2 suggests a point system to be used in evaluating the case study.

TABLE 2. Suggested Grading Emphasis for Case Study

<u>Grading Categories</u>	
Relations With Company	15 pts.
Depth and Quality	45 pts.
Report Structure	20 pts.
Grammar, Spelling	<u>20 pts.</u>
	100 pts.

Research papers must be approved before submission. The student should thoroughly examine a topic that pushes the frontiers of knowledge concerning that subject. Students might examine cogeneration potential for small industries, or they could look at industrial uses of solar energy. Table 3 shows the point system suggested for the research paper.

TABLE 3. Suggested Grading Emphasis for Term Paper

<u>Grading Categories</u>	<u>Points</u>
Choice of Subject	10
Originality	10
Depth and Quality	40
References	10
Report Structure	15
Grammar, Spelling	<u>15</u>
Total	100

A complete outline of the undergraduate energy management course appears in Table 4. Laboratories are recommended at intervals throughout the course. A key to references is shown at the bottom of the table.

TABLE 4. Energy Management Course Outline

Period	Topic	Ref. # - Page
1	Introduction To Course, Overview of Material	Syllabus
2	Today's Energy Situation - the global and national energy picture and predictions for the future	1-3, 2-1, 3-1, 4-6, 6-5, 8-1
3 to 4	Initiating, Organizing, and Managing Energy (EM) Management Programs. How to design an EM organization and start it properly. How to monitor it.	1-7, 2-82, 5-2, 6-395, 7-3, 8-7
4 to 5	Energy Auditing - The role of the energy auditor. Specific areas of concern and necessary equipment. Auditing checklists.	1-29, 2-86, 3-359, 4-22, 5-7, 6-51, 7-4, 8-25
6	Utility Bills - How energy is billed. How to read rate schedules. Calculating and checking bills.	1-67, 2-16, 3-249, 5-33, 6-104, 7-64, 8-678
7	Laboratory 1 - Auditing, Utility Rate Schedules	See Laboratories Section
8, 9, 10	Lighting - How to measure light levels. Advantages and disadvantages of different light sources. Energy efficiency. Design of light systems.	1-90, 2-172, 3-212, 5-172, 6-91, 7-82, 8-399, 9-100
11	Laboratory 2 - Lighting Systems	See Laboratories Section
12, 13, 14	Insulation - The importance of insulation. Calculation of heat loss and gain. Economics of heat loss and gain. Types of insulation.	1-204, 2-362, 3-90, 5-83, 6-392, 7-192, 8-459
15	Laboratory 3 - Insulation Laboratory	See Laboratories Section
16, 17, 18	Electrical Energy Management - Reducing energy costs. Energy management control systems, motors, and power factor improvements, etc.	1-141, 2-269, 3-250, 5-170, 6-80, 7-89, 8-322, 9-3
20	Laboratory 4 - Electricity	See Laboratories Section
19, 20, 21	Heating, Ventilation, and Air Conditioning - Brief introduction to the different types of HVAC equipment. Economics, economizers, night setback, and duty cycling	1-109, 2-352, 3-166, 5-128, 6-237, 8-303, 9-83
22	Laboratory 5 - HVAC - Velometer, Economizer	See Laboratory Section
23, 24, 25	Building Envelope - What can be done in the envelope itself? Building insulation, energy-efficient glass, passive solar planning, infiltration, new facility design.	3-85, 5-129, 6-218, 8-269

TABLE 4. (contd)

Period	Topic	Ref. # - Page
26	Laboratory 6 - Facility Design	1-257
27, 28, 29	Waste Heat Recovery - What is waste heat? Methods of waste heat recovery. Economics of waste heat recovery. Practical considerations.	1-163, 2-178, 3-38, 4-132, 5-165, 6-113, 7-106, 8-115
30	Laboratory 7 - Waste Heat Recovery Laboratory	See Laboratories Section
31, 32, 33	Boilers and Fired System - Chemistry of combustion, heat losses, reducing heat losses, insulation, excess air control, boiler blowdown, economizers, recuperators.	1-138, 2-165, 3-148, 5-97, 6-183, 7-58, 8-10
34	Laboratory 8 - Boiler and Fired Systems Laboratory	See Laboratories Section
35 to 40	Steam-Condensate. Layout of a typical steam system. Economics of insulation, flash steam recovery, steam traps and monitoring, and condensate return	1-170, 2-306, 3-112, 5-113, 6-153, 7-96, 8-164
41 to 45	Actually scattered through the course - guest speakers, plant tours, tests, and review sessions.	

REFERENCES

All references are keyed to numbers in this list.

Ref.

1. Kennedy, W. J., Jr., and W. C. Turner. 1984. Energy Management. Prentice-Hall, Englewood Cliffs, New Jersey.
2. Lawrence, K., A. McRae and S. Alley. 1980. Energy Conservation. Aspen Systems Co.
3. Mahon, H. P., M. G. Kiss and H. J. Leimer. 1983. Efficient Energy Management. Prentice-Hall.
4. O'Callaghan, P. W. 1981. Design and Management for Energy Conservation. Pergamon Press, Oxford-New York.
5. Payne, G. A. 1984. Managing Energy. Butterworth & Co., London.
6. Thumann, G. A. 1984. Fundamentals of Energy Engineering. Fairmont Press.
7. Thumann, G. A. 1983. Plant Engineers and Managers Guide to Energy Conservation. D. Van Nostrand Reinhold Co., New York.
8. Turner, W. C., et al. 1982. Energy Management Handbook. John Wiley & Sons, New York.
9. Zackrisson, H. B., Jr. 1984. Energy Conservation Techniques for Engineers. Van Nostrand Reinhold Co.

ENERGY MANAGEMENT LABORATORIES

The laboratories described in this section provide students the opportunity to gain firsthand experience with both the equipment at their disposal and the various techniques used by energy managers. These laboratories were written to accompany the undergraduate energy management course.

LABORATORY 1

Three laboratories are presented in this section that may be used individually or combined.

Energy Auditing

The objective of this laboratory is to instruct students in the "art" of energy auditing and methods used in conducting an audit. A sample energy audit report and energy audit equipment are needed for this laboratory. The reasons for conducting audits, step-by-step procedures, auditing techniques, sample reports, and typical auditing equipment are covered in this laboratory.

Discussion

The instructor will probably wish to use a format similar to the outline given below.

1. Discuss the reasons for conducting an energy audit. The rationale might include:
 - accounting for all energy users within a plant
 - gaining knowledge about plant processes
 - locating possible savings opportunities.
2. Discuss example standard operating procedures for conducting an energy audit. One example might be as follows:
 - meet with plant personnel
 - conduct a brief tour of plant
 - hold a short meeting to discuss initial observations
 - take measurements needed (e.g., temperature, light levels)
 - plan another short team meeting

- Discuss findings with plant personnel
 - prepare a formal report during the next few weeks.
3. Discuss auditing techniques. The auditing techniques emphasized in this laboratory might include a physical inspection of the plant and personnel interviews. During the physical inspection, the energy auditor would "touch, listen and look" and take instrument readings. When giving personnel interviews, the energy auditor might
- speak with maintenance crews
 - speak with technicians
 - speak with management personnel
 - watch for consistent answers from the various groups. Perhaps management and maintenance disagree on how long the lights are on daily.
4. Discuss example report formats and show a sample report. The format might include the following sections, for example:
- a description of plant
 - the main energy users
 - an outline of energy saving opportunities
 - the calculations for each saving opportunity
 - a summary of total savings opportunities.

Show typical auditing equipment and discuss each. Examples might include digital thermometers, velometers, tape measures, or flash lights.

References (See Reference List)

Kennedy and Turner 1984, p. 29
Lawrence, McRae and Alley 1980, p. 86
Mahon, Kiss and Leimer 1983, pp. 60, 65, 359
O'Callaghan 1981, pp. 22, 117, 211
Payne 1984, pp. 7 to 16

Thumann 1983, p. 4

Thumann 1984, p. 51

Turner et al. 1982, pp. 24 to 71.

An audit tape has been developed by The American Consulting Engineering Council. This tape is highly recommended for a laboratory-type "audit." Contact:

Mr. Alex Willman

ACEC Research

1015 15 St. N.W.

Suite 802

Washington, DC 20005.

Electric Rate Schedules

The objective of this laboratory is to familiarize students with the complexities of utility rate structures in their home state and in other states. The materials necessary for this laboratory are rate schedules and sample electric profiles.

Discussion

The instructor should cover the material listed below.

1. Discuss the purpose of various rate schedules. The discussion should focus on the necessity for various types.
2. Discuss the following types of rate schedules:
 - a. residential
 - b. commercial
 - c. industrial
 - d. experimental (standby, buy back, interruptable).
3. Discuss kilowatt-hour (kWh) and its measurement.
4. Discuss how utilities charge for kWh. Discuss declining rates based on usage.
5. Discuss how and why utilities bill for peak demand. Ratchet clauses, actual demand and billed demand should be covered.

6. Discuss power factor and how it is measured. Discuss how and why utilities bill for power factor.
7. Discuss the fuel adjustment factor.
8. Show students examples of how a total bill would be calculated for the same business on various rate schedules.
9. Give students hypothetical electric usage profiles and have them calculate the total bill based on different rate schedules. Have them compare the total costs for the different rate schedules.

References

- Kennedy and Turner 1984, p. 67
Lawrence, McRae and Alley, p. 16
Mahon, Kiss, and Leimer 1983, p. 249
Payne 1984, p. 33
Thumann 1983, p. 64
Thumann 1984, p. 104
Turner 1982, p. 678.

Water and Natural Gas Rate Schedules

The objective of this laboratory is to familiarize students with the methods utilities use to bill residential, commercial, and industrial water and natural gas customers. Students will work with actual water and natural gas consumptions.

Discussion

The discussion will center on measuring consumption and the calculation of costs for both natural gas and water.

Natural Gas

1. Discuss units of measurement for natural gas consumption - this is usually determined in thousands of cubic feet (mcf).
2. Discuss the cost of natural gas.

Water

1. Discuss the units of measurement for water consumption - this is usually determined in thousands of gallons.
2. Discuss the cost of water.
3. Discuss sewer costs and how they are calculated by the utilities. Sometimes sewer costs are based on water consumption. Discuss how excessive bills can result if much of the water consumed is not returned through the sewer but stays with the product or is evaporated.

Activity

Give students actual consumptions and have them calculate actual bills. Include taxes and other costs.

References (See Reference List)

- Kennedy and Turner 1984, p. 67
Lawrence, McRae and Alley 1980, p. 16
Mahon, Kiss and Leimer 1983, p. 249
Payne 1984, p. 33
Thumann 1983, p. 64
Thumann 1984, p. 104
Turner 1982, p. 678.

LABORATORY 2 - LIGHTING

This laboratory would appropriately follow lectures dealing with such topics as measurement of light sources, advantages of different types of sources, and energy-efficient lighting systems. The objective of this laboratory is to give students firsthand experience in recognizing various lighting types and characteristics. The equipment needed for this laboratory includes a variety of light sources, color charts, and power consumption charts.

Discussion

1. Show examples of various light sources. High pressure sodium (HPS) and mercury vapor are good examples.
2. Discuss the applications of the various types of lights. Discuss light quality, energy consumption and color determination.
3. Darken the room and turn on one of the light types. Point out the color characteristics and luminosity.
4. Discuss the economics of converting from one light source to another more efficient light source. Areas to be covered here might include power savings, fixture costs, bulb costs and bulb life.
5. Discuss the basics in lighting design, e.g., coverage area, lumen rating, mounting and height.
6. Have the students locate a specific lighting system on campus and suggest a more practical and efficient light source.

References (See Reference List)

Kennedy and Turner 1984, pp. 90 to 109
Lawrence, McRae and Alley 1980, pp. 172, 343, 351
Mahon, Kiss and Leimer 1983, pp. 212 to 249
Payne 1984, pp. 172 to 178
Thumann 1983, p. 82
Thumann 1984, p. 91
Turner et al. 1982, pp. 399 to 417
Zackrison 1984, pp. 100 to 267.

LABORATORY 3 - INSULATION

The objective of this laboratory is to familiarize students with various types of insulation and to discuss their applications. The laboratory also provides an opportunity for students to review basic heat flow equations and their applications to insulation. The only materials needed to present this laboratory are various samples of insulation material.

Discussion

1. Review basic heat flow equations. Cover surface resistance and insulation resistance. Discuss the units involved with the thermal resistance and conductance. Discuss equivalent thickness for pipe insulation.
2. Show example equations involving various composite cross sections. Give examples of different materials, thicknesses and temperatures. Show pipe insulation examples.
3. Discuss the various types of insulations, their properties and applications.
4. Give students example problems with various goals in mind. An example is listed here.

Given the inside and outside temperatures and a stainless steel surface with no insulations, calculate heat loss per hour.

Given the surface temperature and the ambient temperature, select an insulation type and thickness to give a desired surface temperature. (Personnel Protection)

5. Discuss the law of diminishing returns as it applies to the thickness of insulation applied. Give students an opportunity to explore the economic aspects of insulation.

References

- Kennedy and Turner 1985, p. 204
Lawrence, McRae and Alley, p. 362
Mahon, Kiss and Leimer 1983, p. 90
Payne 1984, p. 83
Thumann 1983, p. 192
Thumann 1984, p. 392
Turner et al. 1982, p. 459.

LABORATORY 4 - ELECTRICAL ENERGY MANAGEMENT

During this laboratory, students will have an opportunity to explore wise energy management in a specific building or plant. Students will become familiar with the equipment used to measure electrical quantities. Peak times are also discussed.

The objective of this laboratory is to introduce students to the basics of electrical energy management. A volt meter, amp meter, watt meter, demand meter, and a kilowatt-hour meter are needed for this laboratory. To obtain this equipment, contact the electrical engineering department of a college or a local electric utility.

Discussion

1. Introduce basic electrical terminology:
volts, amps, watts, volt-amps, volt-amps-reactive (VAR), power factor (pf), capacitance, inductance, alternating current, peak demand, kilowatt-hours
2. Show students examples of the various instruments used to measure electrical quantities. Volt meters, amp meters, watt meters, VAR meters, and demand meters are suggested.
3. Demonstrate how the various instruments work. A test may be set up, or the students might visit an electrical engineering laboratory.
4. Show the class examples of a plant's demand profiles. Discuss the types of loads that make up the daily peaks or the seasonal peaks. Discuss the impact of ratchet clauses and how ratchet penalties can be reduced.
5. Show how the daily demand can be cut, and discuss how the plant's load profile would change. Show students how rescheduling operations, reducing lighting demands during peak hours, and duty cycle air handling units may be useful in decreasing the daily demand. "Before and after" load profiles might be used for illustration.

6. Discuss the importance of reducing demand during the "peak times." A question for students to consider is given below.

Question: Will reducing the bulb wattage in existing light fixtures reduce the peak demand?

Answer: Only if the lights are on during the time of peak demand.

7. Have students work various electrical problems. A sample problem is listed here.

- Calculate the annual cost of running a motor.
- Calculate the kVAR needed to correct the power factor.

References

- Kennedy and Turner 1984, p. 41
Mahon, Kiss and Leimer 1983, p. 250
Payne 1984, pp. 170-183
Thumann 1984, p. 80
Turner et al. 1982, pp. 322 to 355, 659 to 672
Zackrison 1984, pp. 1 to 40, 73, 268

LABORATORY 5 - HEATING, VENTILATION, AND AIR CONDITIONING

Students will focus on the various methods for improving the heating/cooling loads on a given building.

The major objective of this laboratory is to discuss the costs associated with heating, ventilating, and air conditioning buildings. A velometer, a thermometer, and diagrams of HVAC configurations will be needed in the presentation of this workshop.

Discussion

1. Show examples of heating and air conditioning load profiles for a year. Include both electric and natural gas heating.
2. Discuss methods of calculating the heat load of a building. Compare degree day, bin data, and other methods.

3. Discuss the various building types and how internal heat affects the amount of heating and air conditioning needed. Examples of internal heat might include lighting, human body heat, the heat generated by compressors, and the heat generated by machines.
4. Discuss how outside temperatures affect building heating and air conditioning. It is important for students to understand that some buildings must be air conditioned even when it is freezing outside.
5. Discuss the effects of solar heating on building heating and air conditioning.
6. Discuss building envelopes and why a poor building envelope will cause losses.
7. Discuss methods of reducing building heating and air conditioning costs. Instructors will probably want to include night setback and the use of timers, economizers, and enthalpy controls.
8. Show pictures of various types of HVAC configurations; these are extremely important. Discuss the strengths and weaknesses of each. Discuss economizers.
9. Teach students how to use velometer readings to calculate infiltration losses.
10. Have the students divide into groups. Each group will prepare a mini-report with suggestions for improving the heating/cooling load on a given building.

References

- Kennedy and Turner 1984, pp. 109 to 125
Lawrence, McRae and Alley 1980, pp. 353 to 355
Mahon, Kiss and Leimer 1983, pp. 36 to 59, 126 to 211
D'Callaghan 1981, pp. 128 to 130
Payne 1984, pp. 237 to 239
Turner et al. 1982, pp. 303 to 321
Zackrison 1984, pp. 9, 73 to 78.

LABORATORY 6 - FACILITY DESIGN, LOCATION, AND LAYOUT

This laboratory was designed primarily to foster a greater understanding of the manner in which building locations and design affect energy management.

The objective of this laboratory is to familiarize students with the importance of facility design, location, and layout in energy management. To present this laboratory, you will need pictures or slides of well-designed buildings.

Discussion

1. Discuss the elements that should be considered in the location of a plant. The following items might be considered:

Is the plant near transportation facilities?

Is the plant located away from windy areas?

Are natural windbreaks and sun screens located nearby?

Is there an abundant supply of natural resources, e.g., water or fuel?

2. Discuss the design of the facility. Numerous items will impact the building design. Among these are the following areas:

- sun load
- air infiltration
- outside vegetation or lack of it
- overhangs
- parking.

In this discussion, it might be wise to also show students why it is more effective to design than to retrofit after construction. The instructor should also cover the following areas:

- the location of windows, doors, and insulations
- HVAC, air compressors, waste heat recovery
- material handling and warehousing concerns.

Have students design a specific type of building using energy-efficient construction considerations. Have each student explain the design.

References

"Facilities Planning and Design for Energy, Water, and Hazardous Waste Management," Proceedings AIIE Annual Conference, Dallas, Texas, May 1986

Kennedy and Turner 1984, p. 256

Lawrence, McRae and Alley, p. 127.

LABORATORY 7 - WASTE HEAT RECOVERY

This laboratory focuses on the generation of waste heat and ways that the energy manager can utilize waste heat recovery. The laboratory also covers some of the problems encountered in waste heat recovery.

The primary objective of this laboratory is to discuss various methods used in waste heat recovery. Students should become aware that energy and money can be saved through this utilization.

Discussion

1. Show examples of the various types of heat exchangers, and discuss their use. Examples might include gas-to-liquid exchange or air-to-air exchangers.
2. Discuss specific instances where waste heat might be recovered and how the heat could be used.
3. Discuss the equations involved with calculating the recoverable heat and the size of the heat exchanger.
4. Discuss the recovery of exhaust heat to utilize as process heat.
5. Discuss the economics of heat recovery.
6. Discuss the problems encountered in waste heat recovery. One example is the condensation of stack gases.
7. Describe a hypothetical plant. Have students give suggestions for waste heat recovery.

References

- Kennedy and Turner 1984, p. 163
Lawrence, McRae and Alley 1980, p. 178
Mahon, Kiss and Leimer 1983, p. 38
O'Callaghan 1981, p. 132
Payne 1984, p. 165
Thumann 1983, p. 106
Thumann 1984, p. 113
Turner et al. 1982, p. 115.

LABORATORY 8 - BOILERS

This laboratory will allow an in-depth discussion of the various types of boilers and their efficient operation. The laboratory is most effective if students can tour a local physical plant for practical experience in this area. The primary objective is to cover the energy-saving opportunities concerned with boilers.

Discussion

1. Discuss the various types of boilers, e.g., fire in tube, water in tube. Show pictures. Take a short tour so that students can see boilers in operation.
2. Discuss various types of fuel used. Coal, natural gas, and fuel oil are common examples.
3. Discuss single-pass and multiple-pass boilers.
4. Discuss economizers and recuperators and their applications.
5. Discuss boiler efficiency and factors that affect boiler efficiency such as feedwater solids.
6. Discuss how excess air affects stack heat losses.
7. Discuss flue gas analysis. Show the equipment used and the equations that apply.
8. Discuss savings in minimizing excess air level.

9. Show examples of various boiler types, fuel types, fuel costs, operating hours, and efficiencies.
10. Give students hypothetical problems to work.
11. If possible, tour a local plant, perhaps the university physical plant. Have the students take excess air readings, look for uninsulated lines and tanks, and check for economizers/recuperators.

References

- Kennedy and Turner 1984, p. 138
Lawrence, McRae and Alley 1980, p. 165
Mahon, Kiss and Leimer 1983, p. 148
Payne 1984, p. 97
Thumann 1983, p. 58
Thumann 1984, p. 183
Turner et al., p. 10.

ALTERNATE LABORATORIES

The two laboratories given in this section may be used as alternates or may be incorporated within other laboratories.

ALTERNATE LABORATORY 1 - COST ESTIMATING

The basic considerations in estimating the costs of implementing energy saving ideas are dealt with in this laboratory.

Discussion

1. Discuss the steps of cost estimating procedures. A sample procedure is listed below:
 - a. estimate savings
 - b. estimate cost
 - c. determine economics
 - d. get bids
 - e. determine economics
 - f. decide upon installation (vendor or self installation)
 - g. purchase and install
 - h. monitor for actual savings
 - i. determine economics.
2. Explain cost factors. In this discussion, the instructor will probably wish to cover equipment, installation, maintenance, training, and other recurring costs.
3. Discuss various cost estimating sources. Three recommended sources are the Means Cost Data Book, vendor price lists, and the McMaster Catalog.
4. Give the students an example system and have them get estimates. Compare the range of estimates and considerations that the students give.

ALTERNATE LABORATORY 2 - VELOMETER EXPERIMENT

This laboratory introduces the velometer as an energy-management tool. The basic equations used with the velometer are reviewed. A velometer and bin-data charts are required for the presentation.

Discussion

1. Discuss infiltration, e.g., losses through cracks, under doors, and through vents.
2. Discuss ventilation requirements and health regulations.
3. Discuss the operation of the velometer. Cover six-, eight-, and ten-point measurement schemes. Ask the students why these are necessary.
4. Discuss mass flow rate calculations and heat loss calculations based on flow rate.
5. Break the class into groups, and have them measure an infiltration source. Have the students calculate the losses due to heating and air conditioning. Students will need bin-data weather information or degree-day information.

References

Turner et al. 1982, p. 451.

ADVANCED ENERGY MANAGEMENT COURSE SYLLABUS

The following outline is a possible design for a graduate-level course in the field of energy management. The students should have completed the first energy management course and should have a good basic understanding of the principles involved. No laboratories are used. The sequence is designed to be more flexible than in the model undergraduate course. Outside references and recent articles are much more important in this course.

CATALOG DESCRIPTION

This course is an advanced study of the design, the implementation, and supervision of energy management programs. The course will concentrate on areas more technologically or managerially complex than the basic energy management course. The course covers such topics as cogeneration, alternative energy, energy reporting, and energy management control systems.

COURSE OBJECTIVES

The student should become more adept in increasingly sophisticated areas of energy management. The course will enable the student to become a better manager by examining accounting and reporting measures and cost-center metering. The student will be able to learn more about technologically sophisticated areas of energy management.

METHOD OF INSTRUCTION

The course will be primarily presented in a lecture format. The instructor will choose an appropriate text. Several additional sources are shown in the reference section. Laboratory and field trips should be incorporated. Outside lecturers may be used where appropriate. Table 5 shows one possible scenario for grading this course.

Test questions have been developed that may be suitable for this course. Refer to the Test Questions section for ideas.

TABLE 5. Advanced Energy Management Course Grading

Two tests @ 20%	40%
Research paper	20%
Homework, special assignments	15%
Final exam	<u>25%</u>
TOTAL	100%

One important aspect of this course is the research paper. This paper should be an in-depth analysis of an energy management subject. For example, students could analyze the advantages, disadvantages, and pitfalls of an energy management control system. A paper could present a design and an economic analysis of a solar preheating system for an industrial process. The paper should be of research caliber and worthy of publication in an energy journal.

One possible course syllabus for the Advanced Energy Management Course is presented in Table 6. Reference sources have been keyed and are listed at the bottom of the table. Additional reference sources are listed where applicable.

TABLE 6. Sample Advanced Energy Management Course Syllabus

<u>Period</u>	<u>Topic</u>	<u>Reference Number and Page</u>
1	Introduction to course Review of syllabus	
2 to 12	Energy management control systems - What is an EMCS? What different types are available? (Programmable, controllers, mainframes, micros). Control Schemes (Duty Cycle, Demand Shed and Optimum Start-Stop).	1-177, 2-76, 3-171, 5-77, 6-105, 7-89, 8-356, 9-139

Other References

Ottaviano, Victor B., Energy Management (USA: OTS Publication 1983).

Owens, George R. March 1983. "EMS Parts 1 and 2," Energy Management.

"Reader Survey and Rating," Energy User News, New York.

"Direct Digital Control," Technical Brief #6. Energy Extension Service of
Georgia Tech., Atlanta, Georgia.

"Computer Based Energy Management," Technical Brief #3, Energy Extension
Service of Georgia Tech., Atlanta, Georgia.

13 to 22	Cogeneration - What is cogeneration? Why is it attractive in industrial and institutional applications? Small- scale cogeneration. Types of equipment. Economic analysis of cogeneration. Legal and regulatory aspects.	1-172, 2-189, 3-325, 6-261, 8-203
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Other References

Polimeros, George. 1981. Energy Cogeneration Handbook. Industrial Press, Inc.

The Regulatory Policy Institute, The Industrial Cogeneration Manual,
Washington, D.C.

Kibert, Charles J., and W. A. Smith. 1982/Jan. 1983. "Analysis of Pressure
Reducing Stations for Cogeneration," Energy Engineering, p. 5.

23 to 30	Alternative Energy Applications. What is an alternative energy source? Advantages and disadvantages of each. Economics of alternative energy sources. Solar-, wind-, refuse-derived fuels. Future of alternative energy.	1-243, 3-55, 5-206, 6-291, 7-235, 8-499, 9-295
30 to 34	Energy Reporting - Design of energy reporting-accounting procedures. Variance Identification and quantification. Cost-effective reporting mechanisms.	1-16, 2-15, 3-359, 7-8, 8-14

Other References

Turner, W. C. June 1984. "Energy Accounting: A New Field Results," IIE
Transactions, page 135.

Shirley, James M. 1985. "Multiple Location Energy Accounting Systems: A Case
Study," 1985 Annual International Industrial Engineering Conference Proceedings.
Chicago.

TABLE 6. (contd)

<u>Period</u>	<u>Topic</u>	<u>Reference Number and Page</u>
35 to 37	Experimental Rate Schedules - Unique rate schedules offered to Industries. Interruptable, curtailable and standby schedules: What can they offer companies? Identifying potential applications. Various utility schedules available from the local utility or rate commission. (Concentrate on the new experimental ones, not the conventional ones.)	
37 to 41	Miscellaneous topics not covered elsewhere. Maintenance for energy management, fleet management, other considerations.	
42 to 45	Actually scattered through course - guest speakers, tests, plant tours, review sessions.	

References

- 1 - Kennedy and Turner 1984
- 2 - Lawrence, McRae and Alley 1980
- 3 - Mahon, Kiss and Leimer 1983
- 4 - O'Callaghan 1981
- 5 - Payne 1984
- 6 - Thumann 1984
- 7 - Thumann 1983
- 8 - Turner et al. 1982
- 9 - Zackrison 1984

TEST QUESTIONS

Sample test questions that instructors might be able to use are listed in this section. Major categories have been identified. The solutions are not provided for obvious reasons. These can be obtained by contacting

Dr. Wayne C. Turner
Industrial Engineering and Management
Oklahoma State University
Stillwater, Oklahoma 74078
Work (405) 624-6055

Some questions are more appropriate for an undergraduate course. Others may be most suitable for graduate level courses.

Electric Rate Schedule

1. You work for Ajax, a manufacturer of adjustable wrenches. You are trying to understand the billing procedure and encounter the following. Calculate the bill for the month of November. Ignore any charges other than those listed.

Rate Schedule

\$5.00 per kW of billed demand
\$0.03 per kWh of electric consumption
Allowed kilovar (kvar) (with no charge) = 70% billed demand
Excess kvars billed at \$0.75 per kvar
Demand ratcheted 80% over last 12 months
Sales tax = 3%.

Month of November

Actual demand = 1000 kW
Actual kvar = 790 kvar
Actual consumption = 300,000 kWh.

Previous Demand

Dec. 1000 kW; Jan. 900 kW; Feb. 950 kW; March 960 kW; April 960 kW; May 1100 kW; June 1150 kW; July 1350 kW; Aug. 1150 kW; Sept. 1100 kW; Oct. 900 kW.

Power Factor

2. For the rate schedule in Problem 1, what is the base power factor (pf) (i.e., the pf below which a penalty is charged)?

Heat Loss and Insulation

3. At Ajax, you encounter a large indoor tank (see sketch) that is full of hot oil at 110°F. The tank is heated by steam coils. The boiler supplying the steam is 78% efficient and burns natural gas at \$5.00 per million Btu. Ambient air is at 70°F year round. The tank is used 8760 hours per year. Calculate:

10 pts. A. The total heat loss with no insulation

10 pts. B. The total heat loss with 1 inch of fiberglass blanket insulation covered with an aluminum jacket.

10 pts. C. The savings in Btu and dollars from installing the insulation.

Lighting

4. Recommend a lighting system for each of the following situations. State reasons for each recommendation. Assume that each situation requires average overall lighting (ignore task lighting). Be brief.
- A. A small manufacturing plant (1200 ft²) plant operates 8 hours per day. The ceiling height is 12 feet. The plant is closed on Saturday and Sunday.
- B. A large plant (200,000 ft²) operates continuously on 3 shifts. The ceiling height is 22 ft. The plant manufactures yarn, and each lot is dyed a unique color. The dye colors cover the entire spectrum.

- C. A moderately sized plant ($60,000 \text{ ft}^2$) with 20 ft ceilings operates continuously over 3 shifts. Color determination requirements are not demanding.
- D. A valve manufacturer has a large outdoor storage area for large castings. The plant operates 3 shifts, 5 days per week. Fork-lift trucks drive outside, pick up a casting, and take it to a machining center inside. Approximately 3 trucks per hour go outside. How would you light the outside storage area?

General

5. Define "energy management." Compare and contrast it to energy conservation.

Electricity

6. Using the rate schedule of Problem 1, calculate the cost of running a 50 hp motor.
- A. 24 hours per day
- B. 16 hours per day (during 2nd and 3rd shift).

Ignore ratchets and power factor. Assume that the company peaks at 2:30 p.m. with a very large demand, then power requirements drop significantly for the rest of the day. $1 \text{ hp} = 0.746 \text{ kW}$.

Electric Rate Schedule

7. Calculate the power factor penalty (one month only) in dollars for the following conditions under the rate schedules shown. For each, state what capacitance would be required to remove the penalty.

Company:	Elgin Mfg. Co.
Actual Demand:	100 kW (no ratchet)
Consumption:	240,000 kWh
Power Factor:	75%

SHOW YOUR CALCULATIONS - DO NOT USE TABLES

A. Rate Schedule 1

Demand Charge \$4.00/kW
Consumption Charge \$0.04/kWh (no fuel cost adjustment)
Billed Demand = Actual Demand (0.8/actual pf).

B. Rate Schedule 2

Demand Charge \$4.00/kilovolt-ampere (kVa)
Consumption Charge \$0.04/kWh

Water Heat Recovery

8. An air compressor is constantly circulating cooling water at 3 gallons per minute. If the water can be reused as rinse tank makeup, what is the dollar savings in energy and water for the parameters below? Assume that the compressor is used 6000 hours per year; water cost is \$1.50 per 1000 gallons.

- A. Temp H₂O in: 60°F: Boiler eff. (to heat rinse tank) 0.8
B. Temp H₂O out: 110°F: Gas cost \$6.00/10⁶ Btu.

(Assume water is off when the compressor is off.)

EMCS

9. Briefly define each of the following control strategies for energy savings:
- A. Optimum start stop
 - B. Chilled water temperature reset
 - C. Ventilation economizer (enthalpy control)
 - D. Duty cycling
 - E. Demand limiting
 - F. Night setback.

HVAC

10. While doing a ventilation study for a plant, you find that 2,000 cfm of inside (conditioned) air is being needlessly exhausted. For the conditions below determine the added heating and cooling cost. Ignore any horsepower savings on exhaust fans.

Inside conditions:	70°F 50% RH (relative humidity)
Outside winter average	40°F 50% RH (120 days-24 h per day)
Outside summer average	85°F 50% RH (90 days-24 h per day)
Air condit. eff. 2.5	Cost of elec. = \$0.06/kWh
Heating eff. 0.75	Cost of gas = \$6.00/10 ⁶ Btu

- A. Ignore the impact of humidity
- B. Include the impact of humidity.

Facility Design

11. For a one-story manufacturing plant, as shown below, discuss the placement of tinted glass, i.e., what should be tinted. Assume the plant is heated and cooled. Assume the plant is located in Tennessee.

HVAC

12. Discuss briefly why variable air volume units save energy when compared to conventional dual duct, multizone, or terminal reheat systems.
13. Discuss briefly why closed-loop heat pump systems (see sketch below) often work well in large office buildings.

Cooling Towers

14. Discuss briefly the difference between "strainer cycle" and "thermo cycle" measures for using cooling tower water for energy savings.

Electric Rate Schedule

15. A manufacturing plant has the following characteristics:

- A. Location: Oklahoma City, Oklahoma
- B. Consumption 125,000 kWh per h
- C. Demand (actual): 420 kW
- D. Previous Peak - preceding 12 months = 600 kW
- E. Billing Period: June, 30 days
- F. Fuel cost pass through \$0.0189/kWh
- G. Power factor Actual = 0.72
Power factor Base = 0.80.

Calculate the total bill for OG and E's LPL rate schedule (substitute a local one).

- 1. Don't worry about a minimum bill.
- 2. No franchise payment is required.
- 3. No delivery voltage surcharge or discount is used.

General

16. Define energy management. List two examples of energy management that do not involve energy conservation.

Combustion Flue Gas

17. Draw the lines in the graph below (approximations only) for O_2 , CO_2 , CO , H_2 , and methane CH_4 . Using that plot, state why a good combustion air program is difficult to run when based on tests of one constituent only.

Composition
Percent
By Volume

Boilers

18. You encounter a boiler running @ 9×10^6 Btu per hour 80% of the time (full time = 8760 h/yr). The boiler burns natural gas. Your combustion test shows 8% O_2 and a stack temperature of 600°F.

What present excess air are you utilizing? What would you recommend as a goal? What would the dollar (\$) savings be? Assume that you are burning natural gas at \$5.80 per thousand cubic feet.

Waste Heat Recovery

19. In doing an audit of a large forging operation, you find a natural-gas rotary hearth furnace exhausting 1000 lb/min of stack gases @ 1700°F. You are running at 10% excess air. Using a condensing heat exchanger, you feel you can cool the exhaust gases to 100°F and generate steam. Considering only sensible heat, what is the savings in Btu?

Boilers

20. In a boiler study, you find the following parameters for the water
Solids in make up, ppm	400
Boiler design, ppm	5000
Present condensate return	25%

An expenditure of \$2,000 would increase the condensate return to 50%. If the boiler is 80% efficient and consumes natural gas at \$6/10⁶ Btu is the project worthwhile? Assume the blowdown is managed carefully to what

it should be, and consider energy savings only. Steam production is 5000 lb/h; makeup water is 60°F. Drum pressure is 100 psig. The boiler is used 8000 h/yr.

Lighting

21. In a lighting audit, you find 300 recessed fixtures with 150 W flood lights. You feel you could remove 20 of these and replace the others with 75 W ER bulbs. At \$4.00/kW and \$0.05/kWh, what is the annual dollar savings in energy? The bulbs burn 12 h per day, 6 days per week.

Insulation

22. You find 100 ft of uninsulated steam line 3-1/2 in. nominal pipe carrying steam at 300°F. Calculate the heat loss in Btu/h before and after adding 1-in. foil-coated fiberglass insulation.

HVAC

23. You have installed a dry-bulb economizer control unit for an air conditioner in ----- City. Return air is normally 75°F. Your system is designed to utilize 1000 cfm of outside air whenever the outside dry bulb is below 75°F. Using the bin data attached, calculate the dollar savings for the month of July. Assume the return air is reduced by 1000 cfm when outside air is used. The unit has a coefficient of performance (COP) of 2.2 and an energy cost of \$0.09/kWh (ignore demand).

Electric Rate Schedule

24. At \$6.00/kW per month, calculate the annual demand bill for the following profile. The previous high demand was 1000 kW and the ratchet is 70%.

Month	:	J	F	M	A	M	J	J	A	S	O	N	D
:													
Actual kW	:	600	500	800	900	800	900	1000	900	700	600	700	600
:													

General

25. You are a young engineer working for Ace Manufacturing. You have approached your plant manager about starting an Energy Management program. He asks you the following questions.
- A. "What is Energy Management?"
 - B. "List three typical energy management studies."
 - C. "Distinguish between a gross audit and a detailed audit."
 - D. "Why do you say that energy management is the most economical source of new energy today?"

Waste Heat Boiler

26. For the furnace in Problem 3, you are considering installation of a waste heat boiler. The manufacturer states that the boiler-allowable concentration of impurities is 5000 ppm: your makeup water has 400 ppm. Assuming your final stack gas temperature is 300°F, how many pounds of 150-psig-saturated steam can you produce? Assume your feedwater temperature is 200°F. Flue gas flow is 25,000 lb/h. What is the dollar savings? boiler efficiency is 80%.

Waste Heat Recovery

27. You are considering an investment in a recuperator to preheat combustion air for a heat-treating furnace. The fuel is natural gas for a furnace rated at 75 per million Btu per h. You are running at full load. The present flue-gas temperature is 800°F and ambient air is at 70°F. You are paying a \$3 per thousand cubic feet of gas on the average, but you consume enough that your marginal price is \$2 per thousand cubic feet. If the recuperator cost is \$200,000 installed, what is the payback? Assume that you wish to cool exhaust gases to no less than 300°F.

Boilers

28. You are working with a boiler plant with a total capacity of 400,000 lb/h. There are three boilers rated at 200,000; 100,000; and 100,000 lb/h each. Steam is supplied at 500 psig 600°F. Operating demand varies from 100,000 lb/h to 250,000 lb/h peak. Given the chart below, show how you

100,000 lb/h to 250,000 lb/h peak. Given the chart below, show how you would determine optimum loading for each of the three boilers at a total plant load of 100,000 lb/h; 125,000 lb/h; 150,000 lb/h; 175,000 lb/h; 200,000 lb/h; 225,000 lb/h; and 250,000 lb/h. Demonstrate by calculating the optimum loading profile for a plant load of 175,000 lb/h.

Boiler 1 100,000 lb/h Cap			Boiler 2 100,000 lb/h Cap		
<u>Load Percent</u>	<u>O₂ Percent</u>	<u>Stack Temperature, Degree Fahrenheit</u>	<u>Load Percent</u>	<u>O₂ Percent</u>	<u>Stack Temperature, Degree Fahrenheit</u>
100	2	500	100	3	500
75	3	550	75	4	500
50	3	600	50	4	550
25	4	600	25	5	600

Boiler 3 200,000 lb/h Cap		
<u>Load Percent</u>	<u>O₂ Percent</u>	<u>Stack Temperature, Degree Fahrenheit</u>
100	2	350
75	2	400
50	2	450

Minimum load = 50%

General

29. Define energy management, and discuss why it is important for industry today.

Heat Balance

30. In conducting an energy audit, you find a large industrial furnace operating as shown in the figure. Construct a heat balance diagram (with numbers on all inputs and outputs). Identify all the potential waste-heat sources, and list one good application for each. All gas and air flow is standard cubic feet (scf). (Assume all materials have 0 enthalpy @ 32°F.)

31. In the problem above, exhaust flow was stated in scf. What is the actual flow at 2000°F?

Electric Rate Schedule

32. Given the following electrical parameters for Ace Manufacturing, what are the savings for reducing August demand to 900 kW? Note, there is a ratchet clause (no demand shall be less than 60% of the previous 12-month peak.) Assume all years have monthly demands as shown.

Charge \$6.00/kW June through September
\$4.00/kW October through May

Month	Actual, kW	Billed, kW	Month	Actual, kW	Billed, kW
Jan.	450	600	July	900	900
Feb.	375	600	Aug.	1000	1000
March	475	600	Sept.	800	800
April	650	650	Oct.	700	700
May	675	675	Nov.	400	600
June	700	700	Dec.	400	600

Lighting

33. Your plant has decided to convert from mercury vapor to high pressure sodium (HPS). The plant has 250 mercury vapor fixtures at 1150 W each including ballast. You find that you can replace those with 250 HPS fixtures each at 450 W including ballast. For the parameters shown below, what is the payback on the investment? Ignore ratchet clauses and the impacts of heating and air conditioning. The lights are used 8000 h per year.

	<u>Mercury Vapor</u>	<u>High Pressure Sodium</u>
	50,000 lumen/fixture	45,000 lumen/fixture
	18,000 h bulb life	24,000 h bulb life
	\$35.00 per bulb cost	\$40.00 per bulb cost
		\$250.00 per fixture cost (including installation)
Consumption Charges	\$0.06/kWh	June through September
	\$0.04/kWh	October through May
Demand Charges	\$5.00/kW	June through September
	\$3.50/kW	October through May

Boilers

34. A 100,000 lb/h boiler has been operating at a maximum concentration of 4500 ppm with 40% condensate return. The condensate return can be increased to 75% by installing additional traps, pipes, and receiver tanks at a cost of \$20,000. The boiler operates 8000 per year at a 75% load, producing saturated steam at 100 pounds per square inch absolute (psia). Is the project worthwhile? The fuel is natural gas costing \$3.00/10⁶ Btu. Show the savings for energy, water, and water treatment. Water costs \$1.50/1000 gallons and treatment costs \$0.75/1000 gallons. Makeup water has 400 ppm impurities. Assume that condensate is returned as 100 psia saturated liquid.

Steam Traps

35. In doing an energy audit, you find a cement-curing furnace heated by live injection of steam. You are replacing the steam trap. Discuss whether or not you should buy a trap designed to fail open or shut. Explain why.

Heat Loss/Gain

36. Given a wall constructed as below, what is the annual heat gain in an area with 3000°F cooling degree days? What is the annual heat loss in an area with 5000°F heating degree days?

Lighting

37. You are working with Ajax, Inc., a highly profitable manufacturer of beach balls. The company operates three 8-hour shifts, five days per week with two weeks off each summer for vacation. Their plant is presently lit with 100 mercury vapor lights of 1000 W each including ballast. You have recommended that they switch to 100 high-pressure sodium lights of 400 W each. Other pertinent data is given below:

Electrical Costs

Demand \$4.00/kW mo
Energy \$0.03/kWh (including fuel adj.)

Cooling - Heating Parameters (heating is done with gas)

Heating degree days - 4000
Cooling degree days - 1200
Heating plant efficiency 0.8
Cooling plant efficiency - 2.9
Gas cost - \$3.50/10⁶ Btu.

Cooling is used for the first shift only (12 weeks).

Heating is used for all three shifts (15 weeks).

Calculate the:

- A. estimated electrical savings in kWh and dollars per year
- B. estimated cooling savings in kWh and dollars
- C. estimated heating effect in 10^6 Btu and dollars
- D. Net dollar savings (not including replacements).

Lighting

38. In the same plant as problem above, the new fixture (with bulb) is \$250 each installed. The new bulb cost \$40 and lasts 20,000 h. The old (mercury) bulb cost \$22 and lasts 10,000 h.
- A. Calculate the replacement incremental savings (costs).
 - B. Calculate the first cost of this project.

EMCS

39. A company is selling a programmable controller for use in managing their electrical consumption better. The company intends to cycle the air conditioning equipment as follows.

:			:
:	Air Conditioning Unit	kW draw	Cycle :
:	1	40	20 min on :
:			10 min off :
:	<hr/>		
:	2	20	20 min on :
:			10 min off :
:	<hr/>		
:	3	30	20 min on :
:			10 min off :
:	<hr/>		

The company is paying \$4.00/kW month for demand and \$0.04/kWh for electrical energy. The cycling is such that one unit is always off. If the company operates 10 h per day, 250 days per year and air conditioning is supplied 3 mo of the year, what is the saving in kWh and dollars?

Excess Air

40. In analyzing a gas-fired furnace of 50×10^6 Btu-rated capacity (burns natural gas costing \$4.00/ 10^6 Btu), you find the following:

Flue Gases		
CO ₂	8%	
O ₂	6%	
Temperature	525°F.	

- A. What are the savings for correcting excess air?
- B. What would be the savings for installation of turbulators that would reduce the stack temperature to 300°F?

Window Treatment

41. In auditing an industrial plant, you find 200 windows each 3 ft x 5 ft that serve little purpose except to provide natural lighting. The foreman does not want you to block his windows, so you propose "wonderstick." "Wonderstick" is an adhesive-backed transparent material that insulates the window but does not block light. Wonderstick's R-value is 3.0. It costs \$0.50/ft² installed. If the gas-fired heating plant efficiency is 0.7, gas costs \$3.00/ 10^6 Btu, and the plant experiences 5000 heating degree days per year, what are the heating savings in dollars? Is the project worthwhile? The plant operates 24 h per day, 365 days per year.

HVAC, EMCS

42. For Bismark Manufacturing, estimate the savings per year (10^6 Btu) for a 15-degree night setback. The company gas consumption is shown for the past year. Assume they have a heating demand of 5000 degree days. (Note: provide bin data or rule of thumb.)

<u>Month</u>	<u>Consumption, 10⁹ Btu</u>
Jan.	3000
Feb.	2000
Mar.	1500
Apr.	1400
May	600
June	550
July	600
Aug.	550
Sept.	600
Oct.	1200
Nov.	1500
Dec.	2000

Electricity

43. Given a 3-phase electrical motor with a phase angle (θ) of 30 degrees and an average draw of 15 A at 200 V:
- What is the power factor?
 - What is the hp of the motor, assuming a physical efficiency of 85%?

Combustion

44. Given the following balanced combustion equation for the burning of methane and the fact that air is 23.3% O_2 by weight, how many pounds of air are required to combust 10 lb of methane? Assume perfect mixing and combustion.

	<u>Atomic Weight</u>	<u>Molecular Weight</u>
Hydrogen	1	2
Carbon	12	12
Nitrogen	14	28
Oxygen	16	32
Carbon Dioxide	--	44
Methane	--	16

Steam

45. 200 lbm of steam at 40 psia and 400°F is mixed with 100 lbm of 90% quality steam at 40 psia. Assuming no loss in heat and a constant pressure, what is the final state?

General

46. Some have stated that the U.S. energy crisis is not caused by the quantity of energy but rather by the choice of energy sources. Discuss this briefly giving some statistics to support your beliefs.
47. What is the chief argument against the breeder reactor and spent fuel reprocessing?
48. What is the single most important element for a successful energy management program? Justify your answer.

Audits

49. You work for the plant manager. You have been assigned the responsibility of initiating an energy management program. Your manager asks you:

(A) What is a gross audit, and why should we do one? Also, (B) What is a detailed audit (connected load), and should we do it? Tell me why or why not."

Answer him.

Energy Balance

50. In your position as energy manager, you encounter several situations where you want to do an energy balance for specific pieces of equipment (SUM energy in = SUM energy out). One is a boiler producing X pounds in steam per h at certain conditions. Ten percent of the feedwater is new water at 50°F, and 90% is condensate return at 190°F (10% of the steam is lost). Five percent of the steam is "blown down" (exhausted) for solids control. Describe how you would do a heat balance.

Heat Loss Insulation

51. In an energy audit, you have found a condensate return tank that is uninsulated. The diameter of the tank is 3 ft and 5 ft long. The surface temperature of the flat-black-colored metal tank is 270°F. You are considering insulating the tank with 3 in. of fiberglass with an aluminum jacket. Assuming the insulation reduces the heat loss by 90% and the insulation costs \$1.25/ft² installed, what is the undiscounted payback on the project? The boiler is operated 8000 h per year and is 80% efficient. The ambient temperature is 70°F. Fuel cost is \$2.50 per million Btu (natural gas). What is the total dollar savings?

Steam

52. For the same steam system as in the problem above, you found the following steam leaks. If the steam is 100-psig-saturated, what is the total dollar value (\$) of the leaks?

<u>Size of Hole, Inches Diameter</u>	<u>Number of Leaks</u>
0.1	10
0.25	8

Steam Traps

53. A. What is a steam trap?
B. Why is there so much fuss about monitoring steam traps?
C. Name three ways of checking steam traps.
D. What is the best way of checking these traps?

Waste Heat Recovery

54. In a waste heat study, you have encountered a large gas-fired furnace with two primary sources of potential waste heat. They are 1) the cooling water for the furnace walls and 2) the flue gases. For the data given below, quantify the amount of waste heat available in both sources and discuss potential uses of each source. The furnace operates two 8-hour shifts per day, 250 days per year.

A. Cooling water:

600 gal/min

Outlet temperature = 150°F

B. Flue gases

Temperature 2000°F

Composition 7% CO₂

8% O₂

0% CO

85% N₂

Flow rate 4 10⁶ ft³ h.

Waste Heat Recovery

55. In another audit, someone found a large 150 hp air compressor that was air cooled. They decided to use the air coming off the condenser as space heat and hooked it up as shown in the figure. You immediately spotted something badly wrong! Tell me what's wrong?

Heating, Ventilation, Air Conditioning

56. After a restudy of ventilation requirements, you find that ventilation requirements for a building can be reduced from 10,000 ft³/min to 6,000 ft³/min. Presently, a 25 hp motor drives the blower (assume it is correctly sized for 10,000 ft³/min). Outside air is 25% and will stay at 25% after the reduction is made, i.e., 25% of 6000 ft³/min. If you pay \$0.03/kWh and \$4.00/kW month for electrical energy and demand and \$3.00/10⁶ Btu for natural gas, what is the savings for the change? Heating plant efficiency is 80%, and the system operates 4000 h per year (assume it operates during peak times). The building is not cooled, but the fan runs for ventilation purposes. Heating degree days = 4000°F days. Density air is 0.0725 lbm/ft³. Specific heat of air is 0.248 Btu/lbm °F.

Wind

57. We know the wind energy conversion equation

$$P/A = 1/2 V^3$$

is equivalent to

$$P/A = KV^3$$

with values of K as shown in the Energy Management Handbook, (Turner 1982).

Develop the factors shown in Table 163, Page 518.

EMCS

58. You have been hired to design and install an Energy Management Control Strategies (EMCS) in a convenience store (e.g., Buy and Bye, 7-11). Assuming the company is billed on an electric rate schedule with charges for demand (including a 80% ratchet clause), consumption, and power factor, design a comprehensive system assuming all ideas are cost effective. Then fill in the table below.

Likelihood of Being Cost Effective

<u>Equipment</u> <u>(Type of Control)</u>	<u>Very Likely</u>	<u>Moderately Likely</u>	<u>Unlikely</u>
: _____ :	: _____ :	: _____ :	: _____ :
: 1 :	: _____ :	: _____ :	: _____ :
: _____ :	: _____ :	: _____ :	: _____ :
: 2 :	: _____ :	: _____ :	: _____ :
: _____ :	: _____ :	: _____ :	: _____ :
: 3 :	: _____ :	: _____ :	: _____ :
: _____ :	: _____ :	: _____ :	: _____ :
: N :	: _____ :	: _____ :	: _____ :
: _____ :	: _____ :	: _____ :	: _____ :

If you are uncertain, place the item in the middle column. Defend each placement with a footnote (state why).

Steam

59. You have a pressure-reducing station taking 20,000 lb/h steam at 300 psig - 100°F superheat and throttling it down to 50 psig steam for use in space heating. For a turbine efficiency of 65%, what shaft power can be generated, and how much additional steam is necessary, if any? What is the quality of steam (% steam and % condensate) leaving the turbine?

Cogeneration

60. Briefly discuss what a chiller heater is, and show how it can be considered to be cogeneration. Develop a case study showing good economic analysis. For the first cost, make any reasonable assumption.

Boiler

61. An 80,000 lb/h boiler has been operating at a maximum impurity concentration of 3000 ppm with 50% condensate return. Makeup water has 450 ppm impurities. If the condensate return can be increased to 75%, calculate

the savings from reduced blowdown. The unit efficiency is 0.8, natural gas fuel cost \$3.00/10⁶ Btu and operating time is 8000 h per year. Steam pressure is 100 parts per square inch gage (psig).

Steam Trap

62. An inverted bucket with a 1/4 in. orifice is found to be stuck open. How much steam is being lost? Using the parameters from the problem above, how much is that costing?
63. Briefly discuss what ill effects can occur if a steam trap fails open. Repeat for failing closed.

Cogeneration

64. For cogeneration distinguish between
 - A. topping cycles
 - B. bottoming cycles
 - C. combined cycles.
65. Briefly describe a typical combined cycle.

Waste Heat Recovery

66. In a recuperator study, exhaust stack temperatures are 1100°F and combustion (room) air is supplied at 70°F. A recuperator will yield combustion air of 500°F. At \$3.00 per million Btu fuel cost and a required 3-year undiscounted payback, how much can be spent on the recuperator? Assume the unit is fired 8000 h per year, is 100% efficient, and presently burns 20,000 ft³ of natural gas per hour. Natural gas cost is \$3.00 per million Btu. Assume 13 lb of air are required per pound of natural gas. The density of natural gas is about 0.625 lbm/ft³.

HVAC

67. During an energy audit, it is found that one large exhaust fan operating 8000 h/year presently exhausts 36,000 cfm of air that is "made up" by infiltration. Studies show that 20,000 cfm would be sufficient. If the fan is driven by a 30 hp motor operating at 100% load, what would the savings be for A) fan hp reduction, B) reduced heating costs, and C) reduced cooling costs. Air conditioning is provided at an efficiency of 2.5 (COP)

and heating at an efficiency of 0.7. Heating fuel costs \$3.00/10⁶ Btu; electricity for cooling costs \$0.05 per kWh. Heating degree days = 4000, and cooling degree days = 2000. Specific heat of air = 0.02 Btu/ft³.

Steam

68. A condensate return system returns condensate at 30 psig to an unpressurized - vented receiver tank. What percentage of the condensate is being lost as flash steam? (Calculate - do not use tables.) List the things that can be done to recover some of that lost steam.
69. A 100,000 lb/h boiler has been operating at 25% condensate return. Makeup water has 250 ppm impurities and the boiler can handle 3000 ppm. What would the savings be if the condensate return is increased to 50%? (State savings in Btu and dollars.) Fuel is natural gas costing \$5.00/10⁶ Btu, and the boiler is 80% efficient. Assume the boiler operates at 75,000 lb/h consistently for 8000 h per year. (Calculate - use no tables other than steam tables.) Boiler drum pressure is 100 psig.

General

70. Briefly discuss why it may be more important for a corporate level energy management program to have a technical committee than for a local plant. Assume both already have steering committees.

Combustion

71. Given the following balanced combustion equation for the burning of methane and the fact that air is 23.2% O₂ by weight, how many pounds of air are required for each pound of methane? Assume perfect mixing and combustion.

	<u>Atomic Weight</u>
Hydrogen	1
Carbon	12
Nitrogen	14
Oxygen	16

Assuming that air is $100 - 23.2 = 76.8\%$ nitrogen, how much nitrogen goes up the stack for each pound of methane? Why is that a problem? What can be done about it?

Flue Gas

72. You measure flue gas composition in a 50 million Btu per hour furnace and find that O_2 is 8% and stack temperature is $800^\circ F$. What is the savings for correcting that to the optimum realistic value? The fuel is natural gas costing $\$3.00/10^6$ Btu. Assume the furnace operates at full capacity, 8760 h/year. You may use any tables you wish.

Waste Heat Recovery

73. While studying the furnace above, you realize the flue gas temperature is pretty high. List at least three ways you could recover some of this heat.

Power Factor

74. One utility bills $\$1.00$ for each "excess kvar" where "excess kvars" are all those greater than 60% of the actual kW average demand. What is their base pf, i.e., the pf below which a penalty is incurred? Another bills for pf by expressing demand in kVa. What is their base pf?

Air Compression

75. During an energy audit, you encounter a relatively large air compressor. List below five items that you would check for applicability in reducing energy costs.

Insulation

76. Given a 6-in. pipe covered by 2 in. of aluminum-jacketed fiberglass insulation, what is the surface temperature of the aluminum? The pipe carries a hot fluid at 300°F. Ambient air is 80°F.

Water

77. In a water audit, you find many steam leaks totaling 200×10^6 Btu energy loss per year (from size of leaks and tables). Determine how much water is being lost in these leaks. Steam is supplied at 120 psig saturated and makeup water is 70°F. At \$1.25/1000 gal, how much is the water loss costing?

Energy Accounting

78. In your energy management work with Stillwater Municipal Hospital, you decide to develop one or more "one-shot" energy productivity measures. Propose several candidates, and discuss their advantages and disadvantages.

General

79. It has been said that energy usage does not vary linearly with the level of production but that the rate of energy use, i.e., Btu unit of production does. Discuss this and develop a generalized forecasting model of energy consumption based on production only (ignore other factors).
Hint: Btu/Unit of Production may drop as production increases.

Energy Management Control Strategies

80. Using an industrial setting, give me a good example of each of the following energy management control applications. For each, state the nature of the savings in the form, and enter yes or no as appropriate.

	Gas (a) Savings	Electricity Savings	
		Demand	Consumption
A. Demand limiting Example:			
B. Optimized start stop Example:			
C. Load Cycling Example:			
D. Night Set Back Example:			
E. Optimized Air Source Example:			
F. Temperature Reset Example:			

(a) Gas or other "fuels" such as fuel oil, coal, wood, etc.

Steam Traps

81. In steam trap maintenance, sound is often used. Discuss how this works. Be specific for different types of traps.

Insulation

82. In an energy audit, you found a 4-in. dia pipe that was insulated. The pipe was carrying live superheated steam at 300°F. The installation is indoors. You have decided to insulate the pipe with aluminum-jacketed fiberglass, but you don't know whether to use 2 in. or 3 in. Given that the 2-in. insulation costs \$1.00/ft² installed and the 3-in. costs \$1.35/ft² installed, which is better? You are using 3-year payback as the decision criteria. You are paying \$3.00/10⁶ Btu installed, and the boiler is 75% efficient. Ambient air is 80°F. The boiler operates 8760 h per year.

Wind

83. You are considering the use of wind-generated electricity to power an effluent treatment facility for a local manufacturing company. There is a relatively steady need of 100 kW for 8 h per day (any 8 h in the day). Assuming the wind speed is more than 20 mph for 8 h per day, how many horizontal 5-ft dia windmills would be necessary? Conversion efficiency is 70% at the rated velocity of 20 mph.

Solar

84. As an alternative to the wind system in the problem above, you are looking at a photovoltaic system comprised of cells, each putting out 0.45 V and 1 A. Assuming the power system in question is single phase and draws 440 V at 250 A, what type of an array is required?

Fleet Management

85. You have been hired as energy manager for Joe Smith Office Supplies. They have a fleet of 100 trucks and small vans for delivery purposes. All trucks consume gasoline. The fleet manager asks for ideas that might reduce his fuel costs. List at least 5 such ideas. The trucks are used in town for delivery of no more than 100 miles.

Air Compression

86. In a combination water-energy management survey, you found a 100-hp air compressor that was water cooled. It was a once-through system; city water came in at 55°F and left at 100°F. The flow rate was 10 gal per minute. Assuming the water could be dumped directly into a boiler makeup tank with 1/2 the heat recovered and reused, how much energy (Btu and dollars) and water (Btu and dollars) would the company save? The water costs \$1.00 per 1000 gal and sewage disposal is \$0.30 per 1000 gal. Fuel costs \$2.50/10⁶ Btu, and the boiler is 80% efficient. All the water can be used, and both systems are "up" all the time.

Cooling Tower

87. In our discussion on water management, we looked at air fin cooling of cooling water in lieu of, or in conjunction with, water towers.

Considering air fin cooling in conjunction with a water tower, there are two primary advantages or savings potentials. List those two.

Insulation

88. You are looking at a chilled water line (6 in.) in a process room. The water temperature is 47°F. The room temperature is 70°F with 40% relative humidity. How much fiberglass insulation with kraft-paper backing is required to avoid condensation?
89. For the insulation level determined above, what is the heat gain per hour?

Wind

90. A city is considering the use of wind-generated electricity for its local sewer treatment plant. There is a relatively steady load of 150 kW for 10 h per day. Assuming that the wind speed is a constant 15 mph, how many windmills 6 ft in dia would be required? Conversion efficiency is 65%?

Cogeneration

91. A typical steam turbine cogeneration system is shown below. What is the overall plant efficiency with and without the process load recovery?

92. For the system depicted above, what is the net economic worth to a company with the parameters given below? Assume the system is baseloaded 8760 h/yr.

Purchased electricity	\$0.3/kWh; \$5.00/kW-month
Fuel Cost	\$5.00/10 ⁶ Btu
Normal Boiler Eff.	(Process Load) 75%

EMCS

93. For Energy Management Control Systems, define
- A. Power Line Carriers
 - B. Direct Digital Control
 - C. Twisted Pairs
 - D. MUX
 - E. IMUX
 - F. FID
 - G. Optimal Start/Stop
 - H. Economizer (HVAC Operation)
 - I. Duty Cycling
 - J. Chilled Water Temperature Reset.

Electric Rate Schedule

94. Given the attached rate schedule, calculate the monthly electric bill for Ace Manufacturing as described below:

Month:	January
kWh consumed:	100,000
kW (peak actual):	1,500
Power factor:	70%
No direct current motors	

95. If _____ Power ratcheted demand 70% over the previous 12 mo, and the previous demands were 1500 kW, 1400 kW, 1300 kW, 1200 kW, 1000 kW, 2000 kW, 1000 kW, 1000 kW, 1200 kW, 1300 kW, 2200 kW, and 1300 kW, respectively, what is the demand charge?

What if _____ adjusts demand by penalizing for poor power factor (base = 80%). Using the ratio method we discussed in class, what is the demand charge (ignore ratchet)?

96. In conducting an audit for a manufacturing plant, you encounter a large industrial furnace with a closed firebox. You test the furnace and find the following parameters:

Stack Gas Temperature	600°F
O ₂ in stack gas	10% (by volume)
Furnace Operating Capacity	100 x 10 ⁶ Btu/hr
Fuel cost (natural gas)	\$5.00/mcf

97. Assuming the furnace above has been corrected to 10% excess air and you find 1000 lb/h of exhaust at 600°F, what would be the maximum savings (in dollars) if you installed some type of heat recovery device? Assume the fuel replaced is natural gas at the same price.
98. Recommend and justify a lighting source for the following situations. Assume electricity rates are relatively high in all cases.
- A. A large yarn manufacturer operates 24 h/day 365 days per year in a plant with a tall ceiling. The yarn is dyed various pastel colors that must be discerned.
 - B. A plant assembles components to a small chassis. The plant has a low ceiling and operates 8 h per day, 5 days per week.
 - C. A plant runs all the time. The ceiling is high, and the work is rough assembly with no color determination.
 - D. A large outdoor storage area needs light for security purposes only. No one works in the yard at night, but the lights must be on all the time.
99. Given the following diagram for percent constituents in flue gases, match the gases to the lines (i.e., show which is which).

100. List 3 ways (your university) might reduce its demand charge (assume no power factor penalty or ratchet clause).
101. Define energy management.
102. The walls of a furnace are metal painted a dull green. The surface temperature is 200°F. Calculate the heat loss per ft² and the yearly cost of the loss. What is a reasonable savings estimate for insulating that furnace?

Excess Air Control

103. You are considering a waste heat boiler for an aluminum-can melt furnace with a stack temperature of 1200°F. Flue gas measurement shows 4.5% O₂ under present conditions. The furnace has a rated 100 x 10⁶ Btu/hr capacity but operates at 75% load most of the time. The marginal cost for natural gas is \$3.00/thousand cubic feet. Show the savings if the furnace is adjusted for excess air control. The furnace operates 12 h/day, 250 days per year.

SELECTED ENERGY MANAGEMENT COURSES UNDERGRADUATE AND GRADUATE LEVEL

Several universities offer energy management courses. This section presents a brief description of the courses available, the prerequisites required, textbooks and references used, and course syllabi whenever available.

ENERGY COURSES AT TEXAS A&M

Texas A&M offers several energy management courses at both the undergraduate and graduate level. Some of the courses are presented as student syllabi, some include ABET information, and others appear in outline forms.^(a)

The 400-level courses are all offered as senior level electives. The 600-level courses are offered at the graduate level only. Texas A&M also offers energy-related courses in power engineering, solar energy, direct energy conversion, and combustion. Queries concerning courses offered at Texas A&M should be directed to Dr. Warren M. Heffington, Associate Professor and Assistant Department Head, Mechanical Engineering Department, College Station, TX 77843-3123.

The course outline for ME 436 "Heating, Ventilating, and Air Conditioning" is shown in Table 7. The text used in the course is listed at the bottom of the table.

Table 8 details "Principles of Building Energy Analysis," offered as ME 437, a three-credit class.

The syllabus for Mechanical Engineering 438 "Energy Conservation Industry and Commerce" is presented in Table 9. Four courses are offered at the graduate level: ME 661 "Energy Systems," ME 662 "Energy Management in Industry," ME 664 "Energy Management in Commercial Buildings," and ME 665 "Applications of

(a) Course syllabi and outlines were provided by W. M. Heffington, Associate Professor and Assistant Department Head, Texas A&M, Mechanical Engineering Department, College Station, Texas 77843-3123.

TABLE 7. ME 436: Heating, Ventilating, and Air Conditioning--Texas A&M

Class Period	Topic	Reading Assignment
1	Introduction/Overview	--
2	Refrigeration Equipment/Cycle	8.1 to 8.7
3	Refrigeration Cycle Review	15.1 to 15.3
4	Compressors	15.4
5	Control Valves, Real System	15.5 to 15.6
6	Absorption Refrigeration	15.7 to 15.11
7	Heating Equipment	lecture notes
8	Heating Equipment	lecture notes
9	Performance Calculation	lecture notes
10	Moist Air Properties	2.1 to 2.4
11	Conditioning Processes	2.5 to 2.7
12	Exam No. 1	
13	Fluid Flow/M Measurement	9.1
14	Centrifugal Pumps	9.2
15	Piping System Design	9.3 to 9.5
16	Room Air Distribution	10.1 to 10.3
17	Fans	11.1 to 11.2
18	Fans and Ducts	11.3 to 11.6
19	Duct Design: General	11.7 to 11.9
20	Duct Design: Low Velocity	11.10 to 11.11
21	Duct Design: High Velocity	11.12
22	Humidity Measurement	12.1 to 12.4
23	Exam No. 2	
24	Direct Heat and Mass Transfer	13.1 to 13.2
25	Cooling Towers	13.3
26	Heat Exchanger Design 1	14.1 to 14.3
27	Heat Exchanger Design 2	14.4 to 14.6
28	Heat Exchanger Design 3	14.7
29	Field Trip to HVAC Company	
30	Review/ASHRAE Meeting	
	FINAL EXAM	

Text: Heating, Ventilating, and Air Conditioning: Analysis and Design,
F. C. McQuiston and J. D. Parker, Wiley.

FINAL EXAM

TABLE 8. ME 437: Principles of Building Energy Analysis--Texas A&M

Catalog Data	ME 437: Principles of Building Energy Analysis. (3-0) Credit 3. Application of thermodynamics and heat transfer to the calculation of design space heating and cooling load; computer techniques for estimating annual energy consumption; design methods for reducing energy consumption
Textbook	Faye C. McQuiston and Jerald D. Parker, <u>Heating, Ventilating and Air Conditioning: Analysis and Design</u> , Second Edition, J. Wiley and Sons, 1982
Reference	ASHRAE Guides and Data Books, 1985
Coordinator	Dennis L. O'Neal, Assistant Professor of ME
Goals	To develop an understanding of methods used to estimate heating and cooling loads on buildings

Prerequisites by Topic

1. Thermodynamics
2. Fluid mechanics

Topics

1. Moist air properties and processes (2 classes)
2. Comfort and health (2 classes)
3. Heat transmission in building structures (4 classes)
4. Solar radiation (3 classes)
5. Infiltration (2 classes)
6. Heating loads (3 classes)
7. Steady-state cooling load methods (4 classes)
8. Transient cooling load methods (3 classes)
9. Energy estimating methods (3 classes)
10. Exams (2 classes)
11. Field trip/Professional meetings (2 classes)

Laboratory Projects

None

Estimated ABET Category Content

Engineering Science 1.5 credits or 50%
Engineering Design 1.5 credits or 50%

Energy Management." Student syllabi for the classes are presented in Tables 10, 11, 12, and 13. ME 661 details the various kinds of energy systems available or being developed. ME 662 concentrates primarily on the aspect of energy management in industry, ME 664 covers energy management in commercial buildings, and ME 664 indicates various applications of energy management.

TABLE 9. ME 438: Energy Conservation in Industry and Commerce--Texas A&M

Class Period	Reading Assignment	Subject
1	--	Introduction to industrial and commercial energy conservation
2	Chapter 1, pp. 1 to 13	Implementing an energy conservation program; careers
3	Chapter 2	Industrial and commercial energy systems; energy audit
4	--	Walk-through audit
5	Chapter 3	Electricity and rate structures
6	Chapter 3	Fossil fuels
7	Chapter 4	Energy conservation economics
8	Chapter 1, pp. 15-25	Energy accounting
9	Chapter 5	Lighting systems
10	Chapter 6	HVAC systems
11	Chapter 6	Building envelope
12	--	Hour Examination 1
13	--	Second law efficiency
14	Chapter 7	Fuels and combustion
15	Chapter 8	Combustion and boilers
16	Chapter 8	Boilers and other fired systems
17	Chapter 8	Steam and condensate systems
18	Chapter 8	Waste heat recovery
19	Chapter 8	Cogeneration
20	Chapter 8	Cogeneration
21	--	Hour Examination 2
22	--	Electrical considerations
23	--	Electric motors and circuits
24	Chapter 9	Computer control systems
25	Chapter 10	Maintenance
26	--	Hour Examination 3
27	Chapter 11	Insulation
28	Chapter 12	Process energy management
29	Chapter 12	Process energy management
30	--	Review for final examination

Textbook: Energy Management, by William J. Kennedy, Jr. and Wayne C. Turner, Prentice-Hall, 1984.

TABLE 10. ME 661: Energy Systems--Texas A&M

- I. Introduction
 - A. The relationship of energy consumption to standard of living
 - B. History of energy consumption and future projections
 - C. Energy sources, prices, and availability
- II. Fuel supplies
 - A. Natural gas
 - B. Petroleum
 - C. Coal
 1. Government policy and mining restrictions
 2. Western coal supplies
 3. Coal storage
 4. Converting to coal
 5. Coal gasification
 5. Coal conversion
 - D. Electric utilities
- III. Environmental considerations
 - A. SO₂ control
 - B. Particulate control
 - C. Scrubbers
 - D. NO_x control
 - E. Thermal pollution
 - F. Environmental constraints on plant location
- IV. Financial and other considerations
 - A. Capital formation
 - B. Tax policy
 - C. Occupational safety - OSHA rules and regulations
 - D. Codes and standards
- V. Nuclear power
 - A. Basics of nuclear power
 - B. Nuclear power plants
 - C. Nuclear plant regulation
 - D. Delays in development
- VI. Development of new concepts
 - A. Financing new concepts
 - B. Oil shale development
 - C. Waste utilization
 - D. Integrated utility systems
 - E. Heating and Cooling districts
- VII. Thermodynamics
 - A. Review of concepts
 - B. Second law limitations on energy conversion
- VIII. Efficient energy utilization
 - A. Heating and cooling systems
 - B. Heat rejections systems
 - C. Solar energy
 - D. Integrated utility systems
 - E. Energy conservation
- IX. Special topics
 - A. Oil shale, tar sands, geothermal
 - B. Politics in the Mideast
 - C. Safety
 - D. Student presentations

TABLE 11. ME 662: Energy Management in Industry--Texas A&M

<u>Class Period</u>	<u>Subject</u>
1	Organization and Introduction
2	Careers, implementation of energy management
3	Energy audits
4	Energy audits - walk-through audit
5	Results of walk-through, energy accounting
6	Energy management economics
7	Energy sources
8	Combustion and boilers
9	Boilers and other fired systems
10	Prime movers
11	Steam and condensate systems
12	Waste heat recovery
13	Industrial insulation
14	Electrical considerations
15	Electrical systems - motors and circuits
16	Midterm examination
17	Building envelope, lighting, HVAC
18	Air systems, maintenance
19	Energy audits - instruments, instructions and forms
20	Energy audits - students' present plans
21	Energy management control systems
22	Audit results discussion, reporting
23	Cogeneration
24	Process energy management
25	Thermodynamic considerations
26	thermodynamic considerations
27	Audit results and student presentations
28	Field trip
29	To be announced
30	Energy management program establishment, wrapup, and review
	Final exam, 2 hours

Textbook: Energy Management Handbook, Wayne C. Turner John Wiley
& Sons (Wiley-Interscience), 1982.

TABLE 12. ME 664: Energy Management in Commercial Buildings--Texas A&M

OBJECTIVES: To familiarize students with: a) energy-using equipment and systems in commercial buildings, b) ways to improve energy efficiency in this equipment, and c) energy economics procedures.

Class Period	Topic
1	Introduction 1. Course outline, requirements 2. Energy use in commercial buildings <ul style="list-style-type: none"> a. types of energy-using equipment b. types of buildings in commercial sector c. recent trends in commercial energy use
2 to 3	Energy Economics 1. Analysis of energy bill - energy, power, power factor 2. Economic analysis procedures <ul style="list-style-type: none"> a. time value of money b. simple payback c. discounted payback d. life-cycle costs
4 to 5	Estimating Annual Energy Use/Demand 1. New buildings: modeling energy use/comparisons Measurement methods <ul style="list-style-type: none"> a. single measurement methods b. bin method c. hourly method 2. Audits in commercial buildings: audit procedures, what to look at and for, and expected results
6 to 7	Lighting Systems 1. Significance of lighting on energy use 2. Definitions of lighting terms (footcandle, lumen) 3. types of lights: efficacy and applications, e.g., fluorescent, incandescent, sodium 4. New lighting technologies and their applications, e.g., photocells, solid-state ballasts
8	DDC Presentation by private company in Dallas
9 to 10	Energy Management Symposiums Attendance at commercial-building-related paper sessions and seminars
11	Electric Motors 1. Applications of electric motors, e.g., fans, compressors, 2. Types of motors, a discussion of starting characteristics, efficiency, power factor, and part-load characteristics 3. Typical economics of electric motors
12 to 15	Air Distribution Systems 1. Overview of systems and energy-using characteristics including <ul style="list-style-type: none"> a. single-zone b. variable air volume c. reheat d. dual duct 2. Psychrometrics review 3. Duct design 4. Fans, including <ul style="list-style-type: none"> a. types and characteristics b. applications: fan laws c. energy use 5. Air flow measurement

TABLE 12. (contd)

Class Period	Topic
16 to 17	<p>Project No. 1: Presentations</p> <p>Topic: recent energy management applications in commercial buildings</p> <p>Requirement: a written report and a 20-minute oral presentation summarizing 4 or more papers or articles all on the same theme (e.g., heat pump applications, retrofits)</p>
18 to 19	<p>Water Distribution Systems</p> <ol style="list-style-type: none"> 1. Types of systems: 2-pipe, 3-pipe, and 4-pipe 2. System sizing and balancing 3. Pumps, including characteristics and sizing
20 to 21	<p>Refrigeration Plant</p> <ol style="list-style-type: none"> 1. Chillers - sizes, typical performance <ol style="list-style-type: none"> a. centrifugal b. reciprocating c. screw d. absorption 2. Single package systems
22 to 23	<p>Control Systems</p> <ol style="list-style-type: none"> 1. Role of controls in energy management 2. Types of control strategies: on-off and proportional (integral and derivative) 3. Typical transient performance of components <ol style="list-style-type: none"> a. valves and dampers b. heat exchangers c. thermostats 4. Energy management control systems--types and applications
24 to 26	<p>Energy Recovery Systems</p> <ol style="list-style-type: none"> 1. Typical applications 1. Types of systems <ol style="list-style-type: none"> a. fixed, rotating, etc. b. heat recovery and enthalpy recovery 3. Calculating sizing, performance, and economics
27 to 28	<p>Thermal Storage Systems</p> <ol style="list-style-type: none"> 1. Typical applications 2. Types of systems. Discussion of heating applications and cooling applications 3. Calculation of performance
29 to 30	<p>Project No. 2 Presentations</p> <p>Topic: Probably use DOE 2.1B to model a simple commercial building. Evaluate prospective retrofit possibilities.</p> <p>REQUIREMENTS: Written report and 20- to 25-minute oral presentation</p>

TABLE 13. ME 665: Applications of Energy Management

- I. Load Calculation Fundamentals
 - A. Design building loads
 1. heating load
 2. cooling load
 - B. Building energy analysis
 1. transfer function method
 2. commonly used algorithms
 2. state-of-the-art programs
- II. C. Development of a system energy model
- II. Energy Audit Analysis
 - A. Steam generation and use
 - B. Process heating
 1. design and control
 2. heat recovery
 - C. HVAC
 1. lighting loads
 2. comfort conditioning
 3. ventilation requirements
 - D. Prime mover energy consumption
 1. pumps
 2. fans

UNIVERSITY OF FLORIDA - INDUSTRIAL ENERGY MANAGEMENT COURSE

The University of Florida offers one course in industrial energy management.^(a) Prerequisites include junior level standing and courses in physics, calculus, engineering economy, and thermodynamics. Topics covered in the course include:

- energy supply and demand
- the National Energy Act
- energy audits
- energy conservation and management
- alternative energy sources
- investment analysis
- the energy future.

(a) Dr. B. L. Capehart, Department of Industrial Engineering, University of Florida, provided information concerning this course.

Application areas for this course include homes, institutions, businesses, large buildings, and industry. The emphasis is the appliance of energy conservation. Guest speakers from other departments and from industry give students the opportunity to hear "real world" energy applications. Previous guest speakers for the class have included lighting design consultants, utility energy conservation representatives from utilities, and a phosphate industry energy manager.

EIN 4321 presents both the current energy picture and the trends for the future. The following objectives are listed for the class:

- to enable the student to understand the basic energy picture and where the world is heading
- to enable the student to review basic energy-related sciences
- to enable the student to understand the methods of energy management in homes, institutions, businesses, large buildings, and industry
- to enable the student to understand the realistic potential of renewable energy sources by listening to speakers, researching, and formulating their own opinions
- to enable the student to develop an overall energy awareness and a conservation ethic.

A course outline is shown in Table 14. Grading in the course was done on the following basis:

• Exam No. 1	20%
• Exam No. 2	25%
• Exam No. 3	25%
• Audit report and case study	20%
• Homework assignments	10%

TABLE 14. EIN 4321: Industrial Energy Management--University of Florida

- I. Introduction
 - A. Need for energy management and conservation
 - B. Energy supply demand data
 - C. Projections on our energy future
- II. Energy Economics
 - A. Economic decision criteria
 - B. Energy pricing structures
 - C. Energy-conservation investment analysis
- III. Energy Audits
 - A. NECPA and residential conservation service
 - B. Schools and hospitals audit program
 - C. Industrial audits
- IV. Energy conservation and use legislation
 - A. EPCA and ECPA
 - B. NEA 1978
 - 1. Power Plant and Industrial Fuel Use Act
 - 2. PURPA
 - 3. Energy Tax Act
- V. Energy Management Systems
 - A. Monitoring and control functions
 - B. Lighting, HVAC, demand leveling
 - C. Research in optimum scheduling for cost minimization
- VI. Other Tools
 - A. Lighting and lighting design
 - B. Heating and cooling load calculations
 - C. Insulation cost and benefits
- VII. Waste Heat Recovery
 - A. Waste heat boilers
 - B. Cogeneration
 - C. Topping and bottoming cycles
 - D. Total energy-system case study
- VIII. Commercial Energy Management
 - A. Energy use characteristics
 - B. Lighting, HVAC systems, boiler efficiency
 - C. Case studies--grocery store, fast food establishment
- IX. Inspection Tours
 - A. Natural gas liquids plant
 - B. University heat plant
 - C. University energy management computer
 - D. University solar research park
- X. Guest Speakers
 - A. Lighting design consultant
 - B. Utility energy conservation representative
 - C. Phosphate Industry energy manager

COURSES AT CALIFORNIA STATE POLYTECHNIC UNIVERSITY

California State Polytechnic University at Pomona offers ME 306 "Energy Management."^(a) The course covers the history of energy management, strategies used in efficient management, HVAC, lighting, electrical power, sources of energy, automation systems, sources of energy, economics, and energy and the environment. Tables 15 and 16 detail the course outline, outlines of the required texts and appendices, and a list of references used in the course.

TABLE 15. ME 306: Energy Management--California State Polytechnic University

<u>Class Session</u>	<u>Topic</u>	<u>Reading Assignment</u>	<u>Other Assignments</u>
1	Introduction	None	None
2	Past, Present and Future	Chapters 1 and 2	SP-1 and 2
3	Strategies	Chapters 3 and 4	SP-3
4	Strategies	Chapters 5 and 6	SP-4 and 5
5	Total Energy Management	Chapter 7	SP-6
6	TEM Surveys	Chapter 7	SP-7 and 8
7	Thermodynamics	Chapter 8	Audit Report No. 1
8	Heat Transfer	Chapter 9	SP-9, 10 and 11
9	Building Structure and Systems	Chapter 10	SP-12
10	Special Systems and Processes	Chapter 11	SP-13 and 14
11	Heating and Ventilating	Chapters 12 and 13	Audit Report No. 2
12	Air Conditioning Systems	Chapter 14	SP-15 and 16
13	Survey of a Campus Building	None	Update/Supp Report
14	Refrigeration	Chapter 15	SP-17 through 25
15	Lighting and Electrical Power	Chapters 16 and 17	Audit Report No. 3
16	Automation Systems	Chapter 18	Sp-26 through 35
17	Survey of a Campus Building	None	SP-36
18	Energy Economics	Chapter 19	None
19	Sources of Energy	Chapter 20	Audit Report No. 4
20	Energy and the Environment	Chapter 21	Course Evaluation

Text: Readings for ME 306, Energy Management.

(a) Course information was provided by Dr. Douglas Dowell, California State University, Pomona, California.

TABLE 16. Text Contents--Readings for ME 306--California
State Polytechnic University

Chapter	Title	Page
1	Energy Management	1-1
2	Energy Data, Problems and Management	2-1
3	Past, Present and Future	3-1
4	Energy Strategies	4-1
5	Personal Strategies	5-1
6	Government Strategies	6-1
7	Total energy Management	7-1
8	Energy and Thermodynamics	8-1
9	Heat Transfer	9-1
10	Building Structure and Systems	10-1
11	Special Systems and Processes	11-1
12	Comfort Heating Systems	12-1
13	Ventilation	13-1
14	Air-Conditioning Systems	14-1
15	Refrigeration Systems	15-1
16	Lighting Systems	16-1
17	Electrical Power	17-1
18	Energy Management Automation Systems	18-1
19	Energy Economics	19-1
20	Sources of Energy	20-1
21	Energy and the Environment	21-1
--	Appendices	A-1

Appendices

1. Excerpt from the California Energy Commission, Energy Conservation Manual for New Residential Buildings
2. Home Energy Manual
3. Excerpt from the California Energy Commission Energy Auditor Training Manual
4. Southern California Edison: If This Number Is Too High
5. Southern California Gas Company: Free Do-It-Yourself Energy Survey Questionnaire
6. San Diego Gas and Electric: Little Things Do Count
7. Los Angeles Department of Water and Power: Optimum Energy House
8. Southern California Edison: How to Beat the Heat
9. Southern California Edison: Join the Conservation Generation
10. Shell Oil Company: Conservation Payback
11. Shell Oil Company: The Conservation Bonus
12. Discount Factors
13. UPW Factors Modified for Energy Price Escalation
14. Data and Control Points for Various HVAC Systems

TABLE 16. (contd)

References

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26. Plugging Cogeneration into the Grid. July/August 1981. EPRI Journal.
27. Introduction to Automation Systems. December 1983. Southern California Edison Training Manual.
28. Handbook 132. Date? National Bureau of Standards.
29. Ruegg and Marshall. July 1981. "Economics of Building Design." Solar Age.
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32. Controls Division, Butler Manufacturing Company. January 1986. Facilities Management Systems.

COURSES AT LOUISIANA TECHNICAL UNIVERSITY

Prerequisites for Mechanical Engineering 438 "Industrial Energy Conservation" include Chemical Engineering 321 or Mechanical Engineering 331. The course offered at Los Angeles Technical Institute stresses identification and analysis of energy conservation opportunities in the manufacturing and process industries. As a part of the course, each student visits an industrial plant, participates in the identification and analysis of energy conservation opportunities, and prepares a report.

A syllabus for the class is presented in Table 17. In order to share the knowledge gained from individual studies, each student is expected to present an oral report.^(a)

The course covers the following areas:

- energy sources and rate structures
- combustion (analysis, fired equipment, controls)
- waste heat recovery
- steam systems
- electrical equipment (motors, power factor, demand control)
- compressed air systems
- insulation
- heating, ventilating, and air conditioning
- lighting
- cogeneration
- energy management systems
- energy conservation survey (energy usage analysis, plant survey, data gathering and measurements, analysis, and reporting).

(a) Course information was provided by Dr. James Lowther, Mechanical Engineering, Louisiana Tech.

TABLE 17. ME 438: Industrial Energy Conservation--Louisiana Technical University

Class Period	Topic	Reading	Assignment Written
1	Introduction	Chapters 1 and 2	
2	Cost Estimate Rate Structures	Chapters 3, 4.0 and 4.1	
3	Rate Structures		
4	Combustion	Chapter 7	
5	Combustion		
6	Waste Heat Recovery	Chapter 9.2	
7	Test 1		
8	Steam Systems	Chapters 8.1, 8.3 through 8.5	
9	Electrical Systems Motors		
10	Electric Furnaces		
11	Power Factor, Demand Control		
12	Lighting	Chapter 5	
13	Compressed Air Systems		
14	Test 2		
15	Energy Conservation Survey	Chapters 2 and 12	
16	Measurements		
17	Audit Visit		
18	Audit Visit		
19	Analysis	Chapters 4.2 through 4.5	
20	Audit Visit		
21	Insulation	Chapter 11	Preliminary ECO Rots
22	HVAC Systems	Chapter 6	
23	HVAC Systems		
24	Analysis		
25	Energy Management Systems	Chapter 9	ECOs (1st Draft)
26	Cogeneration		
27	Cogeneration		
28	Oral Reports	ECOs (Final)	ECOs (Final)
29	Oral Reports		
30	Test 3		

Text: Kennedy, W. J. and W. C. Turner. 1984. Energy Management. Prentice Hall, Englewood, Cliffs, New Jersey.

COURSES AT THE UNIVERSITY OF KANSAS

ME 729 "Introduction to Energy Management," a semester class, was designed to enable students to recognize and evaluate energy management opportunities in manufacturing plants. Students participate in four all-day energy audits and report on these. ME 612 "Heat Transfer" is a prerequisite for this class.^(a)

Grading for the course was done on a point system. Each of the four field trips was weighted at 100 points for a total of 400 points. The one project report was weighted at 50 points. Table 18 details the course outline.

TABLE 18. ME 729: Introduction to Energy Management--University of Kansas

<u>Period</u>	<u>Topic</u>	<u>Text Reading</u>
1	Startup	
2	Startup	
3	Lighting: Lamp characteristics, efficacy, replacement frequency	Chapter 2, p. 42 Chapter 5, pp. 90-109
4	Lighting (Continued): Implementation costs, life-cycle costs, calculations	Chapter 12, pp. 231-240
5	Lighting (Continued): Sensors, audit procedure	
6	Infiltration: Theory, calculations, Implementation costs, audit procedure	
7	Infiltration (Continued)	
8	Domestic Hot Water: Reduce temperature, switch from electric to gas heat, calculations, audit procedure	
9	Insulation: Types, temperature ranges, conductivities, costs, optimal thickness, liquid surface energy loss, operating temperature reduction, audit procedure. Audit Field Trip	Chapter 8, p. 161 Chapter 11
10	Compressed Air: Compressor heat recovery, outside air, pressure reduction, scheduling and load control, filters, air-leaks, audit procedure. ECOs and audit report preparation	
11	Compressed Air (Continued)	
12	Combustion Equipment: Boilers and furnaces, flue gas analysis, air-fuel ratio control, stack dampers, turbulators, stack heat recovery, preheat combustion air, audit procedure. ECOs and audit report preparation	Chapter 7 Chapter 8
13	Combustion Equipment (Continued)	

(a) Dr. Louis Burmeister, Department of Mechanical Engineering, University of Kansas, provided the course information.

TABLE 18. (contd)

Period	Topic	Text Reading
14	<u>Boilers: Blowdown control and heat recovery, condensate return, preheat makeup and feed water, water treatment, steam traps, steam leaks, boiler and steam line insulation, audit procedure. Audit Field Trip</u>	
15	<u>Boilers (Continued): ECOs and audit report preparation</u>	
16	<u>Boilers (Continued)</u>	
17	<u>Synthetic Lubricants: Types, cost, applications, audit procedure. Fans: fan laws, variable speed control, ventilation time and rate reduction, paint booths</u>	Chapter 6, p. 124
18	<u>Synthetic Lubricants (Continued):</u>	
19	<u>Exhaust Heat Recovery: Gases, liquids, cost</u> <u>Air Cleaners: ECOs and audit report preparation</u>	Chapter 8, pp. 165-168 Chapter 12, pp. 227-231 and 240-241
20	<u>Air Cleaners (Continued):</u>	
21	<u>Cogeneration</u>	Chapter 8, pp. 172-175 Chapter 3, p. 67
22	<u>Cogeneration (Continued)</u>	
23	<u>Utility Data: Plots, information from U-Data, examples, quick calculations and formulas</u>	
24	<u>Utility Bills: Structure, demand cost and its control, power factor correction and cost</u>	Chapter 3 Chapter 4
25	<u>Thermostat Control: Weather data, building load and energy calculations, heating and cooling degree hours, setup and setback</u>	Chapter 6
26	<u>Thermostat Control (Continued): Destratification, computer program, audit procedure. Audit Field Trip</u>	
27	<u>Thermostat Control (Continued): ECOs and audit report preparation</u>	
28	<u>HVAC Equipment: Chillers, controls, economizers, dirty coils, air-handler cabinet leakage</u>	
29	<u>HVAC Equipment (Continued)</u>	
30	<u>ECOs and audit report preparation</u>	
31	<u>Alternative Energy Sources: Wood, solar, waste</u>	Chapter 13
32	<u>Alternative Energy Sources (Continued): Completed Audit Report</u>	
33	<u>ECOs and audit report preparation</u>	
34	<u>Process Energy Conservation Opportunities, Control Systems Maintenance</u>	Chapters 9, 10
35	<u>Continued</u>	
36	<u>Utility Data Reduction: Example of computer program use</u>	
37	<u>Cogeneration</u>	

TABLE 18. (contd)

Period	Topic	Text Reading
38	<u>Project Reports</u>	
39	Contingency	
40	Contingency	

Text: Kennedy and Turner. 1984. Energy Management, Prentice-Hall.

UNIVERSITY OF UTAH-INDUSTRIAL ENERGY MANAGEMENT

The University of Utah offers Industrial Engineering 579 "Energy Management." Students must have previously completed courses in chemistry, thermodynamics, and engineering economy.^(a)

An energy audit, estimation of cost savings, cash flow analyses, examination of industrial energy systems, waste heat recovery, and boiler efficiency comprise the major topics covered in this class.

An outline of the course and the topics covered during each class period are shown in Table 19. Three tests, homework assignments, and an energy audit have all been weighted equally in grading the class.

When students have successfully completed Industrial Engineering 579, they should be able to perform the following:

1. Do a thorough energy audit of an industrial facility, complete with a report of the findings and of possible cost savings or production improvements, in a form that is technically correct and easily understood.
2. Estimate the cost savings possible from these measures: inside and outdoor relamping, boiler combustion improvements, pipe insulation, waste heat recovery, HVAC system improvements, rescheduling, motor rewinding, and maintenance improvements.
3. Perform a technically correct after-tax, after-inflation discounted cash flow analysis of a proposed energy management project.
4. Develop, initiate, and monitor a maintenance improvement program intended to reduce energy costs.
5. Describe techniques for examining each of these systems: lighting, HVAC, electrical, boiler and steam distribution, hot water, compressed air distribution, envelope, and general industrial process.
6. Perform a heat balance for use in determining potential for waste heat recovery and process improvement.

(a) Dr. W. J. Kennedy, University of Utah, Industrial Engineering Department, provided the information on IE 579.

TABLE 19. Industrial Engineering 579--University of Utah

<u>Class Session</u>	
1	The energy audit process. Analysis, Action, Monitoring. The report format: Introduction, graphics, methodologies, Electricity, and natural gas costs. Power and load factors. Estimating first-year cost savings. Problems: Numbers 1 and 2
2	Weighing costs versus benefits. Simple payback. Engineering economy techniques with inflation and taxes. The effect of ACRS. Problems 3 and 4.
3	The major systems and how to evaluate them. Problems 5 and 6
4	One hour test. Estimating first-year cost savings from various improvements: lighting, boiler improvements, waste heat recovery, rescheduling, motor rewinding. Problems 7 and 8
5	Lighting systems. Kinds of lamps. Desirable lighting levels, indoor and outdoor lighting. Color rendition, maintenance, the building envelope, physical and psychological factors. Problems 9 and 10
6	Energy audit of an industrial facility. Assignment: Energy audit report by teams.
7	HVAC systems. Kinds of HVAC systems, controls, estimating heating and cooling loads, energy improvements. Problems 11 and 12
8	Boilers, industrial processes, and flue gas analysis. Estimating efficiency from flue gas analysis. Problems 13 and 14
9	One-hour test on material. The steam distribution system. Problems 15 and 16
10	The heat balance as an analytical tool. Calculating inputs and outputs, finding improvements, presenting results. Problems 17 and 18
11	Insulation and waste heat recovery, developing and maintenance program. Problems 19 and 20
12	Designing, initiating, and managing an energy management program
13	Final examination. Comprehensive, 3 hours

Text: Turner, Wayne et al. 1982. Energy Management Handbook, Wiley/Interscience, New York.

7. Analyze the composition of flue gas coming from a fuel with known proximate analysis in order to determine boiler efficiency.

UNIVERSITY OF CINCINNATI--ENERGY MANAGEMENT/AUDITING CURRICULUM

The University of Cincinnati offers a certificate in Energy Management/Auditing Technology for students who have already earned a bachelor's degree or who are enrolled and actively pursuing a bachelor's degree. Requirements, a description of the technical core and three course syllabuses are shown in Tables 20 to 23.^(a)

(a) Information on the Energy Management/Auditing Technology program at the University of Cincinnati was provided by University College, Mathematics and Applied Sciences Department, Cincinnati, Ohio 45221.

TABLE 20. Energy Management/Auditing Technology--University of Cincinnati

Technical Core

REQUIREMENTS

Students must take a minimum of twenty-seven (27) quarter credit hours of courses from the Energy Management/Auditing Technology core of courses. The specific program for each student will be developed in consultation with the Program Coordinator. An assumption of the program is that students from the College of Engineering shall have different educational needs and interests than students from the College of Business Administration or the College of Design, Architecture and Art, etc. A maximum of three (3) quarter credit hours in the program may be awarded as advanced standing for courses taken outside of the University College.

See approved core courses.

- 17-241-191 Energy Resource Technology. General overview of world, national, and regional energy situation and its implication for enterprise or institutional management. Discussion of present and future utilization for various energy sources will be featured.
6 ug/cr
- 17-241-184 Electrical Energy Systems. Comparative study of electrical power distribution and area illumination systems for commercial, institutional, and industrial facilities. Discussion of various system design concepts will be emphasized.
6 ug/cr
- 17-241-174 Mechanical Energy Systems. Comparative study of heating, ventilating, and air conditioning systems for commercial, institutional, and industrial facilities. Discussion of various system design concepts will be emphasized.
6 ug/cr
- 17-241-271 Energy Systems Laboratory. Energy analysis presentation; correct use of drafting equipment in producing clear, precise, and attractive drawings. (6 contact hours)
3 ug/cr
- 17-241-272 Independent Study in Energy Management. Individual research and work for students related to career development in Energy Management/Auditing Technology.
3 ug/cr
- 17-241-284 Solar Energy Systems. Comparative study of the application of active and passive solar energy systems to residential and commercial structures. Discussion of various system design concepts will be featured.
6 ug/cr
- 17-241-273 Energy Auditing Procedures. Methods of conducting energy use surveys in commercial, institutional, and industrial facilities. Practical experiments in measuring building energy consumption and distribution will be performed. Use of energy metering and instrumentation will be demonstrated.
6 ug/cr
- 17-445-204 Data Processing for Energy Management I, II, III. Introduction to computers and computer systems, numeric bases used in computers, flowcharting, programming using BASIC, FORTRAN, and COBOL. To be taken sequentially or with permission of instructor.
205
206
3 ug/cr

TABLE 21. Mechanical Energy Systems--University of Cincinnati

Course No. 17-241-174

Course Description: A comparative study of heating, ventilation, and air-conditioning systems for commercial, institutional, and industrial facilities

The course will start with the basic concepts of heating, ventilating, and air-conditioning systems. The terms used to describe these systems will be discussed. Basic concepts of heat gain and heat loss calculations will be presented and problems in the calculation of these concepts will be developed and problems assigned.

Various types of heating systems will be discussed and methods of heat distribution. Air-conditioning systems will be studied including refrigeration. Concepts on comfort heating and cooling using various types of temperatures will be learned.

Ideas and concepts of energy management of these various systems will be presented.

Course Evaluation:

The following criteria will be used in determining final grades for this course:

Assignments 4 @ 50	200 points
Mid-term exam	300 points
Final exam	500 points
Total	1000 points

Course Outline

Class Session	Topic	Assignment
1	Introduction and General Discussion	--
2	Environmental Comfort	4.1 to 4.12
3	Heating Losses	4.13 to 4.19
4	The Arkansas Story	4.23
5	Heat Gains	4.24 to 4.27
6	Heating Systems	5.1 to 5.3
7	Warm Air Heating	5.4 to 5.6, 5.9
8	Hot Water, Steam and Central Heating Systems	5.7 to 5.8
9	Cooling Systems	5.10 to 5.13
10	Heat Pumps	5.14 to 5.16
11	Mid-Term	
12	Ventilation	5.17 to 5.18
13	Terminal Reheat Systems	
14	Variable Air Volume Systems	5.17
15	Environmental Planning	6.1, 6.8
16	Climate Control Systems	7.1 to 7.6
17	All-Electric Systems	7.9
18	Solar Energy and Energy Conservation	8.1 to 8.6
19	Solar Heat Pump	8.6
20	Energy Conservation in Design and Operation of Mechanical Systems	8.10

Text: McGinness, W. J., B. Stein, and John S. Reynolds.
Mechanical and Electrical Equipment for Buildings.

In addition to the above reading assignments starting with the third week and every other week thereafter, a problem will be assigned covering material that has been discussed in previous class sessions. The problems will be due one week after they are assigned.

TABLE 22. Electrical Energy Systems--Course No. - 17-241-184--
University of Cincinnati

Course Outline

1. -- Concepts of Energy
2. Chapter 1 Energy Sources for Buildings
3. Chapter 2 Climate and the Site
4. Chapter 3 Energy and Architectural Design
5. Chapter 14 Principles of Electricity
6. Chapter 18 Lighting Fundamentals
7. Chapter 19 Light Sources
8. First Exam February 11, 1986 (50% of grade for quarter)
9. Chapter 20 Lighting Design
10. Chapter 21 Lighting Applications
11. Chapter 17 Electrical Wiring Design
12. Chapter 15 Electrical Systems and Materials
13. Chapter 16 Electrical Systems and Materials
14. Second Exam Finals Week (50% of grade for quarter)

Text: McGuinness, W. J., B. Stein, and John S. Reynolds.
Mechanical and Electrical Equipment for Buildings.
6th Ed., John Wiley and Sons.

TABLE 23. Energy Resource Technology--Course No. - 17-241-191--
University of Cincinnati

Textbook--None (Exams will be based solely on materials covered in lectures)
Exams--Closed book and no reference to lecture notes
Attendance--No specific penalties for missed classes

Course Outline

1. Introduction to Energy Resource Technology
2. Fossil Fuels Technology
 - a. coal
 - b. petroleum
 - c. natural gas
 - d. nuclear energy
3. Steam Generation
4. First Exam - 50% of final grade
5. Renewable Resources Technology
 - a. wood
 - b. hydropower
 - c. tidal power
 - d. geothermal
 - e. chemical fuels
 - f. ocean thermal conversion
 - g. windpower
 - h. satellite power
6. Electrical Energy
7. Solar Energy
8. Energy Management as a Resource
9. Second Exam - 50% of final grade

CONTINUING EDUCATION COURSES

Several universities and colleges offer energy management courses through their continuing education programs. These courses are often aimed at two distinct groups of individuals. One type of course is specifically directed toward the practicing professional in such disciplines as engineering, architecture, or physical science.

Another type of course trains high school graduates for entry-level positions with constructions, engineering, and architectural firms.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Virginia Polytechnic institute and State University offers an Energy Management Diploma Program with continuing education (CE) credit. The four courses offered in this program are 1) EM1 Organized approach to Managing Energy, 2) EM2 Developing a Cost-Effective Energy Project Inventory, 3) EM3 Energy Systems, and 4) EM4 Energy Design and Analysis. A detailed outline of course topics is given in Table 24.^(a)

(a) Information from Virginia Polytechnic Institute and State University was provided by Dr. W. H. Mashburn, Department of Mechanical Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

TABLE 24. Energy Management Diploma Program--Virginia Polytechnic Institute and State University

<u>EM1 Organized Approach to Managing Energy</u>	<u>EM2 Developing a Cost-Effective Energy Project Inventory</u>
Steps in Developing an Energy Management Program <ol style="list-style-type: none"> situation reporting organization budget audits economic analysis selling the program using consultants educational goals strategic planning 	Energy Cost and Availability <ol style="list-style-type: none"> review of current estimates and forecasts cost and availability workshop
Group Dynamics <ol style="list-style-type: none"> Identifying barriers workshop problem solving 	Understanding Electrical Costs <ol style="list-style-type: none"> demand kW-h power factor motors lighting utility rates
Profile of a New Corporate Program <ol style="list-style-type: none"> organization strategy reporting successful projects 	Utility Load Management <ol style="list-style-type: none"> economic dispatching load management hands-on simulator
EM Computer Selection Process <ol style="list-style-type: none"> defining needs vendor selection installation follow-up 	Energy Audits <ol style="list-style-type: none"> types team selection climatic data energy equations energy index
Personal Computer for Reporting <ol style="list-style-type: none"> spread sheet file systems word processing hands-on experience 	Industrial Audit Process <ol style="list-style-type: none"> consulting arrangement case history
Energy Strategic Planning <ol style="list-style-type: none"> components of a strategic plan a successful corporate program developing key issues - workshop 	Industrial Audit <ol style="list-style-type: none"> case history
A Corporate Tuning-Operations-Maintenance Program <ol style="list-style-type: none"> identifying TOM Opportunities coordinating with energy surveys economics of TOM 	Walk-Through Audit <ol style="list-style-type: none"> audit of local industrial plant
Organization and Implementation of EM <ol style="list-style-type: none"> basic organization role of the plant energy coordinator successful projects 	Economic Evaluation <ol style="list-style-type: none"> time value of money payback return on investment life-cycle costing internal rate of return
Utility Monitoring and Reporting <ol style="list-style-type: none"> evolution of MRS establishing and justifying the MRS practical examples 	Workshop <ol style="list-style-type: none"> preparation of audit report
Information Sources <ol style="list-style-type: none"> publications associations people 	
Round Robin Workshops <ol style="list-style-type: none"> successful projects problem solutions 	

TABLE 24. (contd)

EM 3 Energy Systems	EM4 Energy Design and Analysis
Industrial Ventilation <ul style="list-style-type: none"> a. basic fan laws b. characteristics of axial flow fans c. characteristics of centrifugal fans d. ventilation problems 	ASHRAE Calculations <ul style="list-style-type: none"> a. degree-day method b. BIN method c. load profiles
Controls for Improving Energy Efficiency <ul style="list-style-type: none"> a. basic control theory b. controlling the primary equipment c. controls for energy conservation 	Computerized Energy Analysis <ul style="list-style-type: none"> a. programs available b. program comparison
Heating, Cooling, Refrigeration <ul style="list-style-type: none"> a. psychometrics b. air conditioning fundamentals c. load estimating d. systems 	Boiler Optimization <ul style="list-style-type: none"> a. efficiency determination b. multiple operation
Motors <ul style="list-style-type: none"> a. fundamentals b. types and efficiencies c. efficient motor selection d. upgrading program 	Chiller Operation <ul style="list-style-type: none"> a. theory of operation b. efficiency c. multiple operation
Lighting <ul style="list-style-type: none"> a. design b. efficient sources c. switching d. maintenance e. energy conservation opportunities 	Performance Analysis <ul style="list-style-type: none"> a. data typically available b. engineering analysis c. economic evaluation
Compressed Air Systems <ul style="list-style-type: none"> a. energy consumption b. compressor selection c. system conservation 	Cogeneration <ul style="list-style-type: none"> a. cogeneration cycles b. fuels c. generating sets d. strategies e. economics
Boilers <ul style="list-style-type: none"> a. types and selection b. efficiencies c. controls 	Energy Analysis and Case Histories <ul style="list-style-type: none"> a. heating and refrigeration processes b. tuning, operation and maintenance c. project identification
Treatment <ul style="list-style-type: none"> a. water properties b. energy considerations c. boilers d. cooling towers 	Workshop <ul style="list-style-type: none"> a. discussion of successful projects

ENERGY MANAGEMENT SERIES - UNIVERSITY OF WISCONSIN

The College of Engineering at the University of Wisconsin-Madison has developed a series of four one-week courses. An Energy Management Diploma is available to qualified individuals who complete all four courses. Instructors include practicing energy managers, management consultants, and engineers. Participants earn continuing education units (CEU).

Courses are presented in a workshop format and are limited to no more than 30 students. Participants are encouraged to share work experiences that relate to course topics.

Energy Management Diploma candidates are required to have professional registration or a B.S. degree in engineering, architecture, or a physical science. Individuals who cannot meet the prerequisites but who have previous energy or engineering experience may inquire about their eligibility.^(a) Previous engineering or management experience is especially helpful.

The University of Wisconsin describes these courses to students in their "Energy Management Series" brochure as follows:

Role of the Energy Manager (EM1) Effective energy managers in business and industry will present their keys to success. You will discover how you can reduce your firm's energy usage indices by 50 percent within a few years. Plan to study energy management program organization, management strategies, and specific tools for obtaining reliable, affordable energy supplies and efficient energy use in your facility.

This five-day course will teach you how to:

- Identify your organization's critical needs
- Organize a successful energy management program
- Identify barriers to effective energy management programs and develop solutions
- Utilize methods for working with groups and committees
- Incorporate energy into your strategic planning process

Data Gathering and Analysis (EM2) This course will help you develop an organized approach to energy data gathering and analysis

(a) This information was provided by Dr. Charles E. Dorgan, Department of Engineering and Professional Development, University of Wisconsin, Madison, Wisconsin 53706.

in your facility. You will learn how to use a key energy management tool--a thorough and efficient walk-through energy audit. You will analyze energy use and identify measures to conserve energy. In addition, you will evaluate the different sources of energy use information--in-house technical personnel, consultants and utility companies, studying the strengths and weaknesses of each and determining the best source of information for your facility.

Study of the following will help ensure good energy calculation and economic analysis:

- What to include in effective energy audit reports
- How much time to budget
- What auditor experience is necessary
- What procedures and calculations to use
- What instruments and measurements are useful
- How to determine or evaluate energy savings estimates
- How to calculate economic benefits

Building Energy Systems (EM3) Using sound energy management practices, you can obtain a 35-50 percent reduction in energy use for existing buildings. New buildings, properly designed, may consume only 25 percent of the energy required by existing buildings. In this course you will learn how your building and energy systems operate, how to analyze present system efficiencies, what improvements are possible and what gimmicks to avoid. Concepts apply to individual buildings, complexes and nonprocess industrial applications.

This five-day course will cover building envelope characteristics and energy-using systems. Topics include:

- Energy system operating principles
- Energy efficiency of typical existing systems
- Operation and control strategies for optimum efficiency
- Recommended efficiency-improving retrofits
- Energy-efficient systems and components for replacement and new construction

Industrial Energy Systems (EM4) Successful industrial energy managers have cut energy indices by 25 percent or more. This course will provide methods to help you develop an appropriate energy index for measuring performance and controlling energy costs. You will review the basics of process energy analysis and compare theoretical, potential, and actual performance of industrial energy systems. Your learning will include the latest heat recovery technology, combustion equipment, energy efficient electric motors and variable speed drives. Plan to work with other energy managers in solving typical industrial energy problems.

Topics for this course will include:

- Energy management performance analysis and forecasting
- Process energy analysis techniques
- Energy efficiencies of commonly used systems
- Optimization of process and non-process operation and control
- Cost-effective retrofits
- Latest technology for waste heat utilization
- Energy-efficient designs, systems, and components for replacement and new construction
- Methods for analyzing potential savings

Individuals completing all four courses may take an Energy Management Diploma examination. In most cases, participating individuals can take this exam where they work. Individuals who have other energy responsibilities may wish to consider other courses offered at the University of Wisconsin - Energy Audit Programs, Air Conditioning Design, and Alternative Energy Systems.

ENERGY MANAGEMENT/AUDITING TECHNOLOGY - UNIVERSITY OF CINCINNATI

The University of Cincinnati has developed the Energy Management/Auditing Technology program, which teaches students basic skills necessary for entry-level positions in construction, engineering, and architectural firms. This program is one of only five such programs in the nation offering a complete associate degree curriculum. The program was designed to develop engineering technicians with specific vocational skills, including

- the ability to draft engineering drawings
- the ability to measure energy consumption and distribution in a variety of buildings
- capability to assist in designing energy-efficient mechanical and electrical systems
- a knowledge of various detailed energy auditing procedures.

An energy management laboratory, containing the latest equipment and instrumentation, provides students with practical experience.

High school graduates, or those who have completed the General Education Development (GED) test, may enter the course. Requirements for successful completion of this program are detailed in Table 25.

TABLE 25. Certificate in Energy Management/Auditing Technology
University of Cincinnati

Program A. This program is offered for students who have a high school diploma but do not plan to continue on and earn an associate degree or higher degree. However, all courses required for this certificate are also required in the associate degree program in Energy Management/Auditing Technology. If a student would later decide to earn the associate degree he/she would normally expect to be able to complete those requirements by taking one additional full year of course work.

I. Technical Core Requirements		Credit Hours
17-241-191	Energy Resource Technology	6
17-241-184	Electrical Energy Systems	6
17-241-174	Mechanical Energy Systems	6
17-241-271	Energy Systems Laboratory	3
17-241-272	Independent Study in Energy Management	3
17-241-273	Energy Auditing Procedures	
	or	
17-241-284	Solar Energy Systems	
		<hr/> 30
II. Related Studies Requirements		
17-241-101, 102, 103	Principles of Economics I, II, III	9
	or	
17-025-101, 102, 103	Elementary Math Analysis I, II, III	
	or	
17-025-201, 202, 203	Calculus and Analytic Geometry I, II, III	
III. General Studies Requirements		
Freshman English I, II		
Basic Technical Writing		
	or	
Humanities or Social Science Elective I, II, III		9
Total Credit Hours		<hr/> 48

ANNOTATED BIBLIOGRAPHY

Ref.
No.

1. Kennedy, J., Jr. and W. C. Turner. 1984. Energy Management. Prentice Hall, Englewood Cliffs, New Jersey.

Written specifically as a textbook for college courses in energy management organizations the text book discusses, energy auditing, rate structures, lighting, HVAC, combustion, and many other topics. The text contains worked-out examples as well as homework problems at the end of each chapter. Due to the instructional content of the book, some of the topics are not covered in as much depth as they would be in a reference book.

2. Lawrence, K., A. McRae and A. Salley. 1980. Energy Conservation Source-book. Aspen Systems.

This book contains many topics concerned with energy management policy rather than the quantitative side of energy management. Among the topics covered are energy trends, government involvement, and industry programs. The text also contains reproductions of sample reports. There are also some worked examples given, but no homework problems.

3. Mahon, H. P., M. G. Kiss and H. T. Leimer. 1983. Efficient Energy Management. Prentice Hall, Englewood Cliffs, New Jersey.

This book was written for plant engineers as well as students. Topics include management decisions, heat recovery and cogeneration, and energy-saving examples. There is a complete chapter dedicated to examples of various energy-management case studies. The text is easy to read with very good illustrations and checklists. The subject matter is general and not very quantitative. There are no assignment problems given at the end of the chapters.

4. O'Callaghan, P. W. 1981. Design and Management for Energy Conservation. (Pergamon Press, Oxford, New York.

Written as a handbook for plant engineers and designers, the text covers many topics concerning the scope of energy management activities, alternate energy sources, and system design. The text also reviews areas of thermodynamics as they apply to the energy conservation field. The subject matter of the book is quite technical. There are very few example problems given and no assignment problems at the end of the chapters. The text does cover a wide range of energy-related topics and would make a useful reference book.

5. Payne, G. A. 1984. Managing Energy in Commerce and Industry. Butterworth and Company, London, England.

This book covers economical aspects of energy management at the plant and household level. Among the many topics covered are energy auditing, combustion and heat transfer, boilers, heat recovery, and electricity. The text covers a wide range of topics and is presented in a very practical manner. Although many good ideas are presented, the text does not show how to implement the ideas. No example problems or assignment problems are given at the end of the chapters.

6. Thumann, A. 1984. Fundamentals of Energy Engineering. Fairmont Press.

This text was written as a reference book assuming the reader had no prior knowledge of energy topics. The text covers topics in economic analysis, energy auditing, electrical systems, waste heat, HVAC, and others. The wide range of coverage makes this book a good choice for a course text. Although the book does show some worked examples, it does not provide homework problems.

7. Thumann, A. 1983. Plant Engineers and Managers Guide to Energy Conservation. Van Nostrand Reinhold Company, Inc., New York.

Written as an engineer's guide to reducing energy consumption in both new and existing buildings, the book covers many topics in the energy management field. Topics include economic decision making, electrical systems, heat transfer, HVAC, and maintenance. The book is easy to read and covers a broad range of topics. The text includes example problems but no assignment problems. Due to the breadth of the book, topics often lack detail in their explanation.

8. Turner, W. C., et al. 1982. Energy Management Handbook. Wiley and Sons, Inc., New York.

Written as a handbook for the daily practitioner of energy management, the text covers topics in boilers, waste heat, insulation, lighting, and others. Sections review thermodynamics, economics, and electricity. Because the text covers such a wide range of topics, it could be used for two energy courses. The text would also be a valuable tool after graduation. Since the book was not designed specifically as a text, only a few examples are used; no homework problems are included.

9. Zackrison, H. B. 1984. Energy Conservation Techniques for Engineers. Van Nostrand Reinhold Company, Inc., New York.

This book concentrates primarily on electrical systems. Sections on lighting, HVAC, and controls are extensive. The text presents many practical methods of electrical energy consideration. The topics are covered in a very easy-to-read and easy-to-follow manner. Because the book concerns primarily electrical systems, no topics are presented in process energy, steam, heat recovery, or insulation. No examples or assignment problems are given.

REFERENCES

- Kennedy, Jr., W. J., and W. C. Turner. 1984. Energy Management, Prentice-Hall, Englewood Cliffs, New Jersey.
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