ENERGY CONSERVATION PROGRAM GUIDE FOR INDUSTRY AND COMMERCE

NBS HANDBOOK 115

U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards
in cooperation with
FEDERAL ENERGY ADMINISTRATION / Conservation and Environment

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.
[4] Part of the Center for Building Technology.

Energy Conservation Program Guide for Industry and Commerce (EPIC)

Robert R. Gatts, Robert G. Massey and
John C. Robertson

Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

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FOREWORD

Industry and commerce, which account for over one-half of the national use of energy, have a tremendous opportunity for energy conservation. This handbook was prepared as an energy management tool, a guide to those in industry and commerce who are responsible for the use of energy in intermediate to small sized firms. While the emphasis may appear more oriented toward manufacturing, the ideas and much of the information included are equally applicable to commercial business.

This guide has been largely assembled from information which has been used or suggested as useful by engineers and energy managers in industry and commerce. Without the contribution of that information this document could not have been possible in the present form or at this time.

The National Bureau of Standards and the Federal Energy Administration will continue their collection and distribution of information in support of energy conservation. Information on your successes in conserving energy can result in similar success by others. Whether that information is a specific technical fact, an idea to stimulate employee participation, an answer to a question on conservation, or the description of a successful energy conservation project, we solicit your assistance in making this guide more useful.

If you would like to contribute to this guide, or if you have questions about energy conservation, please contact The Office of Energy Conservation, National Bureau of Standards, Washington, D.C. 20234.

Richard W. Roberts
Director

ACKNOWLEDGEMENTS

Many individuals and companies have enthusiastically contributed ideas, information, constructive criticism, and perhaps most importantly, encouragement to the preparation of this handbook. To each of these the authors express their sincere appreciation. To single out individuals is difficult, but inspiration and concept for the handbook may be traced through Dr. Charles A. Berg of the Federal Power Commission, formerly with the National Bureau of Standards, to the conferees at the conference on "Energy Conservation Through Effective Utilization" at Henniker, New Hampshire, in August 1973, and to the attendees at an energy seminar sponsored by *Power* magazine in New York City in November 1973.

The opportunity to discuss thermal process systems and energy conserving opportunities and actions in many industrial plants was a valuable part of the preparation of this handbook. Of special assistance in this regard were Mr. R. J. Simko, Peoples Natural Gas Company; Mr. B. N. Clarke, Metallurgical Processing, Inc.; Professor W. Rudoy, University of Pittsburgh; and Mr. D. K. Seizert, Columbia Gas Distribution Companies.

Many valuable contributions have been received, not all of which could be included in the initial issue of the handbook. Those whose contributions have been used directly in the preparation of the handbook, but not credited in the text, include Mr. N. Artman, Sears Roebuck and Company; Prof. B. C. Barr, Univ. of Kansas; Mr. R. Cammack, Westinghouse Electric Corporation; Mr. J. P. Chisholm, Eastman Kodak Company; Mr. R. E. Doerr, Monsanto Corporation; Mr. S. G. Dukelow, Bailey Meter Company; Mr. W. Hung, Deltak Corporation; Mr. P. S. Minor, Environmental Protection Agency; Mr. D. K. Niver, General Electric Company; Mr. A. J. Pennington; Prof. G. Schrenk, Univ. of Pennsylvania; Prof. W. T. Snyder, University of Tennessee; Mr. G. C. Strickler, PPG Industries; and Mr. M. A. Williams, Union Carbide Corporation.

The document received helpful internal review by nineteen members of the staff with industrial experience of the National Bureau of Standards, and external review by fifty-one companies, technical societies, consultants, and federal agencies and by the twenty-four members of the National Industrial Energy Conservation Council.

Several members of the staff of the National Bureau of Standards, Mr. J. J. Collard, Mr. W. F. Druckenbrod, Mr. W. J. Niessing, Mr. S. R. Petersen, and Mr. W. G. Street, deserve special mention for their efforts, particularly in preparing the manuscript for publication. Mr. J. E. Moriarty was responsible for editing and Mrs. T. A. Schultz and Mrs. S. M. Mader for coordinating the secretarial services. Very special credit is due Mrs. B. L. Oberholtzer for production and printing of this handbook.

R. R. Gatts
R. G. Massey
J. C. Robertson

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ABBREVIATIONS

A	ampere
ac	alternating current
bhp	brake horsepower
Btu	British thermal unit
C	degree Celsius (Centigrade)
cfm	cubic feet per minute
cu ft	cubic feet
d	day
dc	direct current
eff	efficiency
F	degree Fahrenheit
fpm	feet per minute
ft	foot
gal	gallon
gpm	gallons per minute
h	hour
hp	horsepower
i.d.	inside diameter
in	inch
k	thousand or kilo
kcf	thousand cubic feet
kVA	kilovolt ampere
kVArh	kilovolt ampere reactive hour
kVAc	capacitance kilovolt ampere
kW	kilowatt
kWh	kilowatt hour
lb	pound
ln	logarithm (natural)
M	million or mega
MBtu	million Btu
min	minute
mo	month
o.d.	outside diameter
oz	ounce
PF	power factor
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
q	rate of heat transfer (Btu/h)
ROI	return on investment
rpm	revolutions per minute
s	second
sat	saturated
scf	standard cubic feet
scfm	standard cubic feet per minute
sq ft	square foot
std	standard
t	temperature
V	volt
W	watt
wk	week
yr	year
Δ	delta or difference

The majority of the abbreviations conform with the National Bureau of Standards recommended practice. In a number of cases thc abbreviations more commonly used in industry and commerce were selected.

Energy Conservation Program Guide for Industry and Commerce (EPIC)

Robert R. Gatts, Robert G. Massey, John C. Robertson *

The Energy Conservation Program Guide for Industry and Commerce (EPIC) is a guide to assist business and industry to establish an on-going conservation program. EPIC outlines the steps in an energy conservation program and suggests specific way to reduce energy use in manufacturing and commercial businesses. EPIC focuses on two aspects of energy conservation:
(1) The key steps in an implementation plan for an energy conservation program.
(2) Energy Conservation Opportunities which have been identified by industry.

Key words: Energy conservation; energy conservation guide; energy conservation opportunities; energy conservation program; industrial energy conservation.

1. INTRODUCTION

1.1 WHY ENERGY CONSERVATION

Energy is becoming increasingly expensive. The exploding demand for energy, both in the United States and throughout the rest of the world, will continue to force the cost of energy up and will result in recurring shortages. Increased costs for energy and unpredictable supplies of fuel have created a new dimension in business management.

Many companies are finding that an organized energy conservation program can hold down both energy use and energy costs without disrupting plant production. It has been repeatedly demonstrated that conservation measures can reduce energy use by 15 to 30 percent, or more, with justifying cost savings. More importantly, if by energy conservation your company can maintain production despite a reduction in energy supply, or increase production in the face of frozen fuel allocations, the effect on your sales and profits is obvious.

The unrelenting fact is that we are faced with a continuing shortage of fuel and power, part of which must be compensated for by conservation measures, or major dislocations and even catastrophy are in store for some companies and institutions. Yet we see startling energy conservation achievements reported through such simple plant maintenance and operation practices as reducing or eliminating unnecessary lighting in warehouses and parking lots, turning off equipment not needed at night or over weekends, optimizing maintenance schedules to keep equipment operating properly, planning production schedules to minimize energy use, and improving quality control to eliminate wasted processing. This potential for energy conservation and the equally startling reductions in energy use possible through cost reducing capital projects must be fully and quickly realized if we are to contain the disruptive explosion in energy demand.

1.2 WHAT IS EPIC

The Energy Conservation Program Guide for Industry and Commerce **(EPIC)** is a guide to assist you to establish an on-going energy conservation program in your organization. Basically, **EPIC** outlines the steps in an energy conservation program and suggests specific ways to reduce energy use in your plant. The information in **EPIC** comes from companies which have successful programs in operation. The National Bureau of Standards (NBS) has undertaken the responsibility of collecting, organizing, and making this information available to all Industry. You will be notified when new material becomes available for your **EPIC** kit if you will return the card at the end of this handbook.

The focus in **EPIC** is on two things: (a) the key steps in an Implementation Plan for an energy conservation program and (b) Energy Conservation Opportunities **(ECO's)** which have been identified by industry.

The Implementation Plan is outlined in Section 2.1 and is illustrated in the remainder of Section 2 by a series of memoranda, letters, and intra-company reports. These documents are based on actual experience in several industrial firms and show how

*** Research Associate from The Dow Chemical Company at the National Bureau of Standards 1974.**

energy conservation programs have been implemented.

A list of **ECO's** is given in Section 3. This checklist, collected from many sources, may suggest opportunities for energy conservation in your plant. Also in Section 3, you will find a collection of case studies each of which illustrates the magnitude of energy savings which may be associated with an **ECO** and emphasizes some of the factors to be considered in applying that **ECO.** These case studies are furnished by individuals and industrial firms and represent their reported experience. As such they are valuable, but the inclusion of a particular **ECO** should not be considered as carrying the endorsement or validation of the National Bureau of Standards.

The other sections of **EPIC** provide supporting information which may be useful in your conservation program. A section is devoted to each of the following:

- Engineering Data and Factors pertinent to energy conservation,
- Financial Analysis Procedures for evaluating projects,
- Sources of Assistance in energy conservation activities,
- Safety, Health and Pollution Considerations that impact energy conservation,
- Employee Participation suggestions and examples,
- Energy Flow Measurement related equipment selection and basic measuring methods, and
- Bibliography

EPIC is intended to be most useful for a company without an established energy conservation program although any company interested in energy conservation will find the kit of some use. **EPIC** is also intended to provide one mechanism by which ideas and suggestions on energy conservation will flow freely to the benefit of all segments of industry and commerce. It is in fact just such a flow of information from individuals and companies which has made **EPIC** possible.

1.3 THE PLANT MANAGER AND EPIC

We suggest that you read the Energy Conservation Program Outline which is presented in Section 2.1. This will help you visualize a plan of action for your plant.

Experence in other plants suggests two critical steps for the plant manager to take:

- Establish a clear commitment of top management to energy conservation, and
- Appoint an energy conservation program coordinator.

Clearly, a new box on the company organization chart won't get the job done. Energy conservation will be achieved through the line management. The coordinator's role should be to develop plans, to establish communication channels between departments and with employees, to acquire and disseminate new information, and to develop community contacts on conservation. The energy coordinator's role has been found to be a very important function in a successful program. You may even want to assume the duty yourself. You may want to develop a committee with representation from various parts of the plant to work with the coordinator.

In any case, put **EPIC** in the hands of your coordinator with your recommendations for tailoring the plan to your plant. The following section suggests some of the ways in which **EPIC** may be useful to the energy conservation coordinator.

1.4 THE ENERGY CONSERVATION COORDINATOR AND EPIC

As plant energy conservation coordinator you have a key role in the success of energy conservation in your plant. We hope you will find **EPIC** a helpful source of ideas in your planning.

As you generate your own plan of action, review the energy conservation plan outlined in Section 2.1 for ideas. The case study of an energy conservation program starting in Section 2.2 may also be useful. You will find here a sequence of communications based on those used in several company energy conservation programs.

You may decide to recommend to management that the best approach to achieving results is to hire a consultant to survey your plant and make recommendations. Engineering consultants and consulting firms, your local electric utility or gas company, and equipment manufacturers are potential sources of assistance. Your trade organizations and local chapters of technical societies most closely associated with your company's business are other possible sources of assistance. Check the list in Section 6 of **EPIC.**

As your plant energy surveys proceed, you should find the **ECO** Checklist in Section 3 a source of ideas for reducing energy losses. Your plant engineers will have to evaluate energy and cost savings for different projects or you may require outside engineering assistance. The engineering data in Section 4 may be helpful in these projects and there may be some useful ideas on financial evaluation in Section 5.

In evaluating an **ECO** application you will want to consult Section 7 for possible safety, health and pollution impacts. In some cases, there are constraints which will modify a possible application. In other cases you may realize substantial side benefits, such as removing a safety hazard as a result of insulating a hot surface to reduce heat loss or eliminating an air pollutant while utilizing its fuel value.

As you develop your plan for stimulating and encouraging employee cooperation on energy conservation, consult Section 8 on employee participation. Tailor suggestions to your plant. Posters, stickers, and mailing stuffers shown are often available from the sources listed.

Analyze the ideas presented here; add your ideas; put them together in a way that is useful to your operation. This is **EPIC**, an **E**nergy Conservation **P**rogram Guide for **I**ndustry and **C**ommerce. Make **EPIC** your program for **Energy Conservation.**

NOTE

Your experiences can be valuable to others. Your successful application of energy conservation practice, employee participation ideas, answers to questions on conservations, or other contributions could be included in future additions to **EPIC**. Case reports of energy conservation experiences are most useful when submitted by someone from a company which has taken advantage of the energy conservation opportunity **(ECO)** and realized the energy-savings benefit.

To encourage the free exchange of information conducive to energy conservation, contributors are acknowledged as far as possible. Necessarily, references to trade names are deleted, and acknowledgement of contributors who provide **ECO's** or other information based on their own products or services is without identification of the specific contribution.

If you have questions about conservation or would like to contribute to **EPIC,** please contact the **Office of Energy Conservation, National Bureau of Standards, Washington, D.C. 20234.**

Section 2

ENERGY CONSERVATION PROGRAM IMPLEMENTATION

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2. ENERGY CONSERVATION PROGRAM IMPLEMENTATION

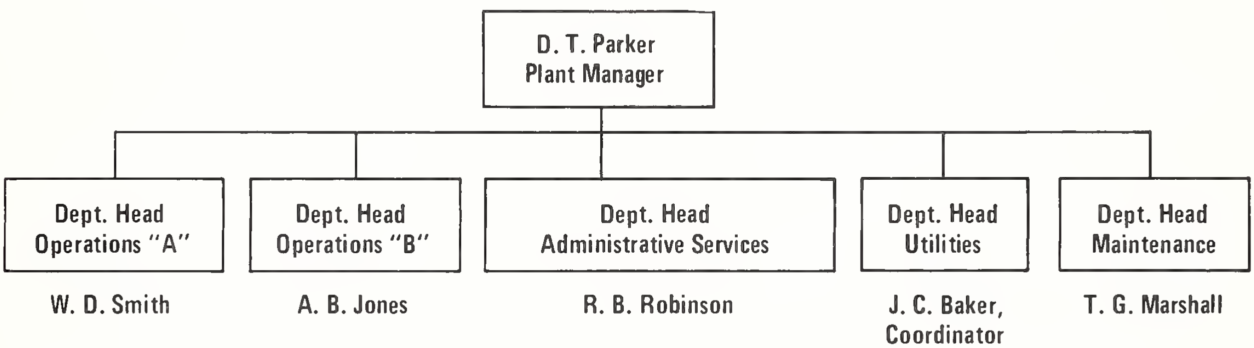
2.0 INTRODUCTION

This section of the kit describes the initiation and implementation of an energy conservation program. Section 2.1 is an outline of the elements of a program. It may be used as a guide to design your own program, tailored to your company's requirements and capabilities.

For those interested in more detail, the remainder of Section 2, starting with 2.2, illustrates the important steps in the program by a series of memoranda based on the internal correspondence generated in several actual energy conservation programs. Many of these communications could be accomplished verbally at staff meetings and committee meetings and then be documented in minutes. All of your needs may not be anticipated and some of the actions illustrated may not be necessary or appropriate for your management structure but you will find illustrated in this section most of the necessary communications. Suggested methods and forms for recording and reporting plant survey data and for tracking the progress of the program are included.

The memoranda are based on a hypothetical company, the ECONERGY Company, which has two production departments, a utilities department, a maintenance department, and an administrative services department responsible for the purchasing, accounting, shipping, and receiving functions.

The formal organization chart for the ECONERGY Company is shown below for reference. The names shown beneath the department blocks are the names of members of the Energy Conservation Committee.



2.1 PROGRAM OUTLINE

	Reference Section
I. TOP MANAGEMENT COMMITMENT	
A. Inform line supervisors of:	2.3.1
1. The economic reasons for the need to conserve energy	
2. Their responsibility for implementing energy saving actions in the areas of their accountability	
B. Establish a committee having the responsibility for formulating and conducting an energy conservation program and consisting of:	2.3.1
1. Representatives from each department in the plant	
2. A coordinator appointed by and reporting to management Note: In smaller organizations, the manager and his staff may conduct energy conservation activities as part of their management duties.	
C. Provide the committee with guidelines as to what is expected of them:	2.3.1
1. Plan and participate in energy saving surveys	
2. Develop uniform record keeping, reporting, and energy accounting	

	Reference Section
3. Research and develop ideas on ways to save energy	
4. Communicate these ideas and suggestions	
5. Suggest tough, but achievable, goals for energy saving	
6. Develop ideas and plans for enlisting employee support and participation	
7. Plan and conduct a continuing program of activities to stimulate interest in energy conservation efforts	
D. Set goals in energy saving:	
1. A preliminary goal at the start of the program	
2. Later, a revised goal based on savings potential estimated from results of surveys	
E. Employ external assistance in surveying the plant and making recommendations, if necessary	6.2
F. Communicate periodically to employees regarding management's emphasis on energy conservation action and report on progress	2.8.1, 2.3.2
II. SURVEY ENERGY USES AND LOSSES	
A. Conduct first survey aimed at identifying energy wastes that can be corrected by maintenance or operations actions, for example:	2.5.2, 2.6.1, 2.6.2, 2.6.3
1. Leaks of steam and other utilities	
2. Furnace burners out of adjustment	
3. Repair or addition of insulation required	
4 Equipment running when not needed	
B. Survey to determine where additional instruments for measurement of energy flow are needed and whether there is economic justification for the cost of their installation	2.5.3
C. Develop an energy balance on each process to define in detail:	2.5.3
1. Energy input as raw materials and utilities	
2. Energy consumed in waste disposal	
3. Energy credit for by-products	
4. Net energy charged to the main product	
5. Energy dissipated or wasted	
Note: Energy equivalents will need to be developed for all raw materials, fuels, and utilities, such as electric power, steam, etc., in order that all energy can be expressed on the common basis of Btu units.	2.5.4
D. Analyze all process energy balances in depth:	2.5.3
1. Can waste heat be recovered to generate steam or to heat water or a raw material?	
2. Can a process step be eliminated or modified in some way to reduce energy use?	
3. Can an alternate raw material with lower energy content be used?	
4. Is there a way to improve yield?	
5. Is there justification for:	
a. Replacing old equipment with new equipment requiring less energy?	
b. Replacing an obsolete, inefficient process plant with a whole new and different process using less energy?	
E. Conduct weekend and night surveys periodically	2.7.5 2.5.2
F. Plan surveys on specific systems and equipment, such as:	2.5.3
1. Steam system	
2. Compressed air system	
3. Electric motors	
4. Natural gas lines	
5. Heating and air conditioning system	
III. IMPLEMENT ENERGY CONSERVATION ACTIONS	
A. Correct energy wastes identified in the first survey by taking the necessary maintenance or operation actions	2.6.3
B. List all energy conservation projects evolving from energy balance analyses, surveys, etc. Evaluate and select projects for implementation:	

	Reference Section
1. Calculate annual energy savings for each project	
2. Project future energy costs and calculate annual dollar savings	
3. Estimate project capital or expense cost	
4. Evaluate investment merit of projects using measures, such as return on investment, etc.	
5. Assign priorities to projects based on investment merit	
6. Select conservation projects for implementation and request capital authorization	
7. Implement authorized projects	
C. Review design of all capital projects, such as new plants, expansions, buildings, etc., to assure that efficient utilization of energy is incorporated in the design.	2.7.2
Note: Include consideration of energy availability in new equipment and plant decisions.	
IV. DEVELOP CONTINUING ENERGY CONSERVATION EFFORTS	
A. Measure results:	2.5.7
1. Chart energy use per unit of production by department	2.5.6
2. Chart energy use per unit of production for the whole plant	
Note: The procedure for calculating energy consumption per unit of product is presented in "How to Profit by Conserving Energy"	2.5.7
3. Monitor and analyze charts of Btu per unit of product, taking into consideration effects of complicating variables, such as outdoor ambient air temperature, level of production rate, product mix, etc.	
a. Compare Btu/product unit with past performance and theoretical Btu/ product unit	
b. Observe the impact of energy saving actions and project implementation on decreasing the Btu/unit of product	
c. Investigate, identify, and correct the cause for increases that may occur in Btu unit of product, if feasible	
B. Continue energy conservation committee activities	2.7.5
1. Hold periodic meetings	
2. Each committee member is the communication link between the committee and the department supervisors represented	
3. Periodically update energy saving project lists	
4. Plan and participate in energy saving surveys	
5. Communicate energy conservation techniques	
6. Plan and conduct a continuing program of activities and communication to keep up interest in energy conservation	
7. Develop cooperation with community organizations in promoting energy conservation	
C. Involve employees	2.7.5
1. Service on energy conservation committee	2.7.4 2.6.4
2. Energy conservation training course	
3. Handbook on energy conservation	
4. Suggestion awards plan	
5. Recognition for energy saving achievements	
6. Technical talks on lighting, insulation, steam traps, and other subjects	
7. "savEnergy" posters, decals, stickers	
8. Publicity in plant news, bulletins	
9. Publicity in public news media	
10. Letters on conservation to homes	
11. Talks to local organizations	
D. Evaluate program	
1. Review progress in energy saving	
2. Evaluate original goals	
3. Consider program modifications	
4. Revise goals, as necessary	

2.2 FORMAT AND CONTENTS

Throughout this section, the letters, reports, forms, and meeting agendas are in time sequence. Where appropriate, there are comments or explanations which relate to the following memoranda.

Energy costs and cost projections, quantities of energy, and equivalent energy factors for utilities have been left as blanks, rather than stated numerically, in order to avoid any implication that the figures are typical. Such numbers will vary from industry to industry, plant to plant, and region to region. Each plant must make its own determination of these figures.

Names of individuals and of the company are, of course, fictitious.

Please note the definitions of the following symbols used in this section:

k = thousand or kilo
M = million or mega

2.3 PLANT MANAGER TAKES FIRST ACTION

The plant manager has decided that energy conservation must become a specific part of the company management program. He takes action by appointing an energy conservation coordinator and requesting the head of each department to select someone to work with the coordinator. His actions are expressed in the following memoranda.

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 7, 1974

To: Department Heads

From: D. T. Parker, Plant Manager

Subject: Formation of Energy Conservation Committee

The rising costs of energy and the allocations brought about by shortages have become a problem of increasing concern. The need for energy conservation has been discussed in previous staff meetings, but frankly we are not getting the results we want.

Many companies achieved 5 to 10% savings in energy usage last year by implementing formal energy conservation programs. Our plant uses ______ million Btu of energy yearly and our annual bill for purchased fuel and electric power is about $______ at current energy prices. If we could achieve, for example, a 10% cut in our annual consumption, that would be a saving of $______ -- an appreciable amount of money. Consider also that energy costs are rising at a rate of about ______% per year.

We must initiate an aggressive energy conservation program at once. We need to establish a committee with the responsibility for formulating and conducting the program. I am appointing J. C. Baker to the fulltime responsibility as committee coordinator, reporting directly to me, and I am asking that by one week from today each of you assign someone to represent your department on the committee. That person should be knowledgeable and influential. He will be the communication link between the committee and the key supervisors in your areas. Appointment to this committee will be considered a major assignment requiring a significant amount of time, particularly during the early stages of the energy conservation program.

We expect the committee to research and come up with ideas, to establish an energy conservation goal, to communicate suggestions on ways of achieving that goal, to develop a common economic base to work from, and to do some record keeping. The committee will need to compile lists of energy conservation projects, their costs and benefits so that we can plan our expenditures. It will be the line supervisors, however, who must see to it that actions are taken to accomplish energy conservation.

I suggest that a good way to kick off the program would be to conduct surveys throughout our plant - tracing out the energy streams to identify where our energy is used so that wasted energy can be reduced or eliminated. Fixing leaks of steam and other utilities, adjusting furnace burners, repairing steam traps, and repairing or adding insulation are some of the maintenance and operating actions we can take immediately to start realizing energy savings. The Energy Conservation Program Guide for Industry and Commerce (EPIC) published by the U. S. Department of Commerce will provide the guidance for developing our program.

I am thoroughly convinced that the continuing success of our company requires that we use our energy supplies as effectively as possible. The success of our program will depend upon the support and interest that we, as management, demonstrate.

I think we should set a tough, achievable goal for ourselves. Let's set an initial target of 10% savings in energy this year. This goal can be revised after we conduct our surveys and estimate the actual potential savings.

ECONERGY COMPANY

EMPLOYEE BULLETIN

Date: January 15, 1974

To: All Employees

From: D. T. Parker, Plant Manager

Subject: Initiation of Energy Conservation Program

Television, radio and newspapers are filled with reports on the energy shortages. This problem has implications far beyond the inconvenience we experience at our local gasoline service stations. This energy problem has a potentially serious impact on American industry, including the ECONERGY Company.

Not only are the costs of purchasing electricity and fuels soaring but the availability of our vital raw materials is declining as a result of the energy shortages. To avoid production disruptions which may result from these shortages, the ECONERGY Company is initiating a far-reaching Energy Conservation Program (ECP) to identify and eliminate inefficient, unnecessary, or wasteful uses of energy throughout the plant.

To accomplish this task I have appointed Mr. J. C. Baker, Utilities Department, to head the Energy Conservation Committee. This Committee will formulate a program which will enable us to reduce our energy consumption without disruption to our production flow. The support and active participation of every employee is essential if we are to achieve our goal of 10% savings in energy use this year.

You will soon be seeing signs that say "savEnergy." This is more than a catchy slogan: it is a reminder that energy will always be available at home and at work if we are careful in the ways we use it.

2.4 FIRST MEETING OF ENERGY CONSERVATION COMMITTEE

As soon as the committee coordinator learns of his new assignment, he starts planning how the committee can go about accomplishing the tasks set forth in the plant manager's letter (2.3.1). When he has the names of all members of the committee and a plan in mind, he calls a meeting of the committee and submits to them the proposed plan in the following letter.

For simplification, we are assuming that the plan and assignments were accepted by the committee and no additional topics were discussed. However, if the committee agreed on some changes to the plan and/or talked about other matters, minutes of the meeting would be written and copies given to committee members.

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 18, 1974

To: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: J. C. Baker
Energy Conservation Coordinator

Subject: Committee Assignments

D. T. Parker's letter dated January 7, 1974 outlines the formation of the Energy Conservation Committee, to which we have been appointed, and indicates some of the actions we are to undertake. As he suggests, each of us should become thoroughly familiar with the program suggestions and energy conservation opportunities described in EPIC.

We must get started on several of the tasks immediately, so I have developed a plan for dividing these duties among us. The first priority is to conduct a survey of present energy usage and to begin reducing or eliminating waste. Because of their familiarity with these problems, our operations representatives, W. D. Smith and A. B. Jones, should be responsible for developing a plant-wide plan for energy saving surveys.

Another area that requires early attention is the establishment of a common economic base from which to work. There will be energy saving projects that will involve dollar expenditures which require financial justification. We need a uniform method of calculating the value of savings for our various forms of energy - electric power, fuel, steam, and compressed air. As Utilities representative, I will undertake this task.

I would appreciate it if R. B. Robinson of Administrative Services could obtain from Accounting data on the quantities of purchased fuel and electric power used monthly last year and this year. A continuing plot of energy consumption per unit of production is necessary to help us monitor the progress in our plant-wide energy conservation effort.

In addition, we need to consider projected energy costs. So, would R. B. Robinson also please ask the Purchasing Section if they can develop fuel and electric power cost projections for this year, three years and five years into the future.

We are going to need to communicate ideas and suggestions on energy conservation techniques applicable to our plant. Since T. G. Marshall of Maintenance has had broad experience throughout the plant, I am asking that he assume responsibility for coordinating this function. To start with, we have several literature references and the Energy Conservation Opportunities (ECO's) in EPIC. As time goes along, we surely will have generated additional ideas deserving of broad communications through our committee.

If all of you are in agreement with this plan, I suggest that each of us meet with the key supervisors in our areas this week to inform them of our program plans and to ask them to come up with energy saving projects.

Let us meet again in my office one week from today, at the same time, to report our progress. If you are unable to attend that meeting or any future meeting, please ask an alternate to attend in your place.

cc: D. T. Parker
Plant Manager

2.5 SECOND MEETING OF ENERGY CONSERVATION COMMITTEE

The week passes and the committee holds its second meeting. The coordinator gives each member a copy of the agenda shown on the next page. Then, in the sequence of the agenda, each member presents his report, giving a copy of his letter and attachments to all present. The following six letters document the reports and proposals submitted at the meeting. It is assumed that all these matters were accepted or approved by the committee.

Note that in Section 2.5.4, and elsewhere in EPIC, a ratio of 10,000 Btu/kWh is used for illustrative purposes for the energy used by a utility to generate electricity. According to the Federal Power Commission, the national average for 1972 was approximately 12,000 Btu/kWh. This figure will vary from region to region, however.

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: Energy Conservation Committee

From: J. C. Baker, Coordinator

Subject: Agenda for Second Meeting of the Energy Conservation Committee

1. Report of plans for energy saving surveys
2. Energy equivalents for plant utilities
3. Present and projected future costs of energy
4. Monthly energy use for 1973 and 1974
5. Proposed forms:
    a. Calculation of Btu per unit of production
    b. Tracking chart

cc: D. T. Parker
Plant Manager

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinator
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: Energy Saving Survey Team
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: Plans for First Energy Saving Survey

The first survey will be aimed at identifying energy wastes that can be corrected by maintenance or operations actions. The attached survey form indicates the types of wastes we will be looking for. In addition, we will refer to the Energy Conservation Checklist in EPIC. All process areas and buildings will be included in the survey. The main part of the survey will be conducted during normal daytime work hours, but one or more night visits will be required to search for excess nighttime lighting and HVAC (heating, ventilating, and air conditioning), as well as equipment running when not needed. Areas or buildings that are in a full or partial shutdown condition on weekends will warrant weekend visits to look for energy use that is not necessary.

The survey team proposes to conduct the survey of each area in cooperation with and accompanied by a foreman, supervisor, or engineer designated by the department head. Findings of the survey of each area will be recorded on the attached form and copies will be made available to the department head, the maintenance department, and the Energy Conservation Committee.

Work orders for correction of energy wastes will be prepared by department supervisors, as is the case for any other maintenance work.

This week, the survey team will prepare a timetable for visits to the various areas and communicate the schedule to department heads.

By copy of this letter to Mr. Parker we are requesting management endorsement of our plans for this first energy survey.

cc: D. T. Parker, Plant Manager

ENERGY SAVING SURVEY

Surveyed by: ______________

Department: ______________

Date: ______________

Fuel Gas or Oil Leaks	Steam Leaks	Compressed Air Leaks	Condensate Leaks	Water Leaks	Damaged or Lacking Insulation	Excess Lighting	Excess Utility Usage	Equipment Running & Not Needed	Burners Out of Adjustment	Leaks of or Excess of HVAC	Location	Date Corrected

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinator
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: Energy Saving Survey Team
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: Future Energy Savings Surveys

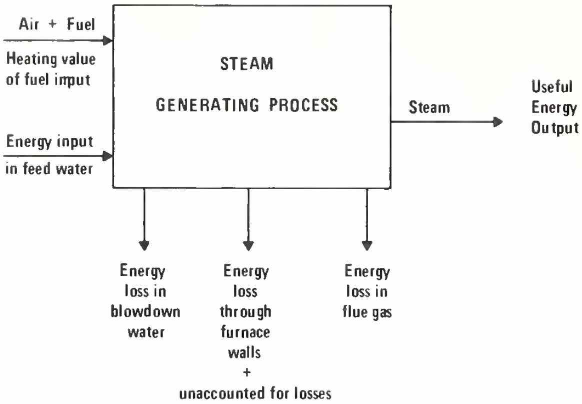
After our first energy saving survey, which is aimed at correction of the more obvious energy losses, there are other surveys which we feel certain will reveal additional ways to reduce energy consumption but which probably will require capital investment.

1. The Energy Balance

The basic data needed for energy conservation efforts is an energy balance on each process and department. This study can be done by an engineer in the department concerned, who is thoroughly familiar with the process flow sheet or the building energy uses. The object is to define in detail the energy input, energy utilized, and energy dissipated or wasted. In some areas this will require improving measuring capability. The cost of this additional measuring capability must be weighed against the potential savings. An example is shown on the following energy flow diagram for a steam generating unit. Having identified the individual energy wastes, the engineer can then determine methods for reducing or using these energy wastes. (The ECO Checklist in EPIC can be helpful.) The engineer's next task is to evaluate the alternate methods and recommend the best one.

Heat Balance Diagram
for
A Simple Steam Generating Unit

Energy Input - Energy Losses = Useful Energy Output



2. Energy Surplus Survey

After the energy balances have been completed, some coordination by the survey team is indicated. The survey team can contact the engineers who have prepared the energy balances to determine if there are energy wastes that could be recovered economically but have no use within their process area. Let's say that there is potential for recovering waste heat from furnace flue gases by using it to (a) preheat combustion air or (b) generate low pressure steam. Suppose that air preheat is impractical because of furnace construction and there is no use for low pressure steam within that department. The survey team can communicate through the energy conservation committee to other departments and perhaps find a use for the low pressure steam.

3. Survey of Pressure Reducing Stations

Determine location of all steam and high pressure gas, pressure-reducing valves, upstream and downstream pressures, and flow rates. Evaluate feasibility of letting pressure down by flowing through an expander driving some equipment, such as a pump or compressor.

4. Survey of Compressed Air Pressure Requirements

Survey all users of plant air to find minimum pressure levels required. Lowering compressor discharge pressure saves energy. If all but one or two users can be satisfied with a lower pressure, an evaluation of the feasibility of installing a separate compressor or a booster to supply these higher pressure users should be made.

5. Steam System Survey

a. Traps

Review all steam trap installations. Are there too many traps on a line? Or too few? Of an efficient type? Or inefficient? Are traps sized properly? Installed properly? Are they functioning as they should? Should traps receive special maintenance attention?

b. Increase Condensate Return to Boilers

Loss of condensate is a waste of heat and of valuable high purity water. Identify all sources of condensate and evaluate economic feasibility of installing pump and insulated piping to return condensate to boiler feedwater tank. If condensate is contaminated, evaluate possible clean-up.

c. Use of Lower Pressure Steam

Search for situations where use of high pressure steam can be switched over feasibly to lower pressure steam. It is advantageous to use the lower pressure steam where the higher pressure is not needed. This is particularly true when the lower pressure steam is being supplied from extraction or back-pressure turbines or a low pressure boiler separate from the high pressure boiler. Of course, lowering pressure by a pressure reducing valve offers no savings in energy.

6. Survey for Oversized Electric Motors and Equipment

Electric motors and equipment, such as centrifugal pumps, operate with best efficiency at rated load. If they are operating at reduced load, efficiency suffers. Take ampere readings on motors and compare to rating. Evaluate replacement of oversized motors and equipment with proper sizes.

7. Insulation

Inspect insulation and furnace walls with infrared scanners to detect excessive heat losses. Repair insulation and walls where needed.

8. Combustion Survey

Determine combustion efficiency in all furnaces. Evaluate economic feasibility of replacing burners with more efficient type and installing oxygen and combustibles analyzers on flue gas along with improved combustion control system to maintain optimum excess air.

cc: D. T. Parker
Plant Manager

savEnergy

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: J. C. Baker, Energy Conservation Coordinator

Subject: Energy Equivalents and Costs for Plant Utilities

We need a uniform method for calculating the value of our energy savings for our various utilities and I recommend we institute an accounting system based on Btu usage. For our purchased electric power, dollar accounting is simply a matter of using the $/kWh rate(s) we pay the utility company. The matter is more involved, however, for our Btu accounting of electric power. One kWh is capable of producing 3412 Btu of heat. But due to power plant inefficiency, approximately 10,000 Btu of fuel are burned by the utility company to generate one kWh. Therefore, the "energy equivalent" for electric power is:

10,000 Btu/kWh

Following this example then, an "energy equivalent" may be defined as the number of Btu of fuel that are consumed in generating a unit of utility, such as a kWh of electricity or 1000 lb of steam. Defined this way, the "energy equivalent" is the factor we can use across the board to put all projects on a common base in our energy conservation program.

Next let us consider the fuels that we purchase. The energy equivalent is the heat of combustion. The unit cost comes from accounting.

Fuel	Cost	Energy Equivalent	Cost/MBtu
Natural Gas	$________/1000 cu ft	________Btu/cu ft	$______/MBtu
Fuel Oil	$________/gal	________Btu/gal	$______/MBtu
Coal	$________/ton	________Btu/lb	$______/MBtu

The costs of our generated steam, compressed air, water and treated boiler make-up water published by our accounting department include depreciation, maintenance and operating costs, etc., and therefore cannot be used in figuring dollar value of energy saving. When we save these utilities we save only the fuel or electric power that was used to generate, compress or pump the utilities. In our boilers generating 400 psig and 150 psig steam, the energy equivalents of steam are the fuel Btu used in generating steam based on the boiler efficiencies. The steam costs to be used in energy saving accounting are, therefore, the costs of the energy equivalents.

Steam	Cost	Energy Equivalent
400 psig	$_______/1000 lb	_______Btu/1000 lb
150 psig	$_______/1000 lb	_______Btu/1000 lb

With regard to compressed air, water and treated boiler make-up water, the costs are for electric power used for compressing or pumping. The energy equivalents take into account 10,000 Btu/kWh.

Utility	Cost	Energy Equivalent
Compressed Air	$_______/1000 cu ft	_______Btu/1000 cu ft
Water	$_______/1000 lb	_______Btu/1000 lb
Boiler Make-Up Water	$_______/1000 lb	_______Btu/1000 lb

When we save condensate and return it to the boilers, we reduce the boiler make-up water requirement and save the Btu difference between the heat content of the condensate at _____F and of fresh water at its temperature. Thus, our energy equivalent for condensate is _____Btu/1000 lb and its cost is $_______/1000 lb.

cc: D. T. Parker
Plant Manager

savEnergy

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinator
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance

From: R. B. Robinson, Administrative Services

Subject: Fuel and Power Cost Projections

The Purchasing Section has provided the following information:

	Cost at Present	Estimated Cost 3 Years	Estimated Cost 5 Years
Electric Power	\$_____/kWh	\$_____/kWh	\$_____kWh
Natural Gas	\$_____/1000 cu ft	\$_____/1000 cu ft	\$_____1000 cu ft
Fuel Oil	\$_____/gal	\$_____/gal	\$_____/gal
Coal	\$_____/ton	\$_____/ton	\$_____/ton

Purchasing has agreed to advise our committee whenever these costs are revised.

cc: D. T. Parker, Plant Manager

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: J. C. Baker, Energy Conservation Coordinator
W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance

From: R. B. Robinson, Administrative Services

Subject: Monthly Use of Fuels and Power - 1973 and 1974

The attached form was developed and submitted to Accounting. They hope to have the information compiled within a few days.

cc: D. T. Parker, Plant Manager

MONTHLY PLANT ENERGY USE

	ELECTRIC POWER			NATURAL GAS			FUEL OIL			COAL			TOTAL Btu	Number of Units Produced	Btu Per Unit of Production
1973	kWh	Btu/kWh	Btu	k cu ft	Btu/k cu ft	Btu	gal	Btu/gal	Btu	TONS	Btu/lb	Btu			
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															
1974															
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 25, 1974

To: W. D. Smith Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: J. C. Baker, Energy Conservation Coordinator

Subject: Department Energy Unit Ratio and Tracking Chart

Attachment A is a copy of the do-it-yourself kit "How to Profit by Conserving Energy" by the Sub-Council on Technology of the National Industrial Energy Conservation Council. The form in the kit details a suggested procedure for calculating the energy content (Btu) of a product.

In our particular operations, we have no by-products, and our energy use for waste disposal is negligible. Therefore, our prime concern is raw material energy and conversion energy. Conversion energy is the energy equivalent of utilities used in manufacturing the product. Raw material energy content can be somewhat more involved. The raw material suppliers may be able to provide this number, or an approximation is available for most materials from the U. S. Department of Commerce. If unavailable from these sources, it can be estimated as the heat of combustion of the material. This estimate is always low. Any energy spent on the raw material in getting it to the point of use should be considered - for example, mining, crushing and sizing, and transportation. Bear in mind that less energy intensive raw materials should escalate less in price as energy costs increase. Having determined the energy content of raw materials, and given a choice, a better raw material selection should be possible.

Attachment B is a three page form for tabulating monthly department use of raw materials and utilities, for calculating Btu content of these quantities, and for determining the total Btu and the energy/production unit ratio in Btu per unit of production. As this information is developed we will probably find that there is a need to install additional metering and to rehabilitate some existing meters, if economically justified.

Attachment C is a graph for plotting the monthly Btu per unit of production for 1973 and 1974. This graph can be used for charting the energy used by individual production departments and also by the total plant.

If you have any questions, see me. These records are important to our on-going program.

cc: D. T. Parker, Plant Manager

ATTACHMENT A

HOW TO PROFIT BY CONSERVING ENERGY

A Do-It-Yourself Kit

SUB-COUNCIL ON TECHNOLOGY OF THE NATIONAL INDUSTRIAL ENERGY CONSERVATION COUNCIL

OBJECTIVE

Encourage industrial firms to set measurable goals for reducing energy consumption per unit of product produced.

GOAL .

X-percent reduction in energy content* expressed in BTU'S per unit of product.

PROCEDURE

Use the energy calculator on page two to determine the current energy content in BTU'S per unit for any kind of manufactured or processed product.

With this yardstick, measure progress to determine if energy reduction goals are being met, exceeded or missed.

*Energy content per unit of product includes energy content of the raw material plus energy spent in converting or upgrading and in waste disposal.

"DO IT YOURSELF KIT" For Calculating The Energy Content of A Product

GUIDELINES OF THE NATIONAL INDUSTRIAL ENERGY CONSERVATION COUNCIL

SUGGESTED PROCEDURE FOR CALCULATING ENERGY CONTENT (BTU'S) OF A PRODUCT

FOR THE PERIOD BEGINNING January 1, 1974, PERIOD ENDING February 1, 1974.

COMPANY	RESPONSIBLE MANAGER
The Dow Chemical Co.	I. G. Snyder, Jr.

PRODUCT	PRODUCT I.D. NO.
1	2

3 TOTAL UNITS PRODUCED

UNITS OF PRODUCTION (LB, GAL, PIECE, ETC.)

RAW MATERIAL ENERGY (LIST MAJOR RAW MATERIALS)

4 RAW MATERIAL	5 TOTAL UNITS	x 6 BTU'S UNIT	= 7 TOTAL BTU'S
A:			
B:			
C:			
D:			
E:			

TOTAL BTU'S 8

CONVERSION ENERGY (LIST ALL MAJOR UTILITIES)

9 UTILITY	10 TOTAL UNITS	x 11 BTU'S UNIT	= 12 TOTAL BTU'S
A:			
B:			
C:			
D:			
E:			

TOTAL BTU'S 13

WASTE DISPOSAL ENERGY

14 WASTE	15 TOTAL DISPOSAL BTU'S	17 TOTAL WASTED UNITS
A:		
B:		
C:		
D:		
E:		

TOTAL BTU'S 16

GROSS ENERGY CONTENT OF PRODUCT (SUM OF ITEMS 8, 13 AND 16) BTU'S 18

BY-PRODUCT ENERGY CREDIT (LIST ALL MAJOR BY-PRODUCTS)

19 BY-PRODUCT	20 TOTAL UNITS	x 21 BTU'S UNIT	= 22 TOTAL BTU'S
A:			
B:			
C:			
D:			
E:			

TOTAL BTU'S 23

NET ENERGY CONTENT OF PRODUCT (ITEM 18 LESS ITEM 23) 24 BTU'S

ENERGY CONTENT PER UNIT OF PRODUCTION (ITEM 24 DIVIDED BY ITEM 3) 25 BTU'S UNIT

GOAL (TARGETED ENERGY CONTENT FOR THIS PERIOD) BTU'S UNIT 26

IF ITEM 26 IS EQUAL TO ITEM 25, GOAL WAS MADE (CHECK ITEM 27) 27 MADE GOAL

IF ITEM 26 IS NOT EQUAL TO ITEM 25, COMPUTE DEVIATION FROM GOAL:

ITEM 26 LESS ITEM 25 28

ITEM 28 DIVIDED BY ITEM 26 29

MULTIPLY ITEM 29 BY 100 30

IF ITEM 26 IS GREATER THAN ITEM 25, COPY ITEM 30 HERE 31 + % BEAT GOAL

IF ITEM 26 IS LESS THAN ITEM 25, COPY ITEM 30 HERE 32 − % MISSED GOAL

GUIDE FOR FILLING OUT FORM ON OPPOSITE PAGE

1 Finished product ready for shipment.

2 Product I.D. No. is the numerical identification of the product.

3 Units of the product (item 1) made during this time period.

4 The material that goes into producing and packaging the product (includes fuels used as raw material).

5 Units of the raw material (item 4) that were used during this time period.

6 Every material has a specific energy content. Energy content is measured in terms of BTU'S. Raw material supplier may provide this number or an approximation is available for most materials from the U. S. Department of Commerce. If unavailable from these sources, it can be estimated as the heat of combustion of the material. This estimate is always low.

7 (Item 5) multiplied by (item 6).

9 Utilities include primarily electricity, fuel oil and natural gas.

10 Units of utility (item 9) used during this time period.

11 For fuel, this is the heat of combustion of the fuel. This number is available from supplier. For other utilities, this is the energy necessary to generate one unit of the utility (e.g., 1 KWH). Use 10,000 BTU'S per KWH unless your supplier has a better number.

12 (Item 10) multiplied by (item 11).

14 Waste is that material which has no economic value and which requires additional BTU'S to dispose of.

15 Estimated energy to dispose of the waste (item 14). This may be the energy to truck away and bury a solid, the energy to burn some scrap or the energy to run a waste disposal plant.

17 Units of waste produced during this time period. Units of waste is not needed for the calculation, but may be recorded for later reference.

19 By-products are those saleable materials which are made incidental to the production of the desired product or products.

20 Units of by-product (item 19) made during this time period.

21 The usable energy in the by-product. As an approximation, use the ratio of the value of the by-product to the value of the product multiplied by the gross energy content of the product (item 18).

22 (Item 20) multiplied by (item 21).

"DO IT YOURSELF KIT" For Calculating The Energy Content of A Product

GUIDELINES OF THE NATIONAL INDUSTRIAL ENERGY CONSERVATION COUNCIL

SUGGESTED PROCEDURE FOR CALCULATING ENERGY CONTENT (BTU'S) OF A PRODUCT

FOR THE PERIOD BEGINNING January 1, 1974, PERIOD ENDING February 1, 1974.

COMPANY	RESPONSIBLE MANAGER
The Dow Chemical Co.	I. G. Snyder, Jr.
PRODUCT (1) Ethylene	PRODUCT I. D. NO. (2) 007-23-1

(3) TOTAL UNITS PRODUCED: 42,000,000

UNITS OF PRODUCTION (LB, GAL, PIECE, ETC.): Pounds

RAW MATERIAL ENERGY (LIST MAJOR RAW MATERIALS)

4 RAW MATERIAL	5 TOTAL UNITS	× 6 BTU'S UNIT	= 7 TOTAL BTU'S
A: Ethane	52.29×10^6	22,304/lb	1166.3×10^9
B: Caustic Soda	$.252 \times 10^6$	12,500/lb	3.2×10^9
C: Hydrogenation Cat.	6.048×10^3	75,000/lb	5×10^9
D: Desiccant	1.117×10^3	50,000/lb	1×10^9
E:			
		TOTAL BTU'S 8	1170.1×10^9

CONVERSION ENERGY (LIST ALL MAJOR UTILITIES)

9 UTILITY	10 TOTAL UNITS	× 11 BTU'S UNIT	= 12 TOTAL BTU'S
A: Steam, 150 psig.	181.31×10^6	1077/lb	195.3×10^9
B: Electricity, KWH	0.71×10^6	10000/KWH	7.1×10^9
C: Natural Gas, $ft.^3$	269.4×10^6	$1030/ft.^3$	277.5×10^9
D: Cooling Water, gal.	1764×10^6	10/gal.	17.6×10^9
E: Process Water, gal.	1.974×10^6	15/gal.	Negligible
		TOTAL BTU'S 13	497.5×10^9

WASTE DISPOSAL ENERGY

14 WASTE	15 TOTAL DISPOSAL BTU'S	17 TOTAL WASTED UNITS
A: Oily, Caustic Water	Disposal Plant 1.0×10^9	Water: 5.92×10^6 gal.
B:	Muriatic Acid 4.9×10^9	Oil in water: 11,200 lbs.
C:		Muriatic Acid to neutralize
D:		Caustic: 699, 120 lbs.
E:		
TOTAL BTU'S 16	5.9×10^9	

GROSS ENERGY CONTENT OF PRODUCT (SUM OF ITEMS 8, 13 AND 16) BTU'S 18 1673.5×10^9

BY-PRODUCT ENERGY CREDIT (LIST ALL MAJOR BY-PRODUCTS)

19 BY-PRODUCT	20 TOTAL UNITS	× 21 BTU'S UNIT	= 22 TOTAL BTU'S
A: Residue Gas	6.048×10^6	20,000	121.0×10^9
B: Pyrolysis Gas	1.722×10^6	17,986	31.0×10^9
C: $C_3 - C_4$ Fraction	2.436×10^6	20,833	50.7×10^9
D:			
E:			
		TOTAL BTU'S 23	202.7×10^9 BTU's

NET ENERGY CONTENT OF PRODUCT (ITEM 18 LESS ITEM 23) 24 1470.8×10^9 BTU'S

ENERGY CONTENT PER UNIT OF PRODUCTION (ITEM 24 DIVIDED BY ITEM 3) 25 35,019 BTU'S UNIT

GOAL (TARGETED ENERGY CONTENT FOR THIS PERIOD) BTU'S UNIT	26	35,000
IF ITEM 26 IS EQUAL TO ITEM 25, GOAL WAS MADE (CHECK ITEM 27)	27	MADE GOAL
IF ITEM 26 IS NOT EQUAL TO ITEM 25, COMPUTE DEVIATION FROM GOAL:		
ITEM 26 LESS ITEM 25	28	481
ITEM 28 DIVIDED BY ITEM 26	29	.0135
MULTIPLY ITEM 29 BY 100	30	1.35
IF ITEM 26 IS GREATER THAN ITEM 25, COPY ITEM 30 HERE	31	+ 1.35 % BEAT GOAL
IF ITEM 26 IS LESS THAN ITEM 25, COPY ITEM 30 HERE	32	− % MISSED GOAL

2

4 All significant input materials are listed even though they may not appear in the final product.

5 These quantities of materials were used during January, 1974. The desiccant may be purchased only once every six months, but a proportional amount is allocated to this month.

6 The energy content of ethane is the heat of combustion which is available from several reference books.

The energy content of caustic was estimated from literature sources.

The heat content of the hydrogenation catalyst and the desiccant are educated guesses. The quantities of these materials used are so small that the error introduced by an incorrect guess is insignificant.

11 The BTU'S per unit of steam are available from steam tables. In this case credit was taken for the hot water returned to the steam plant. 10,000 BTU'S/KWH was used since this is close to the energy that an average utility uses to generate a KWH of electricity.

1030 BTU'S/ft^3 of gas was provided by the gas supplier. The energy in the cooling and the process water is the power necessary to pump the water. The power in KWH'S/gallon was multiplied by 10,000 BTU'S/KWH to arrive at the BTU'S per gallon.

15 The oily, caustic water was neutralized and then treated in a bio-oxidation plant. The total disposal BTU'S include the energy to run the bio-oxidation plant plus the energy in the neutralizing agent, muriatic acid.

21 All of the energy contents here were assumed to be equal to the heat of combustion since these materials may be readily burned as fuel. Residue gas was assumed to be the same as light fuel oil, pyrolysis gas was assumed to be the same as toluene and the $C_3 - C_4$ fraction was assumed to be butene.

The basic information in this example was taken from the Stanford Research Institute report on "Ethylene" dated August, 1967, page 219.

WHY MEASURE ENERGY

As energy is used more effectively, product costs can be reduced and profits improved. This can be accomplished even in the face of sharply increasing energy costs. Since industrial energy consumption accounts for approximately 40% of total energy used in the United States, significant contributions can be made to the national effort.

The first step to meaningful energy conservation is measurement of all the energy that enters and leaves a plant during a given period. This measurement will probably be an approximation at first but should improve with experience.

To calculate the energy content of your products, use the attached form, and then set goals for improvement. The filled in example is for ethylene; but the procedure applies equally well to any manufacturing operation, be it a grain mill pulp mill, steel mill, furniture factory, or assembly line.

Though time consuming and challenging to make the initial calculations, it will be worth the effort. Raw materials which contain, and manufacturing processes which use large amounts of energy will be pinpointed.

What To Expect – Once BTU content is determined, products can be ranked by BTU'S per unit, BTU'S per dollar of sales, and BTU'S per dollar profit. Then, as energy availability becomes more limited, it will be possible to quickly focus on the most profitable products.

Equipment associated with the large energy consuming steps will be identified. Once the energy-hogging equipment is isolated, efforts can be focused on replacing old machinery and equipment, using more energy-conscious designs, and improving maintenance programs.

Less energy-intensive raw materials should escalate less in price as energy costs increase. Having determined the energy content of raw materials, and given a choice, a better raw material selection should be possible.

Stressing the importance of BTU'S per-unit-of-production to plant operating people should provide the incentive for them to chase down where all of the input BTU'S actually end up. Often, the first attempt will account for less than 50% of the input BTU'S. Simply the act of identifying the other 50% will reveal many opportunities for improvement. For example:

1. A reduction in scrap or an improvement in yield will often be the most significant energy reduction that can be accomplished.
2. Leaking water, steam, inert gas or raw material may seem quite small as it escapes into the air, but over time this can represent a sizeable quantity of energy.
3. Heat loss from equipment can sometimes be reduced with more insulation once the losses are identified.
4. Sometimes energy lost to the environment, either through cooling water or through air, can be used advantageously to heat inlet raw materials or process equipment.
5. The energy content of waste may be recovered in part or in total by treating and recycling the waste back through the manufacturing process. In some instances, it may be possible to burn the waste and use the recovered heat in the process.
6. Temperature control equipment may be alternately heating and cooling. This problem is often corrected by a simple adjustment of the controls.
7. Recognizing that it takes 10,000 BTU'S to generate one KWH may suggest using less electricity for heating since this same KWH is capable of producing only 3,413 BTU'S of heat.
8. It may be possible to combine some manufacturing steps so that the product does not cool down between steps and subsequently have to be reheated before it is processed further.

The energy shortage is a national concern. It can also be viewed as an exciting challenge. Those companies that move quickly to meet the challenge will contribute substantially to the solution of a national problem – and make money at it.

The first step is measurement.

DEPARTMENT ______

MONTHLY DEPARTMENT ENERGY USE

	ELECTRIC POWER			NATURAL GAS			FUEL OIL			COAL			COMPRESSED AIR		
1973	kWh	Btu/kWh	Btu	k cu ft	Btu/k cu ft	Btu	gal	Btu/gal	Btu	TONS	Btu/lb	Btu	k cu ft	Btu/k cu ft	Btu
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															
1974															
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															

DEPARTMENT ____________

MONTHLY DEPARTMENT ENERGY USE

	psig STEAM			psig STEAM			CONDENSATE USED OR LOST			WATER			TOTAL CONVERSION Btu	NUMBER OF UNITS PRODUCED	CONVERSION Btu PER UNIT OF PRODUCTION
1973	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu			
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															
1974															
Jan.															
Feb.															
Mar.															
Apr.															
May															
June															
July															
Aug.															
Sep.															
Oct.															
Nov.															
Dec.															

DEPARTMENT ____________

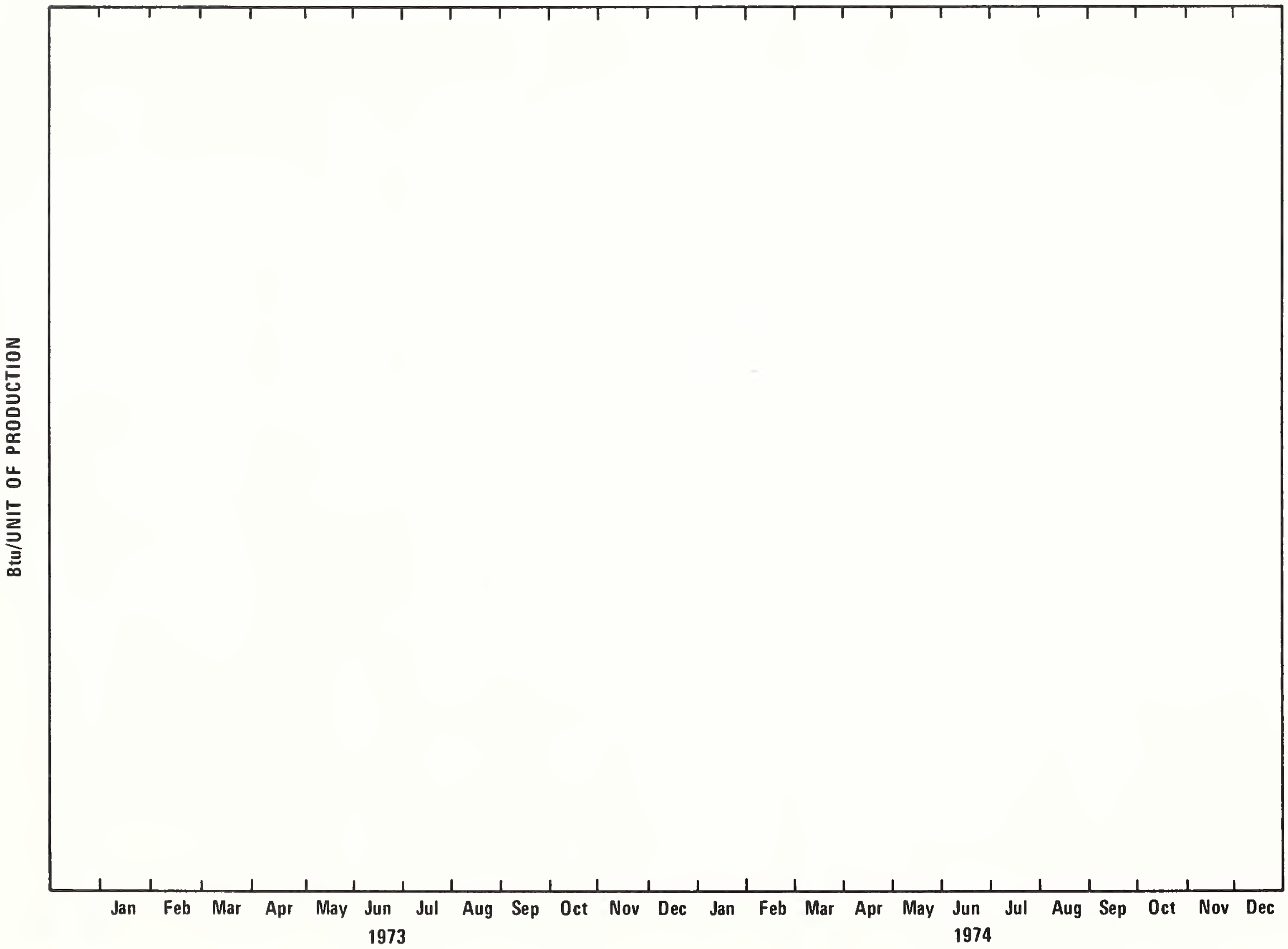
MONTHLY DEPARTMENT ENERGY USE

	RAW MATERIAL "A"			RAW MATERIAL "B"			RAW MATERIAL "C"			Total Raw Material Btu	Raw Material Btu Per Unit of Production	Total Conversion & Raw Material Btu Per Unit of Production
1973	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu	k lb	Btu/k lb	Btu			
Jan.												
Feb.												
Mar.												
Apr.												
May												
June												
July												
Aug.												
Sep.												
Oct.												
Nov.												
Dec.												
1974												
Jan.												
Feb.												
Mar.												
Apr.												
May												
June												
July												
Aug.												
Sep.												
Oct.												
Nov.												
Dec.												

Attachment C

Tracking Chart

Energy Use Per Unit of Production



2.6 First Energy Saving Survey

The survey team's plan for the first survey was approved by the Energy Conservation Committee, you recall. Now we have a sequence of four letters regarding the survey. The manager endorses the survey plan. The team submits their timetable to department heads. Findings of the survey are reported. Finally, the team suggests the need for foreman training in energy conservation. Note the application of:

- Survey
- Employee involvement
- Top management commitment

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: January 29, 1974

To: Department Heads

From: D. T. Parker, Plant Manager

Subject: First Energy Saving Survey

You each have a copy of the January 25, 1974, letter from W. D. Smith and A. B. Jones detailing their plans for the survey aimed at energy wastes that can be corrected by maintenance or operations actions. These are the types of energy losses that can be stopped or reduced right away, or fairly soon, and at little or no expense.

Smith and Jones will contact you in the near future regarding a timetable for the survey. Each of you should inform them of the name of the person you designate to accompany them and participate with them in the survey of areas under your responsibility.

Everyone's cooperation in this program is important. I urge that you put some real priority on this survey and on taking corrective actions as soon as practical.

cc: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: February 1, 1974

To: Department Heads

From: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: First Energy Saving Survey

The timetable for this survey is given below. If any of these dates are not convenient, please contact us so that other times can be arranged.

Area	Date
Furnaces	February 11
Shop	February 12
Heat Treating	February 13
Shipping	February 14
Receiving	February 15
Laboratory	February 19
Utilities	February 20
Chemicals	February 21
Administrative Building	February 22

cc: D. T. Parker, Plant Manager

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: February 28, 1974

To: Department Heads

From: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: Results of First Energy Saving Survey

Attached are the findings of the survey. Some of the operating items have already been corrected by operations personnel. Department supervisors have already written work orders for a number of the maintenance repairs. Those operating or maintenance items that require process shutdown for correction have been added to the lists of jobs to be done at the first shutdown opportunity by department supervisors.

It is important that we monitor the progress of work on correcting these energy wastes by keeping up-to-date records; therefore, it is essential that we are advised when each job is completed.

If there are any questions concerning the survey, please contact us.

As a result of the survey and some energy conservation projects being proposed, we have developed an estimate of potential savings and we suggest that our goal be increased to 12% savings in energy this year.

cc: D. T. Parker, Plant Manager
Energy Conservation Committee

ENERGY SAVING SURVEY

Department: ____________

Date: ____________

Surveyed by: W.D. SMITH
A.B. JONES

Fuel Gas or Oil Leaks	Steam Leaks	Compressed Air Leaks	Condensate Leaks	Water Leaks	Damaged or Lacking Insulation	Excess Lighting	Excess Utility Usage	Equipment Running & Not Needed	Burners Out of Adjustment	Leaks of or Excess of HVAC	Location	Date Corrected
		near #1 furnace									Furnaces	
					#2 furnace lining						Furnaces	
						Parts Storage					Shop	
										Broken Window	Shop	
									#1 furnace		Heat Treating	
#3 furnace											Heat Treating	
								#2 furnace			Heat Treating	
								#1 conveyor			Assembly	
	Bldg. Heater Trap										Assembly	
						Storage Area					Shipping	
										Doors need weatherstrip	Shipping	
								Man cooler fan			Receiving	
						Above Shelves					Receiving	
								Fume hood fan			Laboratory	
				safety shower							Laboratory	
						Chemical Storage					Laboratory	
	#1 boiler										Utilities	
					#2 steam line						Utilities	
		#2 compressor									Utilities	
	#1 reboiler										Chemicals	
			#2 reboiler								Chemicals	
							steam jets				Chemicals	
						Hallways					Administration Building	
										reheat air condition	Administration Building	
				Men's rm. faucet							Administration Building	

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: February 28, 1974

To: J. C. Baker, Energy Conservation Coordinator
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"

Subject: Need for Supervisor Training Program

During our first energy savings survey we had opportunities to discuss energy conservation with the foremen accompanying us. We learned that these foremen should be made more aware of the costs of utilities, the potential of savings through conservation, and the methods for saving energy.

Therefore, we recommend that the Energy Conservation Committee design a course on energy conservation to be included in the Supervisor Training Program.

cc: D. T. Parker
Plant Manager

2.7 THIRD MEETING OF THE ENERGY CONSERVATION COMMITTEE

This meeting is the last to be recorded in this section. On the following pages are four memoranda dealing with the topics shown on the agenda. The last memorandum presents plans for special activities each month for the rest of the year. At this point an active, effective program should be well into the process of implementation.

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: Energy Conservation Committee

From: J. C. Baker, Coordinator

Subject: Agenda for Third Meeting of the Energy Conservation Committee

1. Capital project reviews
2. Energy saving project lists and project evaluation summary
3. Communication of ways to save energy
4. Continuing program

cc: D. T. Parker
Plant Manager

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: Department Heads

From: D. T. Parker, Plant Manager

Subject: Capital Project Reviews

As you know, in our authorization procedure every capital project must be reviewed and approved with regard to safety, fire protection, pollution abatement, and additional utility requirements. As of this date, we are adding energy conservation to this checklist.

Every capital job will be reviewed by the Coordinator of the Energy Conservation Committee. On large jobs the interested committee member will also participate with the coordinator and project team. The purpose of these reviews is to assure that there is efficient utilization of energy in the design. If the project has to do with production, the design Btu per unit of production will be calculated and compared with the historical Btu unit ratio. More efficient use of energy is expected.

cc: Energy Conservation Committee

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: W. D. Smith, Operations "A"
A. B. Jones, Operations "B"
T. G. Marshall, Maintenance
R. B. Robinson, Administrative Services

From: J. C. Baker, Energy Conservation Coordinator

Subject: Energy Saving Project Lists and Project Evaluation Summary

Some of our energy conservation projects will require capital; others can be done on expense. Therefore, we should have two separate lists of projects. In order to have the lists in a uniform format, the two attached forms for capital and expense projects are provided for use by all departments.

The ratio of energy savings/year per dollar invested is an indicator of how good a project is, compared to other projects. The higher the number, the better the project. In the forms, a column for percent return on investment is also included as an aid in assigning priorities on projects.

Also attached is an evaluation summary form to be used for each project.

Please submit copies of these forms to the key supervisors in your area and request that they enter their project information and return completed copies (lists and evaluations) before our next meeting one month from today.

Our manager, Mr. Parker, has requested that we continue working on the lists, revising and updating them monthly, adding new projects that evolve and additional maintenance jobs that become necessary.

cc: D. T. Parker, Plant Manager

ENERGY CONSERVATION
CAPITAL PROJECTS

Department: ____________

Date: ____________

Project Number	Project Description	Energy Savings Btu/Year	Capital Cost $	Ratio $\frac{\text{Btu/Year Saving}}{\text{\$ Capital}}$	Percent ROI	Priority	Status

ENERGY CONSERVATION
EXPENSE PROJECTS

Department: ____________

Date: ____________

Project Number	Project Description	Energy Savings Btu/Year	Expense Cost $	Ratio $\frac{\text{Btu/Year Saving}}{\text{\$ Expense}}$	Percent ROI	Priority	Status

ENERGY CONSERVATION PROJECT
EVALUATION SUMMARY

Capital ________ or Expense ________

Department ____

Date __________________________

Project No.______ Person Responsible ____

Project Title: ____

Description of Project: ____

____

____

____

____

Location: ____

<u>Financial Evaluation</u>

Estimated

Energy saving (electric power kWh/yr steam lb/yr etc.)

Utility or Raw Material	Saving
______________________	______________________ /yr
______________________	______________________ /yr
______________________	______________________ /yr
Total energy saving	______________________ MBtu/yr
Total energy cost saving	______________________ $/yr
Other cost saving due to:	
______________________	______________________ $/yr
Additional cost due to:	
______________________	______________________ $/yr
Net cost saving	______________________ $/yr
Cost of project	______________________ $

ENERGY CONSERVATION PROJECT
EVALUATION SUMMARY

Calculated

Return on investment ____________________ %

Pay back period ____________________ months

Other ____________________ ____________________

Btu/unit of production: Now ____________ After project implemented ____________

Benefits/Problems

Product quality ____________________

Product yield ____________________

Production rate ____________________

Safety ____________________

Pollution ____________________

Maintenance-manpower/materials ____________________

Utilities ____________________

Working conditions ____________________

Employee attitude ____________________

Community ____________________

Other benefits/problems connected with implementation:

____

____

____

Comments: ____________________

____

Project rating: ____________________

____

____

Planned authorization request date: ____________________

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: Energy Conservation Committee

From: T. G. Marshall, Maintenance

Subject: Communication of Ways to Save Energy

I have assembled a group of ECO's from EPIC, which are particularly applicable in our operation, along with a few good articles from the literature. I propose that we publish this as a booklet for plant wide use by supervisors. A copy of the list of ECO's chosen is attached hereto. After each of you has looked over the copy and indicated your approval, I will proceed with publication and distribution.

May I suggest that this booklet could be a useful tool in a training course as suggested in the recent letter from W. D. Smith and A. B. Jones.

cc: D. T. Parker
Plant Manager

LIST OF SUGGESTED ENERGY CONSERVING OPPORTUNITIES

	ECO
Building and Grounds	
Reduce Warehouse Ventilation Air	3.2.1
Reduce Outside Lighting	3.13.1
Reduce Air Conditioning During Non-Working Hours	3.2.5
Electric Power	
Schedule to Minimize Electrical Demand Charge	3.3.1
Steam	
Insulate Bare Steam Lines	3.4.1
Return Steam Condensate to Boiler Plant	3.4.3
Stop Steam Leaks	3.4.5
Inspect and Repair Steam Traps	3.4.6
Other Utilities	
Eliminate Leaks in Combustible Gas Lines	3.5.1
Lower Pressure of Compressed Air to Minimum Necessary Level	3.5.2
Eliminate Leaks in Compressed Air Lines	3.5.3
Use Fan for Personnel Cooling — Not Compressed Air	3.5.5
Combustion	
Replace Worn and Obsolete Controls	3.8.2
Daily Monitoring of Boiler Efficiency	3.8.4
Flue Gas Analysis as a Maintenance Tool	3.8.5
Scheduling	
Standby at Reduced Temperature	3.9.1
Shut Down Idle Heating Equipment	3.9.2
Process Specifications as a Source of Energy Savings	3.9.3
Schedule Equipment for Maximum Utilization	3.9.4

2.7.5

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 8, 1974

To: Energy Conservation Committee

From: J. C. Baker, Energy Committee Coordinator

Subject: Continuing Program

At this point we have our program well underway, but I believe you will agree that we need a continuing program to maintain our momentum. Periodic energy saving surveys are one important activity. Communication and education also need emphasis to develop awareness. I thought it would be well to list the elements in this area, some of which we already have in the mill and others we may wish to include in plans for the future.

1. Monthly meetings of Energy Conservation Committee.
2. Monthly meetings of each committee member with key supervisors in the area he represents.
3. Booklet on ways to save energy.
4. Energy conservation course to be included in Supervisor Training program.
5. Periodic bulletins or features in the Plant News publicizing energy saving achievements and recognizing individuals responsible.
6. Posters on energy saving to be used in much the same way as safety posters.
7. "savEnergy" decals for placing at light switches, typewriters, and on hard hats.
8. Technical talks on energy saving aspects of steam traps, lighting, insulation, etc.
9. Letters to employees and their families giving energy saving tips for the home.
10. In public relations, company ads stressing energy conservation on radio and in newspaper, talks on energy saving before civic groups.

Attached to this letter is the outline of a proposed program of activities for each month for the rest of the year.

cc: D. T. Parker, Plant Manager

Planned Activities in Energy Conservation for Remainder of 1974

The following activities will take place each month and will not be repeated in the plans for individual months:

1. Meeting of Energy Conservation Committee
2. Meeting of each Committee Member with the key supervisors in his area
3. Updating of energy saving project lists
4. Communicate progress with updated plot of Btu/unit of production
5. Department supervision will conduct weekend audit

Month

April
1. Distribute booklet of selected ECO's
2. Review status of corrective actions regarding first energy saving survey
3. Publish bulletin on energy saving tips for driving
4. Technical talk on steam traps

May
1. Energy conservation course in Supervisor Training
2. Departments develop energy balances
3. Distribute "savEnergy" decals
4. Technical talk on economics of insulation
5. Letter to employees at home with energy saving tips for the home

June
1. Trained foremen start holding monthly meetings with their people on energy conservation
2. Publish bulletin on air conditioning tune-up
3. As a result of energy balances, committee will conduct energy surplus survey
4. Coordinator gives talk at high school

July
1. Poster contest
2. Bulletin on energy saving during vacations
3. Survey of steam pressure reducing stations
4. Technical talk on lighting

August
1. Publicize poster contest winner in plant and community newspaper
2. Distribute posters
3. Survey compressed air requirements
4. Bulletin - "Don't use compressed air for cooling"

Sept.
1. Bulletin - "Tune up space heating systems"
2. Survey steam condensate system
3. Coordinator prepares talk with slides for local technical society meeting
4. Committee rides through plant at night and suggests corrective action on lighting

October
1. Demonstration of infrared survey to detect excessive heat losses
2. Steam trap survey
3. Bulletin on steam tracing systems
4. Technical talk on combustion

November 1. Survey oversized electric motors and equipment
2. Bulletin - Recognize someone's energy saving achievement
3. Second course in Supervisor Training
4. Technical talk on electric motors and power factor

December 1. Bulletin - "Use reflectors and reduce Christmas lighting"
2. Report achievements in reductions of energy use and announce goal for next year
3. Survey use of low pressure steam
4. Plan program activities for next year

2.8 CONCLUSION

This section on program implementation began with a discussion of the importance of management interest and support. It seems appropriate to include in the conclusion a letter from the manager to his staff demonstrating his *continuing concern* about energy conservation. His request for a contingency plan is then answered by his department heads with a report on the status of the contingency planning in each deparment.

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 20, 1974

To: Department Heads

From: D. T. Parker, Plant Manager

Subject: Request for Energy Curtailment Contingency Plan

You should all be aware that energy supply is a very real and serious problem to our operations. Briefly, our anticipated allocations of fuel oil, natural gas, electric power, and gasoline are insufficient to support our operation as they have in the past. Our ability to eliminate unnecessary use of these commodities and to allocate fuel to vital functions will ultimately determine how severely our operations are curtailed.

Even more serious is our inability to secure adequate quantities of coal to meet anticipated needs. Efforts during the past two months have failed to increase deliveries, and inventories are currently at a low level. Current fuel suppliers are operating at their ultimate capacity and they face problems associated with weather, fuel shortages for their mining equipment and ever increasing strip mine regulations. To date, we have been unable to secure additional suppliers as those who are mining coal are sold out beyond their production capabilities.

At this time it appears that some production curtailments may be necessary. Each supervisor should review his operations: those pieces of equipment which are operating at less than desired efficiency with respect to energy consumption should be identified and plans made to restrict or curtail their operation. The basic factors which influence fuel efficiency and/or energy utilization in all processes should be identified and immediate steps taken to minimize our energy requirements.

In anticipation of possible short term reductions in energy supply, for instance electric power, we need a contingency plan. This should include a list of the equipment that would be shut down and the sequence of shut down in your department in case of 25%, 50%, 75% and 100% energy curtailments.

Your plan for reducing energy requirements in your area should be formalized and available for review by me one week from today. Remember - NO SAVING IS TOO SMALL TO BE CONSIDERED.

cc: Energy Conservation Committee

savEnergy

ECONERGY COMPANY

INTER-OFFICE CORRESPONDENCE

Date: March 27, 1974

To: D. T. Parker, Plant Manager

From: Department Heads

Subject: Reduction of Energy Requirements and Contingency Plan Status

Significant reductions in energy use have been achieved in our operating units as follows:

Utilities

It has been our operating practice to fire all three boilers even though steam requirements could be provided by two boilers fully loaded. In this way, a forced outage of one boiler could be handled without decreasing steam output and causing interruption of operations of steam users.

We have shut down #1 boiler, the oldest and least efficient boiler, and the result is a fuel saving of _____ M Btu/hr. In case of a forced outage of one of the two operating boilers, we have set up a communications procedure to curtail steam to certain units that can be shut down safely and quickly with the least impact on other operations in the plant and re-started with a minimum loss of productivity.

Operations "A" and "B"

Similarly, in both departments, we have been able to shut down one of three furnaces by rescheduling throughput. The schedule is extremely tight at our present production rate, and on occasion we may need to fire up the third furnace in order to meet commitments. Fuel saving at present is _____ M Btu/hr.

Contingency Plan Status

1. Electric Power

In general, during any curtailment of power, air conditioning thermostats in all buildings will be reset to ____F. System interlocks have been provided to avoid inadvertant operation of the heating system, except in those situations where the controlled lower humidity is required.

If a "brown out" occurs (voltage reduction in excess of 10%), certain motors trip off automatically and others must be tripped manually to avoid damage. We are surveying all motors to identify the ones that require manual tripping. Utilities will set up a communication procedure to inform the appropriate people when a "brown out" occurs.

Following is a tabulation of shutdowns sequence for curtailments of electric power:

Curtailment	Shutdown Section
25%	1
50%	1,2
75%	1,2,3
100%	1,2,3,4

We have designated a number of units that will be included in each of the four sections but the plan is not complete yet.

2. Fuels

For each fuel, we will have a tabulation like the one for electric power. We are holding meetings this week to complete the designation of units in each section for each tabulation. We hope to submit the detailed plan to you next week.

In general, when fuel curtailment causes a cut-back in steam generation, all steam heated buildings will have thermostats reset to ____F. Again, system interlocks will prevent inadvertant operation of the cooling system, except where the controlled lower humidity is required.

savEnergy

Section 3

ENERGY CONSERVATION OPPORTUNITIES (ECO's)

TABLE OF CONTENTS

3. ENERGY CONSERVATION OPPORTUNITIES (ECO's)

3.0 INTRODUCTION

Energy Conservation Opportunities (ECO's) are reported in this section. Section 3.1 is a checklist of such opportunities and Sections 3.2 through 3.13 contain case descriptions of specific applications of ECO's. When a case report is included in EPIC, the checklist item to which it pertains is followed by a subsection number identifving the case report. The checklist and the case reports are categorized in the same manner. One case report may be shown as an example of more than one checklist item.

All of the ECO cases reported are either based on a specific industrial and commercial experience or representative of several experiences. The reports include graphs, tables and/or sample calculations, as well as a brief description of the circumstances and the action. The calculations are intended to illustrate key steps in estimating energy savings potential and associated cost savings. They are not complete engineering analyses of the application. The cases have been checked for internal consistency but do not contain all of the factors which will affect your decision to implement an ECO.

It will be noted that costs of fuel, steam, and electric power vary from case to case. In some instances, low energy costs were reported because the projects were actually implemented two or three years ago. The energy costs in hypothetical examples were chosen arbitrarily to reflect current trends. Even so, it is recognized that energy costs vary widely from region to region. Therefore, if the reader is interested in the economic impact of a particular ECO in a specific application, appropriate local unit costs can be used to revise the cost calculation.

The ECO's have been reported from many different sources and where appropriate both the contributor and the company which supplied the case are listed.

As new examples of energy conservation actions become available, they will be published periodically as supplements to EPIC. You will be notified of the availability of these supplements if you will return the card located in the back of the guide.

Please note the definitions of the following symbols used in this section:

k = thousand or kilo
M = million or mega

3.1 ENERGY CONSERVATION OPPORTUNITY CHECKLIST

3.1.1 FACTORS TO CONSIDER IN EVALUATING ECO's

The ECO's in the checklist are suggested possibilities for conserving energy. However, any ECO requires careful evaluation for a specific application. For instance, the possibility that under certain circumstances an ECO could be counterproductive needs to be determined for the application.

In some cases existing equipment will have operating limits which must be considered. For example, excessive insulation on a furnace roof can confine too much heat, overheat the refractory, and cause failure of the roof.

Other factors to be considered are listed in the form, ""Energy Conservation Project Evaluation Summary" in Section 2.7.3. Information on financial analysis and safety and pollution considerations appears in Section 5 and Section 7 respectively.

3.1.2 BUILDINGS AND GROUNDS

3.1.2 BUILDINGS AND GROUNDS	REFERENCE RELATED ECO
Suggestions for Immediate Action	
Reduce Ventilation Air	3.2.1
Increase Light Reflectance of Walls and Ceilings	
Shut Off Air Conditioning in Winter Heating Season	
Eliminate Unused Roof Openings or Abandoned Stacks	
Reduce Building Exhausts and Thus Make-Up Air	
Reduce Glazed Areas in Buildings	
Reduce Temperature of Service Hot Water	
Shut Down Air Conditioning During Non-Working Hours	3.2.2
Reduce Heating Level When Building Is Not in Use	
Install Timers on Light Switches in Little Used Areas	
Close Holes and Openings in Buildings Such as Broken Windows, Unnecessary Louvers and Dampers,	

	REFERENCE RELATED ECO
Cracks Around Doors and Windows	
Repair Faulty Louvers and Dampers	
Conserve Energy by Efficient Use of Water Coolers and Vending Machines	3.2.3
Schedule Use of Elevators to Conserve Energy	3.2.4

Other Suggested Actions

Reduce Air Conditioning Load by Evaporating Water from Roof

Convert to Fluorescent, Mercury, Sodium, or High Intensity Direct Lighting

Insulate Walls, Ceilings, and Roofs

Install Timers on Air Conditioning for Summer Operation

Periodically Calibrate the Sensors Controlling Louvers and Dampers on Buildings

Eliminate Inefficient Electric Lamps from Plant Stocks and Catalogs

Clean Air Conditioning Refrigerant Condensers to Reduce Compressor Horsepower — Check Cooling Water Treatment

Use "Heat Wheel" or Other Heat Exchanger to Cross-Exchange Building Exhaust Air with Make-up Air

Use Photocell Control on Outdoor Lights

Use Building Materials Which Require Less Energy to Produce

Size Air Handling Grills, Ducts, and Coils to Minimize Air Resistance

Recover Heat in Waste Service Hot Water

Avoid Introducing High Moisture Exhaust Air Into Air Conditioning System

Air Condition Only Space in Use

Shade Windows from Summer Sun

Use Direct Air Supply to Exhaust Hoods

	REFERENCE RELATED ECO
Use Exhaust Heat from Buildings for Snow and Ice Removal from Walks, Driveways, Parkways, Parking Lots, etc.	
Use Separate Switches on Perimeter Lighting Which May be Turned Off When Natural Light is Available	
Use Double or Triple Glazed Windows to Maintain Higher Relative Humidity and to Reduce Heat Losses	
Heat Water During Off-Peak Periods and Store for Later Use	
Use Heat Pump for Space Conditioning	
Heat Service Hot Water with Air Conditioning Compressor Exhaust	
Use Radiant Heater for Spot Heating Rather than Heating Entire Area	
Reduce or Eliminate General Lighting Where Natural Light Provides Sufficient Illumination. Limit Higher Lighting Levels to Task Areas Only	
Reduce Exterior Buildings and Grounds Illumination to Minimum Safe Level	3.13.1
Interlock Heating and Air Conditioning Systems to Prevent Simultaneous Operation	
Recycle Air for Heating, Ventilation and Air Conditioning to Maximum Extent	
Minimize Use of Outside Make-Up Air for Ventilation Except When Used for Economizer Cycle	
Lower Light Fixtures in High Ceiling Areas	
Reduce General Illumination to Minimum Necessary for Safety	
Replace Air Curtain Doors with Solid Doors	
Reduce Heat Gain by Window Tinting	

3.1.3 ELECTRICAL POWER

	REFERENCE RELATED ECO
Other Suggested Actions	
Use Combined Cycle Gas Turbine Generator Sets with Waste Heat Boilers Connected to Turbine Exhaust	
Replace Steam Jets on Vacuum Systems with Electric Motor Driven Vacuum Pumps	
Size Electric Motors for Peak Operating Efficiency—Use Most Efficient Type of Electric Motors	
Use Power During Off-Peak Periods—Store Heated/Cooled Water for Use During Peak Demand Periods	
Use Steam Pressure Reduction to Generate Power	
Use Immersion Heating in Tanks, Melting Pots, etc.	
Reduce Load on Electric Conductors to Reduce Heating Losses	
Increase Electrical Conductor Size to Reduce Distribution Losses	
Optimize Plant Power Factors	
Use By-Product Heat from Transformers for Service Water Heating	
De-energize Excess Transformer Capacity	
Provide Proper Maintenance and Lubrication of Motor Driven Equipment	
Consider Energy Efficiency When Purchasing New Equipment	
Consider Power Loss as Well as Initial Loads and Load Growth in Sizing Transformers	
Schedule to Minimize Electrical Demand Charge	3.3.1
Use Multiple Speed Motors or Variable Speed Drives for Variable Pump, Blower and Compressor Loads.	

3.1.4 STEAM

Suggestions for Immediate Action

	REFERENCE RELATED ECO
Turn Off Steam Tracing During Mild Weather	
Maintain Steam Jets Used for Vacuum System	
Repair Leaks in Lines and Valves	3.4.5
Repair Insulation on Condensate Lines	
Repair Faulty Insulation on Steam Lines	
Repair or Replace Steam Traps	3.4.6
Eliminate Leaks in High Pressure Reducing Stations	
Cover Condensate Storage Tanks	

Other Suggested Actions

	REFERENCE RELATED ECO
Consider Replacing Electric Motors with Back Pressure Steam Turbines and Use Exhaust Steam for Process Heat	
Operate Distillation Columns at Minimum Quality Requirements	
Operate Distillation Columns at Near Flooding Conditions for Maximum Separation Efficiency	
Determine Correct Feed Plate Location on Distillation Columns to Increase Efficiency and Minimize Steam Consumption	
Consider Switching Selected Steam Stripping Distillation Units from Direct (Live) Steam to Indirect (Dry) Stripping	
Use Correct Size Steam Traps	
Flash Condensate to Produce Lower Pressure Steam	3.4.4
Evaluate Replacing Condensing Steam Turbine Rotating Equipment Drives with Electric Motors, If Your Plant Has a Power Generating Capability	
Add Traps to a Distillation Column to Reduce the Reflux Ratio	
Insulate Condensate Lines	
Minimize Boiler Blowdown with Better Feedwater Treatment	
Insulate Steam Lines	3.4.1
Install Steam Traps	3.4.2
Return Steam Condensate to Boiler Plant	3.4.3
Use Minimum Steam Operating Pressure	
Use Waste Heat Low Pressure Steam for Absorption Refrigeration	
Replace Barometric Condensers with Surface Condensers	
Shut Off Steam Traps on Superheated Steam Lines When Not in Use	
Optimize Operation of Multi-Stage Vacuum Steam Jets	
Use Optimum Thickness Insulation	
Use Reflux Ratio Control or Similar Control Instead of Flow Control on Distillation Towers	
Substitute Hot Process Fluids for Steam	

3.1.5 OTHER UTILITIES

Suggestions for Immediate Action

	REFERENCE RELATED ECO
Clean Fouling from Water Lines Regularly	
Shut Off Cooling Water When Not Required	
Reduce Business Travel By Using Telephone When Possible	
Conduct Monthly Audit of Water Meters for Early Leak Detection	
Clean or Replace Air Filters Regularly	
Remove Unneeded Service Lines to Eliminate Potential Leaks	
Eliminate Leaks in Combustible Gas Lines	3.5.1
Eliminate Leaks in Inert Gas and Compressed Air Lines and Valves	3.5.3
Eliminate Leaks in Water Lines and Valves	
Shut Off All Laboratory Fume Hoods When Not In Use	

Other Suggested Actions

	REFERENCE RELATED ECO
Install Adequate Dryers on Air Lines to Eliminate Blowdown	
Install Compressor Air Intakes in Coolest Locations	3.5.4
Recover and Reuse Cooling Water	
Do Not Use Compressed Air for Personal Cooling	3.5.5
Use Flow Control Valves on Equipment to Optimize Water Use	
Evaluate Water Cooling vs. Air Cooling for Specific Situations	
Eliminate Cooling of Process Streams Which Subsequently Must Be Heated and Vice Versa	
Shut Off Cooling If Cold Outside Air Will Cool Process	
Use Cascade System of Recirculating During Cold Weather to Avoid Sub-Cooling	
Operate Cooling Towers at Constant Outlet Temperature to Avoid Sub-Cooling	
Use Minimum Cooling Water to Bearings	
Increase the Level of the Water in a Drainage Ditch To Reduce the Pumping Head and Horsepower Required Where Drainage Water Must be Pumped Over a Levee for Disposal	
Reduce Sewer Liquid Volume Which Reduces Treatment Energy by Returning Steam Condensate to Boilers	
Replace Over-Size Motors and Pumps with Optimum Size	
Reduce the Pressure of Compressed Air to the Minimum Required	3.5.2
Reduce Hot Water Temperature to the Minimum Required	
Recycle Treated Water	
Eliminate Compressed Air Drives from Permanent Installations	

3.1.6 HEAT RECOVERY

Other Suggested Actions	REFERENCE RELATED ECO
Use the Overhead Condenser to Generate Steam From Condensates in a Distillation Process	
Use Hot Flue Gases in Radiant Heater for Space Heating, Ovens, Dryers, etc.	
Use Heat in Flue Gases to Preheat Products or Material Going into Ovens, Dryers, etc.	
Use Hot Process Fluids to Preheat Incoming Process Fluids	
Use Hot Flue Gases to Preheat Wastes for Incinerator Boiler	
Use Waste Heat from Hot Flue Gases to Generate Steam for Processes or Consider Selling Excess Steam	
Use Waste Heat from Hot Flue Gases to Heat Space Conditioning Air	3.6.1
Use Waste Heat from Hot Flue Gases to Preheat Combustion Air	
Use Engine Exhaust Heat to Make Steam	3.6.2

	REFERENCE RELATED ECO
Recover Fuel Value in Polluted Exhaust Air	
Recover Fuel Value in Waste By-Product	
Use Flue Gases to Heat Process or Service Water	
Use Oven Exhaust for Space Heating	
Recover Heating or Cooling Effect from Ventilation Exhaust Air to Precondition Incoming Ventilation Air	
Use Recovered Heat from Lighting Fixtures for Useful Purpose, i.e., to Operate Absorption Cooling Equipment	
Use Flue Gas Heat to Preheat Boiler Feedwater	3.6.1
Use Cooling Air Which Cools Hot Work Pieces for Space Heating or Make-Up Air in Cold Weather	

3.1.7 HEAT CONFINEMENT

REFERENCE RELATED ECO

Suggestions for Immediate Action

Repair Faulty Insulation in Furnaces, Boilers, etc.

Other Suggested Actions

Use Economic Thickness of Insulation for Low Temperatures

Increase Insulation Thickness

REFERENCE RELATED ECO

Use Soft Insulation in Cycling Furnaces to Facilitate Heating Up and Cooling Down

Use Minimum Safe Oven Ventilation

Upgrade Insulation and Linings in Furnaces, Boilers, etc.

Repair Furnaces and Oven Doors So That They Seal Efficiently

3.1.8 COMBUSTION

	REFERENCE RELATED ECO
Suggestions for Immediate Action	
Calculate and Plot Boiler Efficiency Daily	3.8.4
Establish Burner Maintenance Schedule	
Adjust Burners for Efficient Operation	
Other Suggested Actions	
Improve Combustion Control Capability	3.8.1; 3.8.2
Heat Oil to Proper Temperature for Good Atomization	3.8.3
Eliminate Combustible Gas in Flue Gas	3.8.5
Reduce Combustion Air Flow to Optimum	3.8.6
Convert Combustion to More Efficient Fuel	
Replace Obsolete Burners with More Efficient Ones	
Use Waste and By-Products as Fuel	
Limit and Control Secondary Combustion Air in Furnace Operations to the Amount Required for Proper Furnace Operation	

3.1.9 SCHEDULING

	REFERENCE RELATED ECO
Suggestions for Immediate Action	
Shut Down Process Heating Equipment When Not in Use	3.9.2
Other Suggested Actions	
Locate Causes of Electrical Power Demand Charges, and Reschedule Plant Operations to Avoid Peaks	3.3.1
Reduce Temperature of Process Heating Equipment When on Standby	3.9.1
Use Most Efficient Equipment at It's Maximum Capacity and Less Efficient Equipment Only When Necessary	

	REFERENCE RELATED ECO
Heat Treat Parts Only to Required Specifications or Standards	3.9.3
Schedule Routine Maintenance During Non-Operating Periods	
Consider Three or Four Days Around-the-Clock Operation Rather Than One or Two Shifts Per Day	
Minimize Operation of Equipment Required to be Maintained in Standby Condition	
Reduce Operating Time of Equipment to That Actually Required	3.9.4
Optimize Production Lot Sizes and Inventories	

3.1.10 MATERIALS HANDLING

REFERENCE RELATED ECO

Suggestions for Immediate Action

Turn Off Conveyors, Lift Trucks, etc. When Not In Use

Recharge Batteries on Materials Handling Equipment During Off-Peak Demand Periods

Adjust and Maintain Fork Lift Trucks for Most Efficient Operation

Shut Down Diesel Construction Equipment When Not Needed

Other Suggested Actions

Use Optimum Size and Capacity Equipment

Upgrade Conveyors

Use Gravity Feeds Wherever Possible

3.1.11 SHIPPING, DISTRIBUTION, AND TRANSPORTATION

REFERENCE RELATED ECO

Suggestions for Immediate Action

Schedule Regular Maintenance to Maintain Efficiency of Truck Engines

Shut Down Truck Engines While Loading, Unloading, or Waiting

Keep Loading Dock Doors Closed When Not In Use

REFERENCE RELATED ECO

Other Suggested Actions

Size Trucks to Job

Reduce Delivery Schedules

Consolidate Deliveries

Eliminate Lighting on Top of Stacked Material

Install Air Seals Around Truck Loading Dock Doors

Optimize Routing of Delivery Trucks to Minimize Mileage

Evaluate Energy Use in Packaging

3.1.12 PROCESS CHANGES

Other Suggested Actions

	REFERENCE RELATED ECO
Schedule Baking Times of Small and Large Components to Minimize Use of Energy	3.9.3
Use Vapor Recompression Design in Distillation Processes	
Use "Side Draw" Principle in Distillation Column Design	
Use Continuous Equipment Which Retains Process Heating Conveyors Within the Heated Chamber	
Use Direct Flame Impingement or Infrared Processing for Chamber Type Heating	
Convert from Indirect to Direct Firing	
Convert from Batch to Continuous Operation	
Use Shaft Type Furnaces for Preheating Incoming Material	
Convert Liquid Heaters from Underfiring to Immersion or Submersion Heating	
Minimize Unessential Material in Heat Treatment Process	3.12.1
Change Product Design to Reduce Processing Energy Requirements	
Reduce Scrap Production	
Upgrade Obsolete or Little Used Equipment	

3.1.13 COMMERCIAL PRACTICES	REFERENCE RELATED ECO
Suggestions for Immediate Action	
Shut-Down Air Conditioning During Non-Working Hours	3.2.5
Reduce Heating Level When Building is Not in Use	
Air Condition Only Space in Use	
Reduce Business Travel by Using Telephone When Possible	
Turn Off Lights, Electric Typewriters and Other Such Equipment When Not in Use	
Replace Broken Windows and/or Window Sash	
Maintain Space Temperature Lower During the Winter Season and Higher During the Summer Season	
Reduce Interior Lighting to Minimum Necessary Level	
Reduce Hot Water Temperature in Washrooms to 120F	
Avoid Electrically-Powered Animated Displays	
Urge Customers to Take Merchandise with Them	
Reduce Lighting of Used-Car Lots After Midnight	
Eliminate or Reduce Lighting of Outdoor Displays and Signs	
Utilize Daylight Whenever Possible in Lieu of Artificial Light	
Keep Doors and Windows Shut to Retain Heated or Air Conditioned Air	
Overlap the Work Hours of Custodial Services with Normal Day Hours	
Turn On Display Merchandise, Such as Radios, TV Sets, Washers, Dryers, Power Tools, etc., for Demonstration Only When Requested by Customer	
Consolidate Freight Shipments and/or Deliveries	
Other Suggested Actions	
Shade Windows From Summer Sun	
Reduce Exterior Buildings and Grounds Illumination to Minimum Safe Level	3.13.1
Clean or Replace Air Filters Regularly	
Use More Efficient Light Sources, i.e. Fluorescent Lamps for Incandescent Bulbs	
Use Light Color Finishes on Ceilings, Walls, Floors and Furnishings	
Keep Lamps and Reflectors Clean	
Reduce Illumination to Minimum Necessary Level Except Where Custodial Work is Actually Being Performed	

Energy savings may be realized by reducing forced ventilation in buildings to a lesser but still adequate amount required to provide safe air conditions.

The air flow output of a centrifugal fan in cubic feet per minute (cfm) varies directly as its rotative speed. Thus, the forced ventilation of a building can be reduced by decreasing the fan speed. Figure 1 below shows the percent decrease in horsepower accomplished by reducing centrifugal fan speed as a function of the ratio of the new, reduced air flow in cfm to the initial air flow in cfm.

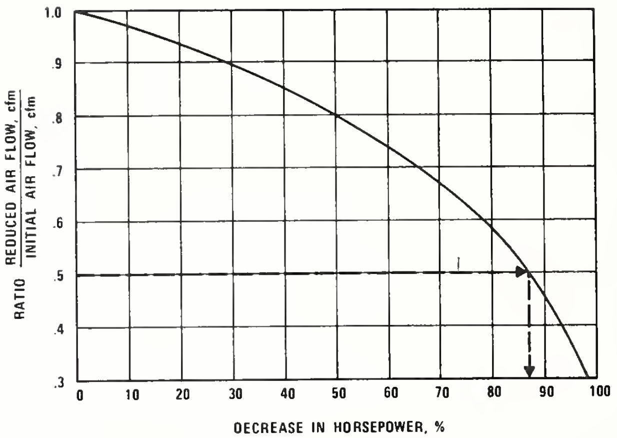


Figure 1 – Decrease In Horsepower Accomplished By Reducing Fan Speed (Based on Laws of Fan Performance)

EXAMPLE

In a new 150,000 cubic foot warehouse, it was originally planned to provide five air changes per hour which would have required a 10 hp motor (with a load of 9.83 hp) driving a 24 inch diameter centrifugal fan at 915 rpm to deliver 12,500 cfm. Subsequent information indicated that 2.5 air changes per hour would provide adequate ventilation. Cutting the fan speed in half to 457.5 rpm would reduce the fan output to 6250 cfm to meet the new requirement of 2.5 air changes per hour.

The ratio of the reduced air flow to the initial air flow is 6250 cfm/12,500 cfm or 0.5. Entering the graph with the 0.5 ratio, it is found that there would be an 87.5% decrease in horsepower.

Annual savings in kWh = 87.5%/100% × 9.83 hp × 0.746 kw/hp × 8760 h/yr = 56,200 kWh per year

If the utility consumes 10,000 Btu of fuel per kWh,

Annual savings in Btu = 10,000 Btu/kWh × 56,200 kWh/yr = 562 MBtu per year

If the cost of electric power is $0.02/kWh,

Annual cost saving = 56,200 kWh/yr × 0.02 $/kWh = $1120 per year

SUGGESTED ACTION

Determine whether the number of air changes per hour provided by your ventilation system(s) may be reduced and still maintain adequate levels for safety.

In cases where the centrifugal fan is belt-driven, the speed reduction may be accomplished by appropriate change-out of pulleys. The decrease in horsepower requirement may be sufficient to justify changing to a smaller electrical motor. Consultation with the manufacturer may be advisable.

(Note: Reducing ventilation may also reduce energy requirements for space heating/cooling).

REFERENCE

Heating, Refrigerating, Ventilating and Air Conditioning Guide and Data Book—Equipment—1972
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
345 E. 47th Street
New York, New York 10017

SOURCE Based on J. R. Kernan—"Examples of Energy Conservation," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

EXAMPLE

An opportunity to conserve energy was identified as a reduction in air conditioning during non-working hours in a fabric slip-cover plant that operates only one eight-hour shift per day, five days per week. The plant consists of a 4800 sq ft office building attached to a 100,000 sq ft manufacturing building. Both buildings were continuously air-conditioned during the cooling season.

By eliminating non-essential air conditioning, a substantial savings in electric power was realized during the normal cooling season. Air conditioning is cut back in both buildings late in the afternoon of working days and the space temperatures drift upward during the evening hours as a result of heat retained in the block walls. At about 11:00 p.m. the space temperature peaks and begins to drift downward due to the cooler outside night air temperature. By 8:00 a.m. air in the buildings has cooled to about the desired working temperature. The reduction in mechanical air conditioning has resulted in a reported savings of 826,000 kWh of electric power during the cooling season.

$$\begin{aligned} \text{Annual cost savings} &= 826{,}000 \text{ kWh/yr.} \\ &\quad \times .0007 \text{ \$/kWh} \\ &= \underline{\$6200} \text{ per year} \end{aligned}$$

SUGGESTED ACTION

Review your air conditioning operational practices.

Determine the feasibility of shutting the system down during non-working hours. Consider the possibility of maintaining slightly higher temperatures during the cooling season.

SOURCE Based on J. R. Kernan—"Examples of Energy Conservation," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

ENERGY CONSERVATION BY EFFICIENT USE OF WATER COOLERS AND VENDING MACHINES

For the convenience of their employees, most industrial and office installations have various types of vending machines, water coolers, etc. These items are generally taken for granted and therefore are seldom considered in a program of energy conservation. Yet, these convenience appliances waste relatively significant amounts of electricity if left operating during non-working hours. Electric water coolers can easily use over 1000 kilowatt hours per year each and vending machine display lighting another 300-400 kilowatt hours per year. These seem like small amounts, but translated into dollars, they amount to $12-$48 per machine or more per year.

EXAMPLE

As a sample of energy savings in this area, consider a company which has eleven water coolers and eight vending machines. The water coolers use 48.4 kWh per day or 17.700 kWh per year and the vending machine lighting uses 8.64 kWh per day or 3160 kWh per year.

Potential savings from operating only 250 days per year.

Present energy use = 17,700 kWh/yr
+ 3160 kWh/yr
= 20,860 kWh/yr

Reduced energy use for 250 days operation = 20,860 kWh/yr × 250d/365d = 14,300 kWh/yr

Energy saving = 6,560 kWh per year

Cost saving at $0.03/kWh = 6,560 kWh/yr × 0.03 $/kWh = $197 per year

SUGGESTED ACTION

Determine whether the number of electric water coolers and vending machines in your plant exceeds actual requirements. Perhaps the number could be reduced by relocation. Remove excess coolers and vending machines and consider shutting down the remainder during extended off-work periods. Consult vending machine service representative about shutting down machines during non-working periods.

SOURCE Based on D. Rudawitz—"Reports on Energy Conservation in Industry," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

TABLE I. SOME REPRESENTATIVE APPLIANCES

Type	Energy Use	Per Day Use	Per Yr Use (365 Days)	$ Per Year (Approx.)*
Small water cooler	Cooling water	2.0 kWh (20 min/h operation)	730 kWh	22
Large water cooler	Cooling water	4.4 kWh	1600 kWh	48
Coffee vending machine	Display and button lighting	0.48 kWh	175 kWh	5
Candy vending	Display lighting	1.08 kWh	394 kWh	12

*Based on assumed average cost of 0.03 per kilowatt hour.

EXAMPLE

Elevators are a common source of energy loss, particularly when used in lieu of stairs for one or two floor trips. Elevator lighting is also an area of energy waste. Elevators often have 300 or more watts of fluorescent lighting when only 30 watts are needed. These lights burn for 24 hours a day, 365 days a year in many installations. This alone is a waste of 2370 kilowatt hours per year per elevator ($71.00) in electrical energy. The following table presents the electrical energy consumption data and its annual cost for four typical elevators used for 600 one floor trips per year.

SUGGESTED ACTION

Energy savings can be realized very quickly by several methods. First, when there are two elevators (or more) side by side serving a building, one (or more) may be shut down. This will force more passengers per load. Educate your employees by the use of memos and signs to use the stairs for short up and down trips. As an additional savings measure, lighting in the elevators being used should be reduced to minimum required for safety.

SOURCE Based on D. Rudawitz—"Reports on Energy Conservation in Industry," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

ENERGY USAGE CHARACTERISTICS FOR FOUR TYPICAL ELEVATORS

Type	Weight Capacity	fpm Average	watts	sec/ floor	600 one floor trips/d
Hydraulic Type I	1500	100	10 kW	8	13 kWh/d 65 kWh/wk 3380 kWh/yr ($101/yr)*
Electric Type I	2000	250	12 kW	5	10 KWh/d 50 kWh/wk 2600 kWh/yr ($78/yr)*
Hydraulic Type II	2000	125	12 kW	7	14 kWd/d 70 kWh/wk 3640 kWh/yr ($109/yr)*
Electric	2500	350	16 kW	3	8 kWh/d 40 kWh/wk 2080 kWh/yr ($62/yr)*

Based on information from Otis Elevator Company and Dover Elevator Company.

*Using an assumed average cost per kilowatt-hour of $ 03.

Reschedule the use of electrical equipment to lower the demand peak. This action will not reduce the amount of electrical energy used, assuming the same equipment is continued in operation, but will reduce the "surcharge" (demand charge) paid to the power company to provide, in effect, the standby equipment that must be maintained to meet your *peak* demand for power. Theoretically, if you and your community reduce the peak demand, this reduces the standby capacity required, which in turn may postpone the power company's need to install additional capacity to meet an increasing load on its systems. While the individual industrial power consumer's contribution to the utility-wide demand peak may be small, reducing his peak demand can be rewarding.

EXAMPLES

1. A plant operates a group of twelve 30 kW resistance heated furnaces. Each furnace draws its full load of 30 kW for two hours after being turned on and then falls back to a temperature holding rate of 10 kW. All furnaces go through one cycle of heating up, holding, and cooling every 24 hours. By scheduling their use so that no more than two furnaces are on heat-up simultaneously, the following savings in electrical demand charge can be achieved.

Where all 12 furnaces heat-up simultaneously:

Peak demand = 12 furnaces × 30 kW/furnace
= 360 kW

Where 2 furnaces heat-up simultaneously and the remaining 10 furnaces are on hold:

Peak demand = (2 furnaces × 30 kW/furnace) + (10 furnaces × 10 kW/furnace)
= 160 kW

Peak demand Reduction = 360 kW — 160kW
= 200 kW

Annual demand charge cost saving 200 kW × 1.50 \$/kW mo × 12 mo/yr
= \$3600 per year

2. A small city utilitiy uses an 800 hp pump for eight hours out of each 24. By operating the pump only at night, an off-peak rate reduction of \$1.40/kW mo in the demand charge results in the following annual savings.

Annual demand charge cost savings = 800 hp × 0.746 kW/hp × 1.40 \$/kW mo × 12 mo/yr
= \$10,000 per year

SUGGESTED ACTION

A plot of demand versus time is helpful in evaluating the possibilities for savings. If one is not available, your local power company will usually cooperate in preparing such a plot. If the plot shows some high cyclical peaks, usually some savings are possible by altering equipment use or possibly scheduling the use of equipment during off-peak hours.

SOURCE Based on L. A. Wood—"Energy Conservation Through Scheduling and Process Changes," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

EXAMPLE

A survey of a plant steam system found 120 feet of bare ½ inch steam line and 70 feet of bare 1 inch steam line operating at 150 psig and 230 feet of bare 2 inch steam line operating at 30 psig. The value of the steam was \$1.20 per MBtu. The amount of heat lost per year was determined from the following figure.

The heat lost as determined from Figure 1 is:

½ inch line = 120 ft/100 ft × 300 MBtu/yr
= 360 MBtu per year

1 inch line = 70 ft/100 ft × 430 MBtu/yr
= 301 MBtu per year

2 inch line = 230 ft/100 ft × 370 MBtu/yr
= 851 MBtu per year

Total heat lost = 1512 MBtu per year

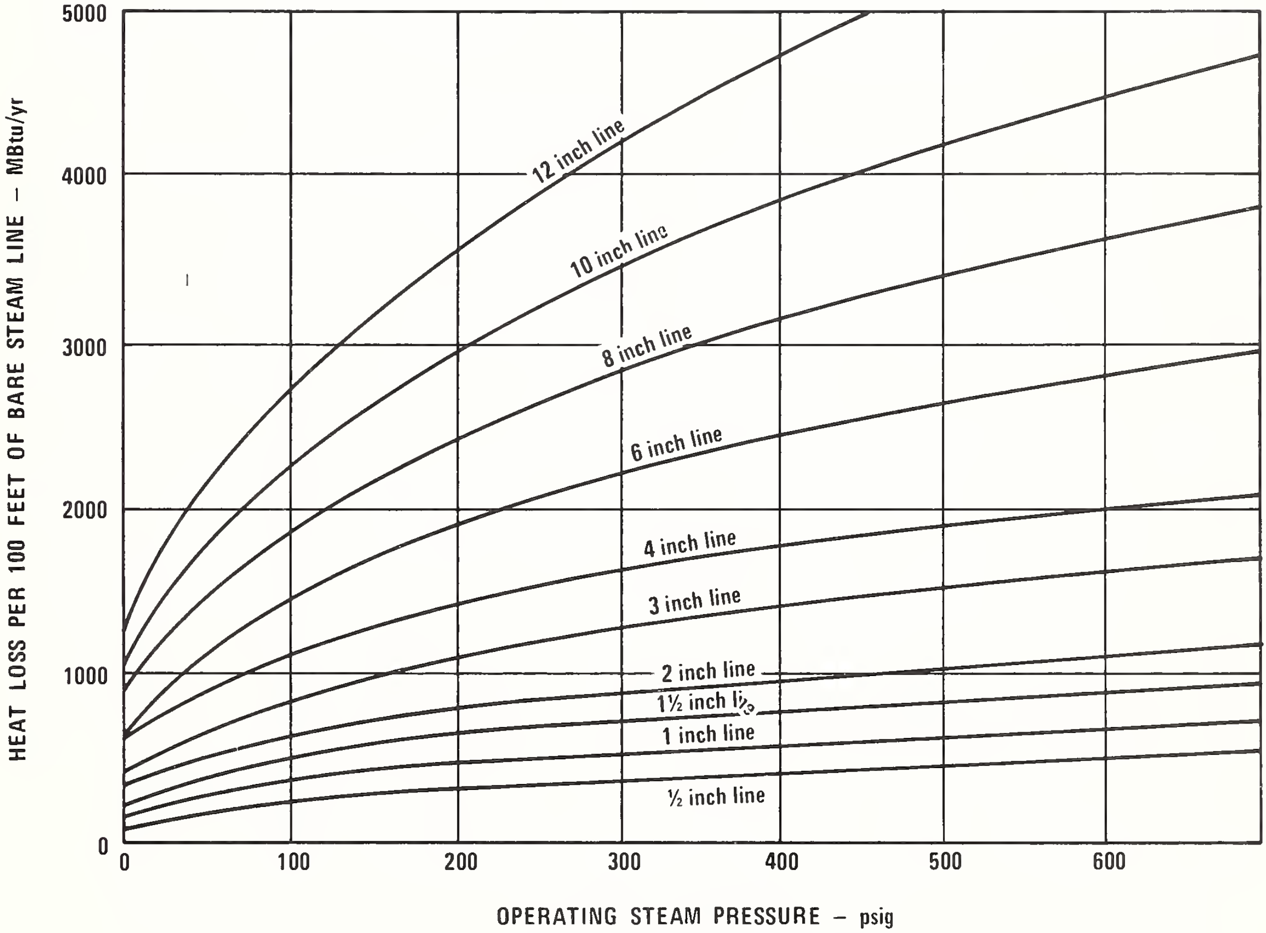


Figure 1 – Heat Loss From Bare Lines
(Based on data from the reference)

The amount of heat saved by insulating bare steam lines depends on the type of insulation and other variables. If it is assumed that a 95 percent efficiency, a value reasonably achieved in insulation installations, is obtained then:

$$\begin{aligned}\text{The cost saving} &= 1512 \text{ MBtu/yr} \\ &\quad \times 95\%/100\% \\ &\quad \times 1.20 \text{ \$/MBtu} \\ &= \underline{\$1720} \text{ per year}\end{aligned}$$

For *superheated* steam, the losses are about the same as for saturated steam. The higher temperatures are about offset by lower heat transfer coefficients from the steam to the pipe.

SUGGESTED ACTION

1. Have plant maintenance install proper insulation or,
2. Contact insulation contractor

REFERENCE *Chemical Engineers' Handbook* Perry, Chilton, and Kirkpatrick, 4th Edition, 1963, McGraw-Hill, New York, page 10–13

SOURCE Based on R. D. Glenn—"Energy Conservation Opportunities in Steam Use," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

EXAMPLE

The installation of steam traps on a group of presses for molding phonograph records was the principal factor in an energy saving of 87,800 MBtu per year.

Phonograph records are compression molded from thermoplastic resins using a steam heating and water cooling cycle. Formerly, the molds were heated by blowing 150 psig steam through the mold channels directly into the drain line. It was felt that traps were not practical, since they offered too much restriction to the flow of cooling water, and lengthened the molding cycle to a degree which was not acceptable.

It was found possible, however, to use traps during the heating part of the cycle and to have no trap during the cooling portion by the installation of both a trap and a solenoid controlled by-pass. The by-pass valve is open during the water cooling cycle, and is closed by a timer about four seconds after the water is shut-off and the steam turned on. These traps and by-passes reduced the steam consumption from 6.1 pounds of steam per record to 3.0 pounds, and actually shortened the molding cycle instead of lengthening it.

Other refinements, such as a newly designed mold with more efficient heat transfer, ultimately reduced the steam consumption to 2.11 pounds per record. At the same time the production rate (theoretical) was increased from 40 records per hour per press to 90 records per hour.

If 20,000,000 records are produced per year and the steam used in the presses provide 1100 Btu per pound,

Annual energy saving
= 20,000,000 records/yr × (6.10 — 2.11) lb steam saved/record × 1100 Btu/lb steam
= <u>87,800</u> MBtu per year

If energy cost is $1.20 per MBtu,

Annual cost saving
= 87,800 MBtu/yr × 1.20 $/MBtu
= <u>$105,000</u> per year

SUGGESTED ACTION

Check all steam heated equipment for the existence of efficient traps. They can be used even when the steam is turned on intermittently for a time as short as 10 or 20 seconds. Also, consider returning steam condensate to the boiler feedwater tank.

SOURCE Based on L. A. Wood—"Energy Conservation Through Scheduling and Process Changes," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

The amount of fuel used for steam generation can be reduced 10 to 30 percent by returning steam condensate to the boiler plant for use as feed water.

EXAMPLE

In a plant where the value of steam is $1.20/MBtu, saturated steam was delivered to one building at a pressure of 200 psig, at an average rate of 27,000 lb/h, and for an average of 8000 h/yr. The steam was reduced through control valves and condensed in heating coils at an average pressure of 25 psig. The condensate was returned to the boiler plant and used as feed water. The amount and value of the heat recovered is calculated below.

From Figure 1 below, it is determined that 17 percent of the heat remains in the 25 psig condensate from the 200 psig saturated steam.

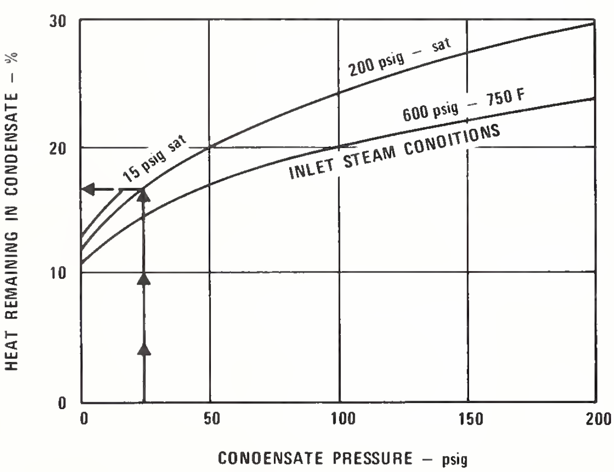


Figure 1 – Heat In Steam Condensate (calculated from steam tables)

From the steam table (See Section 4), the heat value

for 200 psig saturated steam	= 1198 Btu/lb.
for 70 F (assumed ambient temp.) of make-up water if condensate is not returned to boiler	= 38 Btu/lb.
Net heat value	= 1160 Btu/lb.

The heat recovered in condensate

$= 17\%/100\% \times 1160$ Btu/lb $\times$ 27,000 lb/h $\times$ 8000 h/yr

$=$ 42,600 MBtu per year

The value of the heat recovered

$=$ 42,600 MBtu/yr $\times$ $1 20/MBtu

$=$ $51,200 per year

It should be noted that these values represent heat saving potential since no heat loss has been considered for returning the condensate to the boiler plant. The heat loss is dependent on factors such as the length of return lines and the amount of insulation.

In addition to saving heat, the return of condensate to the boiler plant will:

1. Save treated makeup boiler feed water.
2. Save energy and chemicals used in the water treating operation
3. Reduce water pollution.
4. Reduce (but not eliminate) the cost of losses due to steam trap leakage.

SUGGESTED ACTION

Estimate cost of a condensate return system and install, if justified.

The return of condensate to the boiler plant requires precautions to avoid contamination with oil or chemicals.

Condensate return systems should be insulated to conserve heat and to protect personnel against burns.

SOURCE Based on R. D. Glenn—"Energy Conservation Opportunities in Steam Use," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

FLASH CONDENSATE TO LOWER PRESSURE SYSTEM

High pressure steam condensate may be flashed to a lower pressure system to produce significant quantities of steam.

EXAMPLE

In a plant where the value of steam is $1.20 per MBtu, one building was so remote from the boiler plant that a condensate return system could not be economically justified and all condensate was discharged to the sewer. An average of 32,000 pounds per hour of condensate at 150 psig was produced for an average 8000 hours per year. At the same time a lower pressure steam header in the building operated at 15 psig and the load on this header could utilize the entire amount of recoverable heat.

The quantity of 15 psig steam that can be produced by flashing condensate is estimated from Figure 1 as follows:

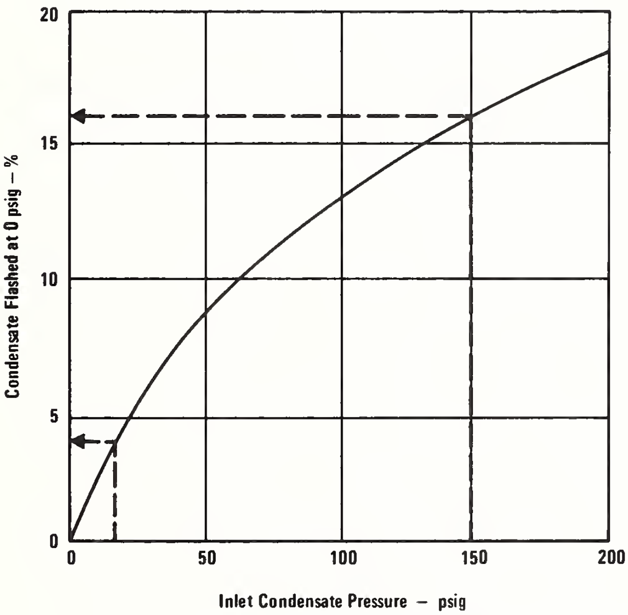


Figure 1 – Flashing Steam Condensate (calculated from steam tables)

Flashing from 150 psig to 0 psig	16.4%
Flashing from 15 psig to 0 psig	4.0%
Difference	12.4%

The potential amount of 15 psig steam available from flashing the 150 psig condensate

$= 32{,}000 \text{ lb/h} \times 12.4\%/100\%$
$= 3970 \text{ lb/h}$

From the steam tables in Section 4, the heat in 15 psig *saturated* steam less the heat in water at 70F = 1126 Btu/lb

Heat available in steam flashed
$= 3970 \text{ lb/h} \times 1126 \text{ Btu/lb} \times 8000 \text{ h/yr}$
$= \underline{35{,}800} \text{ MBtu per year}$

Maximum value of recoverable heat
$= 35{,}800 \text{ MBtu/yr} \times 1.20 \text{ \$/MBtu}$
$= \underline{\$42{,}960} \text{ per year}$

In addition to saving heat, the flashing of condensate will:

1. Save treated makeup boiler feed water.
2. Save energy and chemicals used in the water.
3. Reduce the cost of losses due to steam trap leakage, as a result of eliminating a separate long 15 psig steam line.
4. Reduce the amount of boiler plant capacity required.

SUGGESTED ACTION

Estimate cost of a condensate flashing system and install, if justified.

SOURCE Based on R. D. Glenn—"Energy Conservation Opportunities in Steam Use," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

EXAMPLE

In a plant where the value of steam is \$1.20/MBtu, a leak estimated to be ⅛ inch in diameter was found in a steam tracing line operating at 100 psig. From Figure 1, the steam loss was at an annual rate of 540 MBtu.

By repairing the leak,

$$\text{Annual savings} = 540 \text{ MBtu/yr} \times \$1.20/\text{MBtu} = \underline{\$650/\text{yr.}}$$

SUGGESTED ACTION

1. Survey your steam lines for leaks using appropriate acoustic and temperature probes. Many important steam leaks are hidden, such as:
   a. Leaking or stuck traps or by-pass valves discharging to sewer or condensate system.
   b. Leaking valves leading to idle equipment.
   c. Leaks in heater or other equipment connected to the steam system.
2. Establish a program for regular inspections to detect hidden leaks.
3. Shut off steam to equipment whenever it is taken out of service.
4. Re-route piping, where practical, so that leaks are visible rather than hidden.
5. Repair steam leaks promptly.

REFERENCE *Mechanical Engineers' Handbook,* Baumeister and Marks, 6th Edition, 1958, McGraw-Hill New York, page 4–68

SOURCE Based on R. D. Glenn—"Energy Conservation Opportunities in Steam Use," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

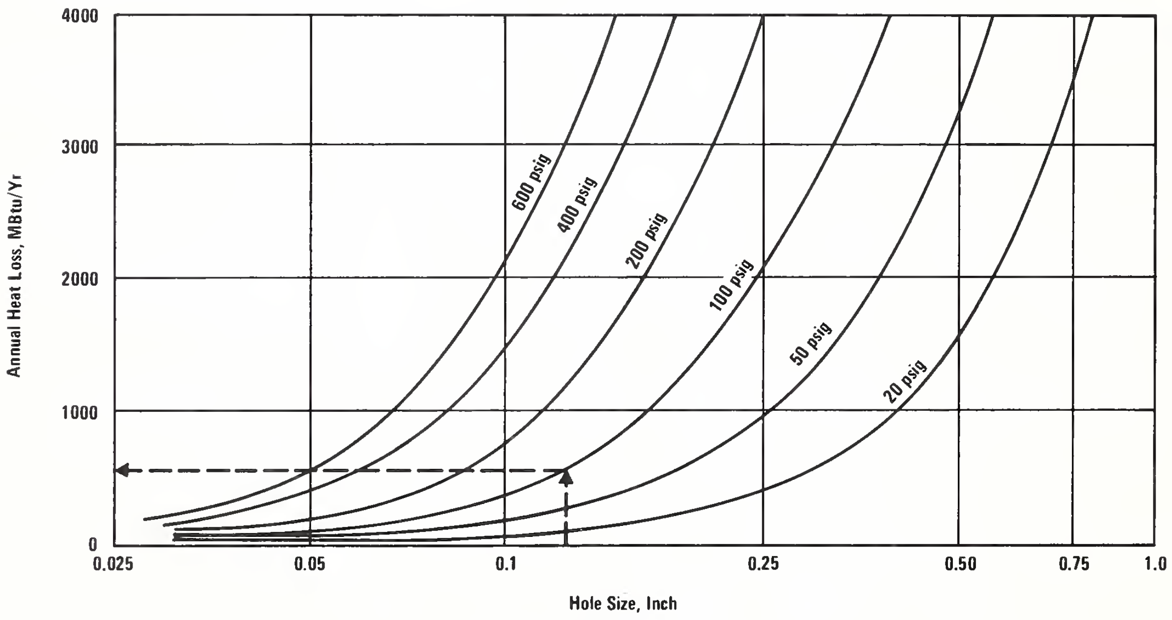


Figure 1 – Heat Loss from Steam Leaks
(Based on data from the reference)

Efficient operation of any steam system requires well designed trapping which is periodically inspected and properly maintained. It is only in this way that condensate and air will be removed automatically as fast as they accumulate without wasting steam.

Initial inspections commonly reveal that as high as seven percent of the traps in a system are leaking. It has been demonstrated that by careful maintenance and frequent inspection this can be reduced to one percent.

EXAMPLE

In a plant where the value of steam is $1.20/Btu an inspection program revealed that a trap on a 100 psig steam line was stuck open. The orifice in the trap was ¼ inch. From the graph in ECO 3.4.5, steam loss was indicated to be at the rate of 2100 MBtu/yr. By repairing the trap,

Annual Savings = 2100 MBtu/yr × $1.20/MBtu
= $2520 per year

SUGGESTED ACTION

1. Establish a program for the regular systematic inspection, testing, and repairing of steam traps. Include a reporting system to insure thoroughness and to provide a means of establishing the continuing value of the program.

2. Inspection and testing, on a suggested frequency of about once a week, should provide answers to the following questions:
   a. Is the trap removing all of the condensate?
   b. Does it shut off tight after operation?
   c. Is by-pass, or separate discharge, closed and free of leaks?
   d. Is frequency of discharge in an acceptable range? Too frequent discharge indicates possible under capacity; too infrequent discharge indicates possible overcapacity and inefficiency.

SOURCE Based on R. D. Glenn—"Energy Conservation Opportunities in Steam Use," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

Loss of combustible gases, natural gas, methane, butane, propane, hydrogen, etc., through pipeline leaks is a direct waste of valuable energy.

The figures in Tables I and II also reflect annual energy and monetary losses. For natural gas with a heat of combustion of 1000 Btu per cu ft, the numbers in the tables represent energy losses in million Btu per year. Considering a "round number" natural gas cost of $1.00 per million Btu, the tabulated numbers indicate losses in dollars per year.

TABLE I. NATURAL GAS LOSS PER YEAR FROM LEAKS IN *UNDERGROUND* PIPELINES AT VARIOUS PRESSURES (KSCF)

Corrosion Hole Diameter, in	Line Pressure (psig) 0.25	5	25	60	100	300	500
1/64	1	4	10	20	30	80	140
1/32	2	6	20	35	60	160	250
1/16	10	40	100	200	320	900	1,500
1/8	50	200	600	1,200	1,800	5,000	8,200
1/4	250	1,200	3,300	6,500	10,300	28,300	46,500
1/2	1,400	6,600	18,800	37,300	58,000	156,500	263,000

Reference (1) is the source of Table 1, which was calculated from a formula that takes into consideration that the leak is confined in the earth and some back pressure is present.

TABLE II. NATURAL GAS LOSS PER YEAR FROM LEAKS IN *ABOVE GROUND* PIPELINES AT VARIOUS PRESSURES (KSCF)

Corrosion Hole Diameter, in	Line Pressure (psig) 0.25	5	25	60	100	300	500
1/64	5	26	69	136	212	581	953
1/32	21	102	277	544	846	2,330	3,810
1/16	85	409	1,110	2,180	3,390	9,300	15,300
1/8	341	1,640	4.430	8,700	13,500	37,200	61,000
1/4	1,360	6,540	17,700	34,800	54,200	149,000	244,000
1/2	5,450	26,200	70,900	139,000	217,000	595,000	977,000

Leak flows in Table II were calculated with an equation and procedure in Reference (2) for square edged orifices discharging compressible fluids to atmosphere.

EXAMPLE

One hundred psig natural gas leaking through a ⅛ inch diameter hole in an *underground* pipeline results in annual loss of 1800 thousand cu ft (kcf), or 1800 million Btu (MBtu), or $1800.

At the same pressure gas leaking from the same size hole in an *above ground* pipe could amount to an annual loss of 13,500 kcf. or 13,500 MBtu, or $13,500.

SUGGESTED ACTION

Eliminate leaks in combustible gas lines to avoid loss of valuable energy and to prevent the hazard of fire or explosion. A continuing program of periodic leak detection surveys and prompt repairs is essential.

REFERENCE

1. "Control of Unaccounted — for Gas" by David A. Crawford, Southern Cross Corp., Atlanta, Ga., *Gas,* May 1973, p. 33.
2. "Flow of Fluids," — Technical Paper No. 410, Crane Co., New York, N. Y., Twelfth Printing—1972

SOURCE Dow Chemical U.S.A., Freeport, Texas

If the users on a compressed air system are surveyed and it is determined that the air pressure can be lowered a certain amount without causing operating problems, the horsepower for the air compression can be decreased resulting in energy savings.

EXAMPLE

A total volume of 2500 cfm of free air was being compressed to 110 psig by 2 two-stage reciprocating compressors, each driven by a 250 hp electric motor fully loaded. The compressors operated 8000 hours per year. A survey revealed that all plant air users could operate satisfactorily with 15 psi lower air pressure. The approximate savings that could be realized by lowering compressor discharge pressure from 110 psig to 95 psig are determined as follows:

From Figure 2 for two stage compressors, the decrease in horsepower would be about 5.4% from reducing the pressure to 95 psig.

Annual savings in kWh = 5.4%/100% × 500 hp × 0.746 kW/hp × 8000 h/yr = <u>161,000</u> kWh per year

If the utility consumes 10,000 Btu of fuel/kWh generated,

Annual savings in Btu = 161,000 kWh/yr × 10,000 Btu/kWh = <u>1610</u> MBtu per year

If the cost of electric power is $0.03/kWh

Annual savings in $ = 161,000 kWh/yr × 0.03 $/kWh = <u>$4830</u> per year

SUGGESTED ACTION

Canvass users of plant air to determine the practicality of lowering the air system pressure. To lower the discharge pressure on some air compressors requires a simple adjustment of the pressure control. On other compressors, modification may be necessary and the compressor *manufacturer should be consulted.* The manufacturer can also provide you with the performance data for your particular compressor and inform you of any limitation on lowering your compressor discharge pressure.

Further savings may be achieved by shutting down the compressor during non-operating periods and

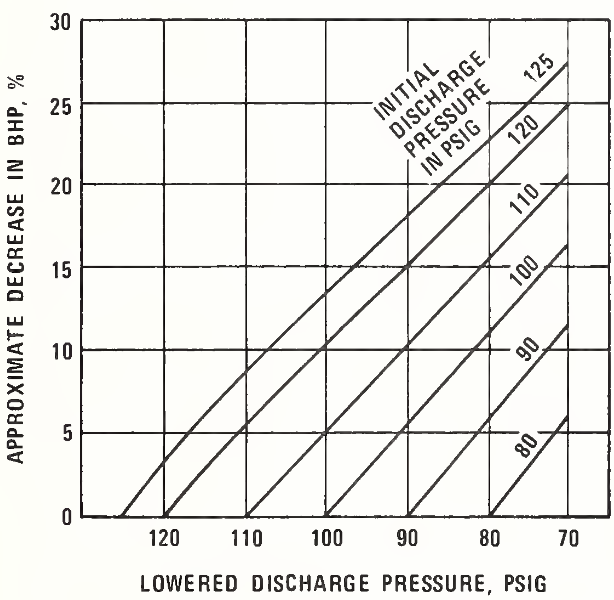


Figure 1 – Single Stage Reciprocating and Rotary Screw Compressors

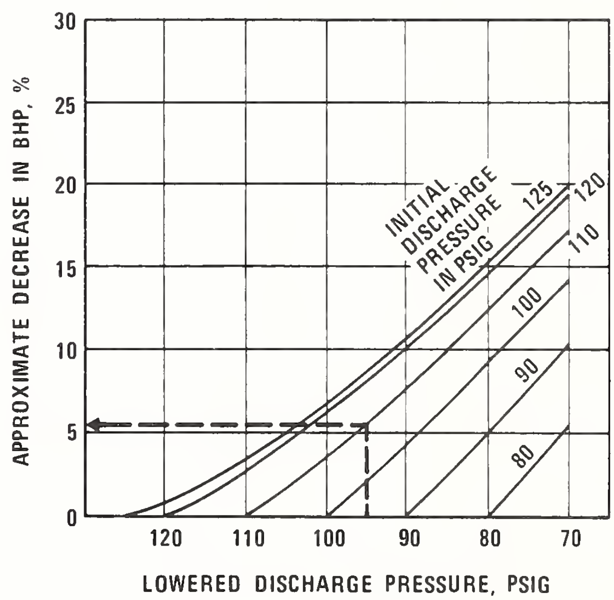


Figure 2 – Two Stage Reciprocating and Centrifugal Compressors

by repairing leaky quick-connects, valves, and joints.

Using the appropriate graph for the type compressor you have, start with Lowered Discharge Pressure, move vertically to intersect the curve for the Initial Discharge Pressure. From that intersection, move horizontally to read out the Approximate Decrease in Brake Horsepower.

REFERENCE Compressed Air and Gas Handbook
Compressed Air and Gas Institute
122 East 42nd Street
New York, New York 10017
Third Edition 1961 (Revised 1966)

SOURCE Dow Chemical U.S.A., Freeport, Texas
Based on data supplied by several compressor manufacturers.

The cost of leaking compressed air is often considered insignificant. The following example illustrates that appreciable energy savings can be realized by repairing leaky air lines.

EXAMPLE

A complete inspection of a plant compressed air system was conducted at the start of a regular monthly leak detection program. Air compressor discharge pressure was 100 psig. At a power cost of $0.015 per kWh, the cost of the leaks found in the compressed air system were:

Number of Leaks	Estimated Diameter, in	Free Air Wasted, cu ft/yr	Fuel Wasted, MBtu/yr	Cost of Power Wasted, $/yr
3	1/4	107,000,000	2920	4370
7	1/8	62,200,000	1700	2550
12	1/16	26,600,000	727	1090
15	1/32	8,300,000	227	341
37		204,000,000	5570	8350

The energy and cost saving possible by fixing compressed air system leaks can be estimated from the following table:

Hole Diameter, in	Free Air Wasted (a), cu ft per year, by a Leak of Air at:	Fuel Wasted (b), MBtu/yr	Cost of Power Wasted (c), $/yr at Unit Power Cost of		
	100 psig		$0.010/kWh	$0.015/kWh	$0.020/kWh
3/8	79,900,000	2190	2190.00	3280.00	4370.00
1/4	35,500,000	972	972.00	1460.00	1940.00
1/8	8,880,000	243	243.00	364.00	486.00
1/16	2,220,000	60.6	60.70	91.00	121.00
1/32	553,000	15.1	15.10	22.70	30.30
	70 psig		$0.010/kWh	$0.015/kWh	$0.020/kWh
3/8	59,100,000	1320	1320.00	1980.00	2650.00
1/4	26,200,000	587	587.00	881.00	1170.00
1/8	6,560,000	147	147.00	220.00	294.00
1/16	1,640,000	36.6	36.60	54.90	73.30
1/32	410,000	9.2	9.18	13.80	18.40

Based on data from the reference.

(a) Based on nozzle coefficient of 0.65

(b) Based on 10,000 Btu fuel/kWh

(c) Based on 22 brake horsepower per 100 cu ft free air per min for 100 psig air and 18 brake horsepower per 100 cu ft free air per min for 70 psig air

Air leaks can easily go unnoticed since they are odorless and invisible and their hissing sound can be hidden by other plant noise. Therefore, it is advisable to inspect pipelines, air hoses, valves and fittings at regular intervals to detect leaks. A common way of detecting leaks in air pipelines is by swabbing soapy water around the joints. Even very small leaks will make their presence known by blowing bubbles. Also there are instruments available that detect air leaks by sound.

SUGGESTED ACTION

Leaks should be repaired as soon as practical. In some situations, there may be need to wait for a scheduled plant shutdown. Temporary repair can often be made by placing a clamp over a leak.

REFERENCE Compressed Air and Gas Handbook, Third Edition 1961 (Revised 1966)
Compressed Air and Gas Institute
New York, New York

SOURCE Dow Chemical U.S.A., Freeport, Texas

Wherever feasible, the intake duct for an air compressor should be run to the outside of the building, preferably on the north or coolest side. Since the average outdoor temperature is usually well below that in the compressor room, it normally pays to take the cool air from outdoors. The energy savings potential in lowering the air intake temperature is illustrated in the following table.

Temperature of Air Intake, F	Intake Volume Required to Deliver 1000 cu ft of Free Air at 70 F	% HP Saving or Increase Relative to 70 F Intake
30	925	7.5 Saving
40	943	5.7 Saving
50	962	3.8 Saving
60	981	1.9 Saving
70	1000	0
80	1020	1.9 Increase
90	1040	3.8 Increase
100	1060	5.7 Increase
110	1080	7.6 Increase
120	1100	9.5 Increase

Regardless of the outside temperature, the compressed air in a shop pipeline will closely approximate the temperature in the shop by the time it reaches the tools. Assume the indoor temperature to be 70 F. If the compressor takes in 1000 cu ft of free air from the shop, it will also deliver 1000 cu ft of free air at the tools because the initial and final temperatures are the same.

Suppose the outside air averages 50 F and the compressor is supplied with intake air from outdoors. Only 962 cu ft of free air will be required to deliver 1000 cu ft of free air at the indoor temperature of 70 F, a saving of 3.8% in the horsepower required.

EXAMPLE

A compressor takes its inlet air directly from the compressor room where the average temperature is 80 F. The compressed air at 100 psig is delivered to a shop building where the temperature is maintained at 70 F. The compressor delivers 750 cu ft per min of free air at 70 F for 8000 hours per year. The 150 hp electric motor drive operates at full load. The average outside air temperature is 50 F. The energy savings to be realized by taking compressor inlet air from outdoors are calculated as follows:

From the table—

For 80 F air at the intake, volume to deliver 1000 cu ft free air at 70 F = 1020 cu ft

For 50 F air at the intake, volume to deliver 1000 cu ft free air at 70 F = 962 cu ft

The saving on power from using the cooler intake,

HP saving = (1020—962) 1020 × 100%
= 5.69%

Annual power savings = 5.69%/100% × 150 hp × 0.746 kW/hp × 8000 h/yr
= 50,900 kWh per year

If the utility uses 10,000 Btu fuel per kWh,

Annual energy savings = 50,900 kWh/yr × 10,000 Btu/kWh
= 509 MBtu per year

If electric power cost is $0.015/kWh,

Annual cost savings = 50,900 kWh/yr × 0.015 $/kWh
= $764 per year

SUGGESTED ACTION

Estimate the cost of running an intake duct from your air compressor to a cool location outdoors. Calculate your potential energy saving and evaluate whether the duct installation is justified.

REFERENCE "Compressed Air Data," edited by F. W. O'Neil, Ingersoll-Rand Company, Fifth Edition 1954.

SOURCE Dow Chemical U.S.A., Freeport, Texas

Heat from sources such as furnaces, steam-driven equipment, etc. often presents a problem for workers in the area. There have probably been many occasions when compressed air was used for personnel cooling because of the convenience of a nearby air line and hose. However, the energy consumption in delivering a given volume of air is much greater for compressed air than for an electric motor driven fan. The following example illustrates how the purchase of a $624 fan to replace the use of compressed air in cooling results in savings of power costs of $1190 per year.

EXAMPLE

In a plant, there are jet air exhausters available which use compressed air to induce a flow of atmospheric air. These devices are quite useful for the safe evacuation of flammable vapors or gases from a vessel. As an energy conservation program was getting underway, it was noted that two of the exhausters were being used about four hours every day for cooling personnel while working in an area adjacent to a furnace. The plant operates 250 days per year.

The specifications for the 6 inch model of air exhauster indicated that 318 scfm of compressed air at 90 psia will induce 3060 scfm of atmospheric air, thus discharging a total of 3380 scfm. A total of 636 scfm of compressed air was being used by the two exhausters. The compressed air was provided by a two stage reciprocating compressor driven by electric motor and requiring about 17 hp per 100 scfm.

The horsepower chargeable to the air exhausters

$$= 636 \text{ scfm} \times 17 \text{ hp}/100 \text{ scfm} = 108 \text{ hp}$$

In a manufacturer's list of heavy-duty, portable cooling fans, the smallest unit moves 9750 cfm of air, which is 44% more than the 6760 cfm total capacity of the two air movers. The 24 inch fan is driven by a 1½ hp electric motor. The unit costs $624.

The energy savings realized by replacing the exhausters with the fan are calculated as follows:

$$\text{Annual power saving} = (108 \text{ hp} - 1.5 \text{ hp}) \times 0.746 \text{ kW/hp} \times 4 \text{ h/d} \times 250 \text{ d/yr} = \underline{79{,}400} \text{ kWh per year}$$

If electricity costs $0.015/kWh,

$$\text{Annual cost savings} = 79{,}400 \text{ kWh/yr} \times 0.015 \text{ \$/kWh} = \underline{\$1190} \text{ per year}$$

If the utility consumes 10,000 Btu of fuel/kWh

$$\text{Annual energy saving} = 79{,}400 \text{ kWh/yr} \times 10{,}000 \text{ Btu/kWh} = \underline{794} \text{ MBtu per year}$$

The fan is clearly the more energy efficient source of localized personnel cooling.

SUGGESTED ACTION

Use fans rather than compressed air for cooling, where possible. Also, evaluate the source of heat for possible energy conservation action; the need for cooling might be eliminated.

SOURCE Dow Chemical U.S.A., Freeport, Texas

EXAMPLE

An opportunity for energy conservation was identified through the recovery of heat loss in the exhaust gases from a natural gas fired boiler of a dairy. Additional natural gas was not available for a conventional expansion of the boiler room capacity to heat a warehouse expansion. Heat would be recovered by a finned coil installed in the boiler stack breeching to transfer heat from hot flue gases to circulating water. This hot water would be pumped to fan coils within the warehouse and to a boiler feed water preheater. When more heat is available than needed, flue gases would be automatically diverted to the atmosphere.

A. Heat Required for Warehouse Addition

$q_i = UAdt$

where q = heat flow, Btu/h
U = heat transfer coefficient, Btu/h sq ft F
A = area, sq ft
dt = difference in indoor and mean outdoor temperature = 50 F for boiler
i = 1, 2, 3

Heat loss through walls

Lower portion, brick and block, U = 0.33 Btu/h sq ft F, 8 ft high, 371 ft exposed perimeter

$$q_1 = 0.33 \text{ Btu/h sq ft F} \times (371 \text{ ft} \times 8 \text{ ft}) \times 50 \text{ F} = 49{,}000 \text{ Btu/h}$$

Upper portion, U = 0.25 Btu/h sq ft F, 12 ft high, 371 ft exposed perimeter

$$q_2 = 0.25 \text{ Btu/h sq ft F} \times (371 \text{ ft} \times 12 \text{ ft}) \times 50 \text{ F} = 55{,}700 \text{ Btu/h}$$

Heat loss through roof

Flat, insulated 1½ in fiberboard plus tar and gravel, U = 0.22 Btu/h sq ft F, 135 ft by 101 ft

$$q_3 = 0.22 \text{ Btu/h sq ft F} \times (135 \text{ ft} \times 101 \text{ ft}) \times 50 \text{ F} = 150{,}000 \text{ Btu/h}$$

Heat loss in ventilating air exhaust

Air changes required = 0.5 warehouse volume per hour

$q = w_a \, c_p \, dt$

where q = heat flow, Btu/h
w_a = air flow, lb/h
c_p = specific heat of air = 0.24 Btu/lb F
dt = difference in temperature of indoor and outdoor air = 50 F

$$q_4 = \frac{0.5 \times 135 \text{ ft} \times 101 \text{ ft} \times 20 \text{ ft}}{\text{h}} \times \frac{0.075 \text{ lb}}{\text{cu ft}} \times 0.24 \frac{\text{Btu}}{\text{lb F}} \times 50 \text{ F}$$

$$= 123{,}000 \text{ Btu/h}$$

Total hourly heat for warehouse

$$= q_1 + q_2 + q_3 + q_4$$

$$= 49{,}000 \text{ Btu/h} + 55{,}700 \text{ Btu/h} + 150{,}000 \text{ Btu/h} + 123{,}000 \text{ Btu/h}$$

$$= \underline{378{,}000 \text{ Btu/h}}$$

Total annual heat for warehouse

$$= 378{,}000 \text{ Btu/h} \times 24 \text{ h/day} \times 6000 \text{ degree days/year} \times 1/50 \text{ F}$$

$$= \underline{1090} \text{ MBtu/yr}$$

B. Heat Required to Raise Feedwater Temperature 50 F

Fuel gas flow rate = 50,000 kcf/yr

Fuel gas heating value = 1 MBtu/kcf

Boiler efficiency = 75%

Enthalpy of steam minus enthalpy of feedwater = 1185 Btu/lb

Steam flow rate

$$= \frac{50{,}000 \text{ kcf/yr} \times 1 \text{ MBtu/kcf}}{1185 \text{ Btu/lb}} \times 0.75$$

$$= \underline{31.6 \text{ Mlb/yr}}$$

Disregarding boiler blowdown, the feedwater flow rate is equal to the steam flow rate. Using a specific heat for water of 1 Btu/lb F,

Feedwater preheat required = 31.6 M lb/yr × 1 Btu/lb F × 50 F = 1580 MBtu/yr

C. Total Heat Requirement = 1090 MBtu/yr + 1580 MBtu/yr = 2670 MBtu/yr

D. Heat available from flue gas

Twenty-five percent of the heat of combustion of the fuel gas is lost in the flue gas. Considering that it is possible to recover 75% of the heat loss in the stack,

Heat available from flue gas
= 50,000 kcf/yr × 1 MBtu/kcf × 0.75 × 0.25
= 9380 MBtu per year

Heat available for future use
= 9380 MBtu/yr − 2670 MBtu/yr
= 6710 MBtu per year

However, any future heat requirement would have to be a warm weather application since all recoverable heat will be used by this system in very cold weather.

E. Annual Savings

The savings realized by heating the warehouse with the heat recovery system would be equivalent to the cost of the alternative of electric heating.

Cost of electric heating of the warehouse addition:

Additional energy rate = \$0.0087/kWh

Additional demand charge = \$1.40/kW month

Annual electric energy cost $= \dfrac{1090 \text{ MBtu/yr}}{3412 \text{ Btu/kWh}} \times 0.0087 \text{ \$/ kWh}$
= \$2780 per year

Monthly demand charge $= \dfrac{378{,}000 \text{ Btu/h}}{3412 \text{ Btu/kWh}} \times 1.40 \text{ \$/kWmonth}$
= \$155 per month

Use this charge for Dec., Jan., Feb.:
\$155 × 3 = \$465

Use ½ this charge for Oct., Nov., Mar.:
½ (\$155) × 3 = \$233

Annual demand charge = \$698 per year

Total electric heat cost = \$2780/yr + \$698/yr
= \$3480 per year

Using the heat recovery system for feedwater heating saves natural gas costing \$0.892/kcf.

Annual cost of gas for feedwater heating (at 75% efficiency)
= 1580 MBtu/yr × 0.892 \$/MBtu × 1/0.75
= \$1880 per year

Total savings for space heating and feedwater preheating
= \$3480/yr + \$1880/yr = \$5360 per year

F. Capital Costs and Payback Period

The following costs are based on estimates from local contractors and will vary depending on equipment details and local prices.

Cost of heat recovery system for warehouse and feedwater heating	= \$17,340
Cost of alternate electric heating system for warehouse	= \$ 8,300
Incremental first cost for heat recovery system	= \$ 9,040

Payback period $= \dfrac{\$9040}{5360 \text{ \$/yr}}$ = 1.69 years

SUGGESTED ACTION

Investigate the possibility of installing heat recovery systems on boilers not so equipped. Evaluate recovery of heat from the flue gases for preheating combustion air or boiler feedwater, or for heating hot water or low pressure steam for space heating or process use.

SOURCE Prepared by the Peoples Natural Gas Company describing the heat recovery system for Johnstown Sanitary Dairy, Johnstown, Pennsylvania

EXAMPLE

By replacing the conventional muffler on a 500 hp gas engine with a waste heat recovery muffler at a cost of $20,000, a process plant is able to realize an annual savings of about 55,600 gallons of fuel oil costing $13,900.

The engine, which is used to drive a compressor, discharges 4225 cfm of exhaust at 1100 F and 6 inches of water back pressure. The plant requires 2000 lb/hr of 15 psig steam, which was supplied by a fired boiler using #2 fuel oil, and has available 220 F water for boiler feedwater. The exhaust heat recovered by the waste heat recovery muffler can provide approximately 1300 lb/hr of the required steam allowing the output of steam from the fired boiler to be reduced resulting in the substantial fuel oil savings. The calculations are shown below.

CALCULATIONS

1. First, we estimate the heat recovery from the exhaust gas when cooled from 1100 F to 350 F, which is 100 F above the temperature of 15 psig saturated steam.

We enter Figure 1 with the initial and final exhaust gas temperatures, 1100 F and 350 F respectively, and determine the approximate heat recovery to be 198 Btu/lb exhaust gas.

Knowing that the specific volume of the flue gas* at 1100 F is 39.5 cu ft/lb, we convert the exhaust flow rate from 4225 cfm to lb/h as follows:

$$\text{Exhaust flow rate} = \frac{4225 \text{ cu ft/min} \times 60 \text{ min/h}}{39.5 \text{ cu ft/lb}}$$
$$= 6420 \text{ lb/h}$$

$$\text{Then, rate of heat recovery} = 6420 \text{ lb/h} \times 198 \text{ Btu/lb} = 1.27 \text{ MBtu/h}$$

2. Next, we calculate the amount of steam generated from the exhaust heat recovered. From Figure 2 we determine that with 220 F feedwater the heat absorbed in generating 15 psig saturated steam is 977 Btu/lb steam.

$$\text{Steam generation} = \frac{1.27 \text{ MBtu/h}}{977 \text{ Btu/lb}} = 1300 \text{ lb/h}$$

Thus, steam generation from the fired boiler is reduced from 2000 lb/h to 700 lb/h.

3. The resulting annual fuel savings with 80% boiler efficiency based on the lower heating value of the #2 fuel oil (18,300 Btu/lb oil) and assuming 4500 hours of operation per year are calculated below:

$$\text{Annual fuel savings} = \frac{1.27 \text{ MBtuh} \times 4500 \text{ h/yr}}{0.8}$$
$$= \underline{7140} \text{ MBtu/yr}$$

Knowing that the fuel oil density is about 7.02 lb/gal, we figure the annual fuel savings in gallons.

$$\text{Annual fuel savings} = \frac{7140 \text{ MBtu/yr}}{18{,}300 \text{ Btu/lb} \times 7.02 \text{ lb/gal}}$$
$$= \underline{55{,}600} \text{ gal/yr}$$

4. If the #2 fuel oil costs $0.25/gal,

$$\text{Annual savings} = 55{,}600 \text{ gal/yr} \times 0.25 \text{ \$/gal}$$
$$= \underline{\$13{,}900} \text{ per year}$$

The total cost of a waste heat recovery muffler and installation is about $20,000 for a 500 hp engine. In this case, the installation can be paid off in about two years or less.

SUGGESTED ACTION

Estimate the potential of heat recovery from exhaust gases from your gas and diesel engines and evaluate the economics. Consider also the recovery of heat from jacket cooling water. Consult a manufacturer of heat recovery equipment for further assistance.

REFERENCE 1967 ASME Steam Tables

SOURCE An equipment manufacturer.

* The specific volume of flue gas at a given temperature is very close to the specific volume of air at that temperature.

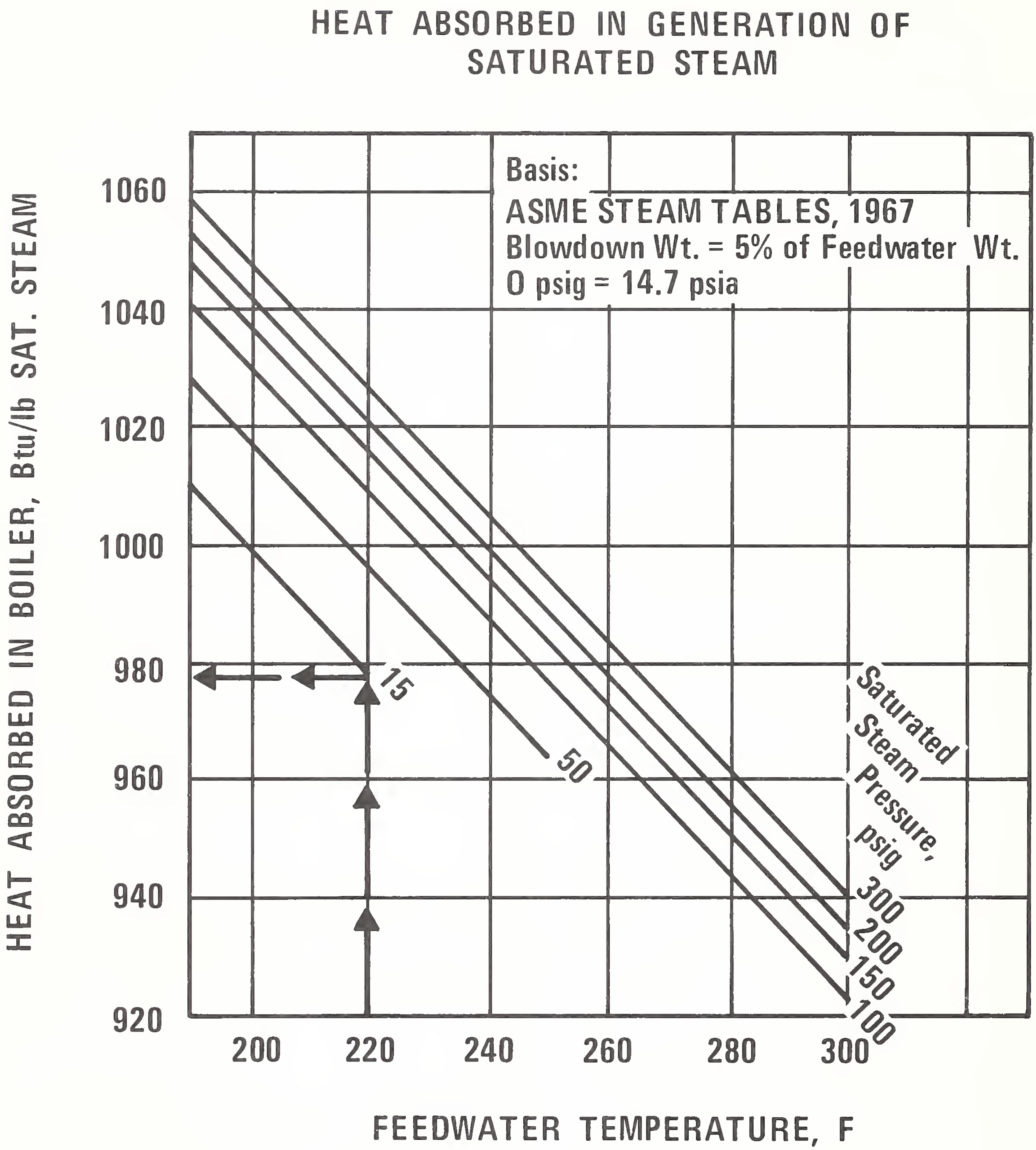
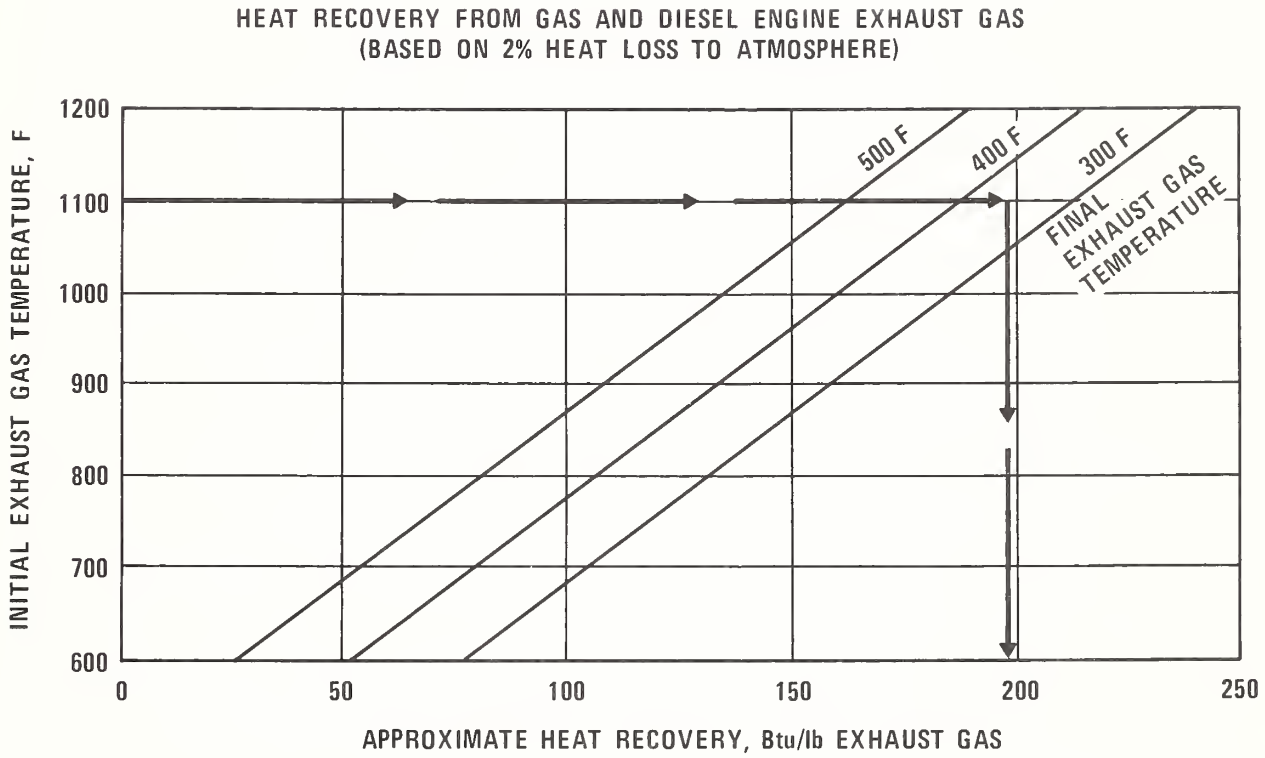


Figure 2 – Heat Absorbed in Generation of Saturated Steam



Deltak Corporation

Figure 1 – Heat Recovery from Gas and Diesel Engine Exhaust Gas
(Based on 2% Heat Loss to Atmosphere)

ECO's under this heading are in preparation and will be available at a later date.

EXAMPLE

A fuel savings potential of $40,000 per year was identified through improved combustion control in a textile mill in South Carolina which required 75,000 lb of steam per hour for operation at plant capacity. The boilers had been originally designed for gas firing. A manually operated alternative oil system was installed in expectation of oil being used no more than 5% of the time. Subsequently, the shortage of gas required oil operation 50% of the time. A boiler plant consulting engineer recommended that the existing two year old control system be replaced with a more sophisticated combustion control system for wide range metering of either oil or gas.

The original system maintained acceptable control of gas combustion at 20% excess air, but on oil the manual control resulted in very poor combustion with average excess air at 80% corresponding to 10% oxygen in the flue gas. Flue gas temperature was 600 F for oil and 500 F for gas.

The potential for fuel savings can be estimated using Figures 1 and 2.

For oil the savings potential is through reducing excess air from 80% to 20%. According to the Percent Oxygen vs. Excess Air Curve in Figure 1 this will reduce the oxygen in the flue gas from 9.7% to 3.7%. According to the curve in the same Figure for 600 F stack gas temperature, this reduction will save 9% of the fuel oil. The estimated annual savings while using oil 50% of the time (4000 h/yr) at an hourly rate of 750 gallons per hour and with a heating value of 140,000 Btu/gal:

Annual oil saving = 4000 h/yr × 750 gal/h × 9%/100% = 270,000 gal/yr

Annual Btu saving = 270,000 gal/yr × 140,000 Btu/gal = 37,800 MBtu/yr

If the oil cost is 1.00 $/MBtu,

Annual cost saving = 37,800 MBtu/yr × 1.00 $/MBtu = $37,800/yr

For gas, the savings potential is through reducing the excess air from the original 20% to 10% through improved control. According to the Percent Oxygen vs. Excess Air Curve in Figure 2 this will reduce the oxygen in the flue gas from 3.9% to 2.1% and interpolating in the same Figure for 500 F stack gas temperature this will save 1% of the gas being burned. With gas at 1000 Btu/cu ft costing $0.60/MBtu being burned 50% of the time (4000 hours per year) at a measured rate of 95,500 scf/hour, the estimated annual savings are:

Annual gas saving = 4000 h/yr × 95.5 kcf/h × 1%/100% = 3820 kcf/yr

Annual Btu saving = 3820 kcf/yr × 1000 Btu/cf = 3820 MBtu/yr

Annual cost saving = 3820 MBtu/yr × 0.60 $/MBtu = $2290/yr

Total annual savings oil and gas (MBtu/yr) = 37,800 MBtu/yr + 3,820 MBtu/yr = 41,600 MBtu per year

Total annual savings oil and gas ($/yr) = $37,800/yr + $2290/yr = $40,090 per year

Equipment Cost Estimate

New Combustion Control System	$17,000
Installation	$12,000
Total Cost	$29,000

SUGGESTED ACTION

Determine excess air produced by existing combustion control systems. Estimate savings potential possible through improved controls. Consult combustion control specialists for recommendations and quotations.

SOURCE An equipment manufacturer.

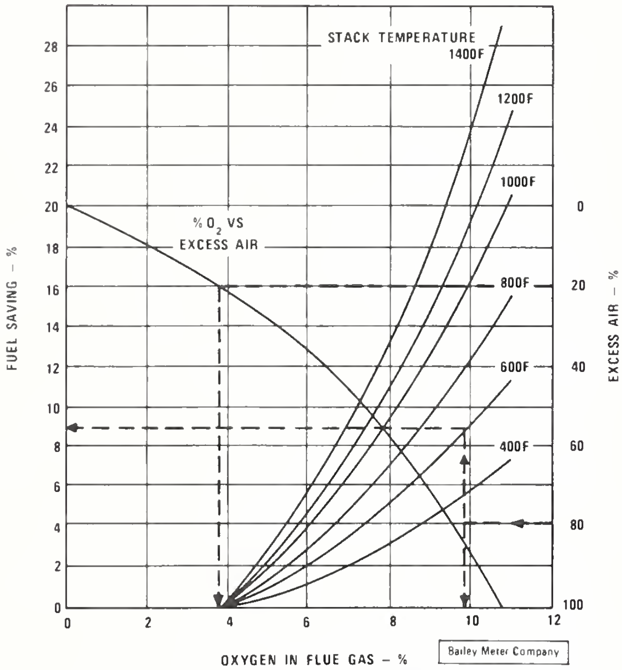


Figure 1 – Liquid Petroleum Fuel Saving Available By Reducing Excess Air to 20%

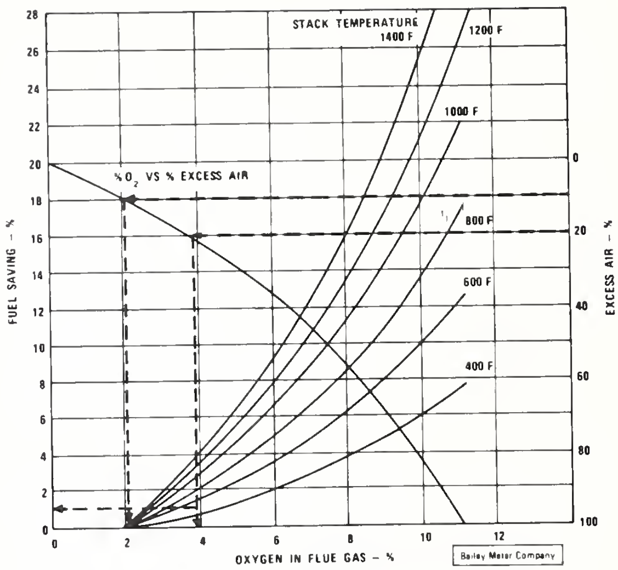


Figure 2 – Hydrocarbon Gaseous Fuel Saving Available By Reducing Excess Air to 10%

Savings determined by these curves reflect the following approximation: The improvement in efficiency of radiant and combination radiant & convection heaters or boilers without air preheaters that can be realized by reducing Excess Air is 1.5 times the apparent efficiency improvement from air reduction alone due to the accompanying decrease in flue gas temperature.

EXAMPLE

A savings potential of $4400 per year was identified through replacing worn combustion control equipment in a manufacturing plant in Missouri. The plant had a gas fired boiler rated at 30,000 lb. of steam per hour equipped with a five year old jackshaft control system which had originally been set up for approximately 40% excess air. A recent combustion test indicated that due to lost motion resulting from linkage wear, the control produced excess air that varied between 20% and 60% and could not be adjusted to safely reduce the excess air.

A representative of an instrumentation and control company recommended that, rather than replace the linkage, a modern control system be installed that could be tuned to operate the boiler continuously at 10% excess air instead of the original 40%. The plant superintendent was reluctant to replace the five year old system which did a good job of maintaining steam pressure until he was shown the economic advantage.

From Figure 1, the estimated fuel savings for reducing the excess air to 10% from 40% at a flue gas temperature of 400 F is 2.5%.

With the boiler operating 8000 hours per year at 75% efficiency; at an average demand of 80% of capacity or 24,000 pounds per hour; and requiring 980 Btu input per pound of steam:

The annual energy requirement

= 24,000 lb/h steam × 8000 h/yr
× 980 Btu/lb steam × 1/0.75 efficiency
= 250,900 MBtu/yr

The annual fuel saving

= 250,900 MBtu/yr × 2.5%/100%
= 6270 MBtu/yr

Cost saving in 1974 at gas contract price of $0.70/MBtu

= 6270 MBtu/yr × 0.70 $/MBtu
= $4390/per year

and after 1974 at gas price of $1.00/MBtu

= 6270 MBtu/yr × 1.00 $/MBtu
= $6270/per year

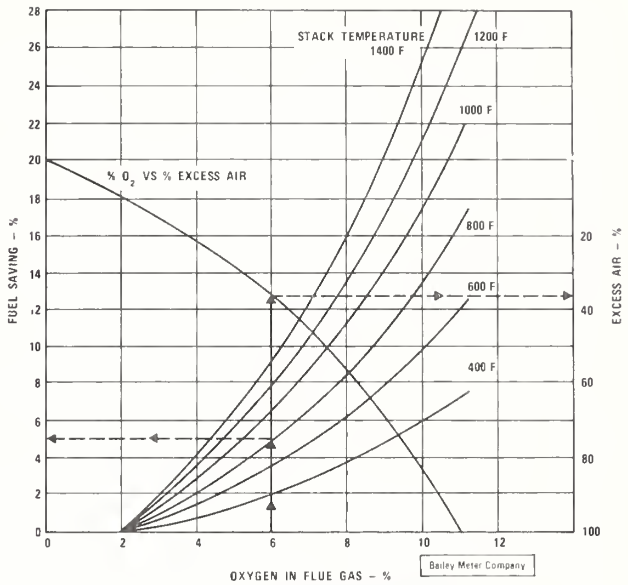


Figure 1 – Hydrocarbon Gaseous Fuel Saving Available By Reducing Excess Air to 10%

FUEL SAVINGS determined by these curves reflect the following approximation: The improvement in efficiency of radiant and combination radiant & convection heaters or boilers without air pre-heaters that can be realized by reducing Excess Air as 1.5 times the apparent efficiency improvement from air reduction alone due to the accompanying decrease in flue gas temperature.

EXAMPLE SHOWN is for a stack temperature of 800 F and O_2 in Flue Gas of 6%. Saving 5.0%. If desired, Excess Air may also be determined as being 36%.

The estimated capital cost for the improved control system was $13,000.

SUGGESTED ACTION

Determine the percentage of excess air produced by all in-plant combustion control systems, and estimate the potential for energy and fuel cost savings. Consult control and instrumentation specialists when savings potential are indicated.

SOURCE An equipment manufacturer.

EXAMPLE

A fuel savings of $14,400 per year was found to be achievable by heating fuel oil to the proper temperature. This savings potential was in a midwestern meat packing plant where three oil burning boilers had a combined rating of 200,000 pounds per hour of process steam. The fuel/air ratio was manually adjusted by the operator to maintain clear stacks. This practice resulted in approximately 15% excess air with the No. 6 fuel oil used at the specified oil supply temperature of 190 F.

After a change of fuel oil suppliers and the purchase of fuel oil with a different specification, it was found necessary to readjust combustion air flow to maintain clear stacks. After some months a flue gas analysis was run and the excess air was found to be between 25% and 30%. The burner manufacturer's representative was called in to determine why excess air could not be reduced without smoke.

The representative determined that the fuel oil supply temperature of 190 F specified for the original No. 6 fuel oil supply was inadequate for the new fuel supply. He advised that the temperature should be increased to 220 F so the viscosity of the oil supplied to the burners would be the same as the original viscosity specification.

From Figure 1, the estimated fuel savings for reducing excess air to 15% from 30% is 1.0% (note: this estimate is conservative due to the limit on Figure 1 which neglects fuel savings below 20% excess air and assumes stack temperatures between 400 F and 600 F).

With the boilers operating 7200 hours per year at 80% efficiency and requiring 1000 Btu input per pound of steam:

Annual energy requirements

= 200,000 lb steam/h × 1000 Btu/lb steam × 7200 h/yr × 1/0.8 efficiency

= 1,800,000 MBtu per year

If the estimated fuel saving is 1.0%

Annual fuel saving

=1,800,000 MBtu/yr × 1.0%/100%

= 18,000 MBtu per year

If the fuel cost is $0.80 per MBtu

Annual cost saving

= 18,000 MBtu/yr × 0.80 $/MBtu

= $14,400 per year

SUGGESTED ACTION

Check fuel oil supply temperature and compare with burner manufacturer's recommendation for the fuel specification used.

SOURCE An equipment manufacturer.

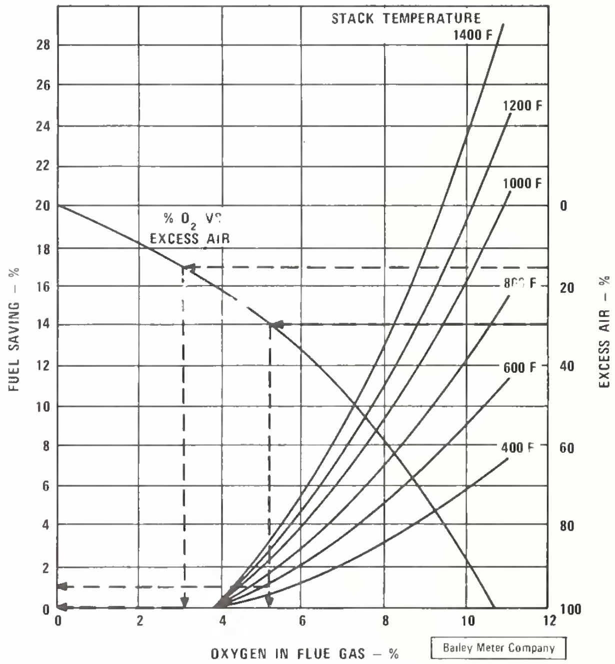


Figure 1 – Liquid Petroleum Fuel Saving Available By Reducing Excess Air to 20%

Savings determined by these curves reflect the following approximation: The improvement in efficiency of radiant and combination radiant & convection heaters or boilers without air preheaters that can be realized by reducing Excess Air is 1.5 times the apparent efficiency improvement from air reduction alone due to the accompanying decrease in flue gas temperature.

EXAMPLE

The potential for saving energy by regularly monitoring boiler efficiency is illustrated by the detection of a deteriorated baffle in the boiler which had an estimated repair cost of $1500 but wasted fuel costing $40.50 per day. This manufacturing plant had oil burning boilers producing approximately 100,000 pounds of steam per hour.

The boilers were modern and were equipped with wide range flow metering combustion control. The total systems were carefully set up, combustion tested by manufacturer's representatives, and the installed boiler efficiency was determined.

A routine was set up to take integrated steam flow and oil flow readings and to compute the boiler efficiencies each day. A running chart of the daily efficiencies was made so that performance could be compared at a glance with the original efficiency. This procedure worked well for several years with gradual degradation showing the need for periodically calling in the control manufacturer's service engineer for a combustion control tune-up.

During one period, the efficiency of one of the boilers which generated 60,000 lb of steam per hour began to fall off rapidly, dropping about 2% over a two week period. An analysis of other readings showed that the average flue gas temperature for that boiler had risen 100 F. This indicated a baffle in the boiler had deteriorated causing the high flue gas temperature and resulting lower efficiency.

This boiler had a total daily steam flow of 1,440,000 lb and each pound of steam absorbed 980 Btu of heat in the boiler. The total daily oil flow to this boiler was 12,700 gallons of oil with a heating value of 139,300 Btu/gallon. The boiler efficiency can then be expressed as:

Efficiency, %

$$= \frac{\text{heat absorbed}}{\text{heat input}} \times 100\%$$

$$= \frac{1{,}440{,}000 \text{ lb steam/d} \times 980 \text{ Btu/lb}}{12{,}700 \text{ gal. oil} \times 139{,}300 \text{ Btu/gal}} \times 100\%$$

$$= 79.8\%$$

Rate of heat loss at a decrease of 2% in efficiency was:

Heat input at 79.8% eff.

$$= 12{,}700 \text{ gal/d} \times 139.300 \text{ Btu/gal}$$
$$= 1769 \text{ MBtu/d}$$

Heat input at 77.8% eff.

$$\frac{1{,}440{,}000 \text{ lb/d} \times 980 \text{ Bt-1 lb}}{0.778} = 1814 \text{ MBtu/d}$$

Heat loss

$$= \underline{45} \text{ MBtu/d}$$

At a fuel cost of $0.90 per MBtu

Cost of loss

$$= 45 \text{ MBtu/day} \times 0.90 \text{ \$/MBtu}$$
$$= \underline{\$40.50} \text{ per day}$$

Estimated repair cost for baffle = $1500

SUGGESTED ACTION

Establish a program to monitor boiler efficiency as a tool to control energy waste.

SOURCE An equipment manufacturer.

EXAMPLE

Improved maintenance procedures, including regular determination of oxygen and combustibles in furnace flue gas, eliminated a fuel loss of over $12,000 per month. This experience occurred in a small chemical plant, where for a period of two months it had not been possible to get more than 80% of rated output from a boiler rated at 120,000 pounds of steam per hour. The boiler had complete flow metering and combustion control equipment but steam flow could not be brought to more than 100,000 lb per hour.

A service engineer from the manufacturer was called to test the combustion controls and found that the flue gas contained no excess oxygen and approximately 4% combustible gas. The ratio of combustion air to fuel was increased until the flue gas contained zero percent combustible gas and steam flow increased to the full 120,000 lb per hour capacity.

In determining the cause of the combustion control malfunction, it was found that moisture from the products of combustion had condensed in the piping to the combustion air flow controller causing an erroneous action.

To eliminate this and similar types of fuel loss in the future, an oxygen and combustibles recorder was installed and a regular maintenance contract was set up with the combustion control manufacturer.

For the two months of operation at 20% below rated output, the boiler was using gaseous fuel at the full rate of 150,000 scf/h. Heating value of the gas was 1000 Btu/cf.

Fuel lost in kcf
$= 0.2 \times 150$ kcf/h $\times$ 24 h/d $\times$ 60 d
$=$ 43,200 kcf

Fuel lost in MBtu
$=$ 43, 200 kcf $\times$ 1000 Btu/cf
$=$ 43,200 MBtu in two months

At a gas cost of $0.60 per MBtu

Cost of lost gas
$=$43,200 MBtu $\times$ 0.60 $/MBtu
$=$ $25,900 in two months

Estimated cost of monitoring equipment:

Oxygen and combustibles recorder	$4500
Installation	2000
Total Installed Cost	$6500

Cost of a maintenance and tune-up contract providing for two combustion tests and two tune-ups was estimated at $1000/year.

SUGGESTED ACTION

Consider the monitoring of oxygen and combustibles as a possible method for assuring that combustion processes are kept in control. Discuss the use of this tool with an instrument and controls manufacturer's representative.

SOURCE An equipment manufacturer.

EXAMPLE

An opportunity to save $18,200 a year in fuel costs was identified in a paper plant when a flue gas analysis was run for the first time in several years. The analysis made on the gas fired boiler showed 8.2% carbon dioxide (CO_2) and 5.3% oxygen (O_2). The flue gas temperature was measured at 515 F. While continuing to measure CO_2, O_2 and the temperature, the combustion air was gradually reduced until readings of CO_2 = 10.5% and O_2 = 2.0% were obtained. The flue gas temperature was then 490 F.

To maintain these conditions on a continuing basis, a continuous recorder was installed for percent oxygen in the flue gas. With this recorder installed, the desired conditions could be maintained if the operator was alert and gave the controls constant attention. However, to get the degree of control desired without continuous operator attention, a completely new control system based on wide range flow metering of fuel and combustion air was installed. As a safety precaution, the system contained cross limiting circuits to limit fuel to available air flow and air flow to fuel burned.

From Figure 1, the potential fuel savings is shown to be approximately 2.3% for 5.3% oxygen in flue gas at 515 F. The same graph indicates that this was at 30% excess air. Cutting back to 2% oxygen in the flue gas is equivalent to reducing excess air to 10%.

For 8000 hours operation per year, at an average flow of 180,000 scf per hour of gas with a heating value of 1000 Btu/cf, and a gas saving of 2.3 percent;

Annual energy saving
= 0.023 × 8000 h/yr × 180 kcf/h × 1000 Btu/cf
= 33,100 MBtu per year

At 1974 contract price of $0.55 per MBtu

Annual cost saving
= 33,100 MBtu × 0.55 $/MBtu
= $18,200 per year

At 1975 contract price of $0.70 per MBtu
= 33,100 MBtu/yr × 0.70 $/MBtu
= $23,170 per year

Estimated cost of instrumentation and controls was;

Oxygen analyzer	$3,000
Combustion control system	$17,000
Installation	$10,000
Total installed cost	$30,000

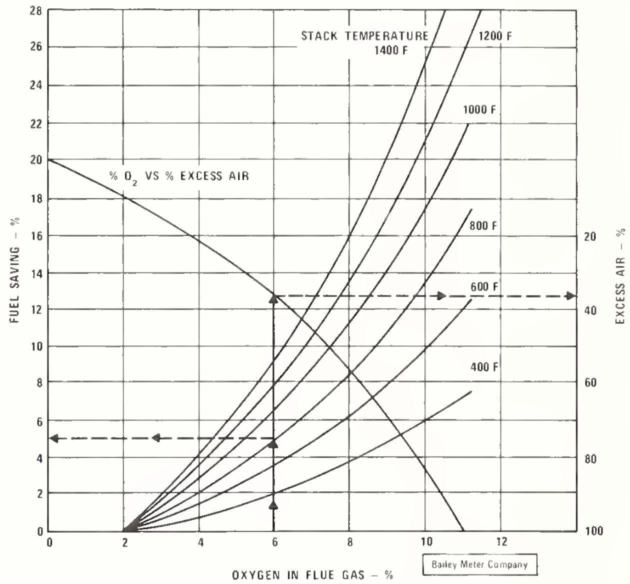


Figure 1 – Hydrocarbon Gaseous Fuel Saving Available By Reducing Excess Air to 10%

FUEL SAVINGS determined by these curves reflect the following approximation: The improvement in efficiency of radiant and combination radiant & convection heaters or boilers without air pre-heaters that can be realized by reducing Excess Air as 1.5 times the apparent efficiency improvement from air reduction alone due to the accompanying decrease in flue gas temperature.

EXAMPLE SHOWN is for a stack temperature of 800F and O_2 in Flue gas of 6%. Saving 5.0%. If desired, Excess Air may also be determined as being 36%.

SUGGESTED ACTION

Review combustion control systems and consult manufacturer for best method to assure adequate combustion control.

SOURCE An equipment manufacturer.

When heating equipment is temporarily not used because production is interrupted or because of the nature of the process, energy can usually be saved by allowing the equipment to cool down and then reheating. For maximum energy saving the heating and cooling characteristics of the equipment must be known so that cooling can be allowed to drop the operating temperature to the lowest practical level and reheat initiated to attain operating temperature no sooner than necessary. There are no general rules of thumb for all cases, but the necessary data are not difficult to obtain.

EXAMPLE

The following table illustrates the type of information needed. These data are for a large oil fired furnace used to heat treat slabs for a rolling mill operating normally at 2250 F.

(a) Turn off power and let the furnace cool for 18 hours.

Energy used = 0. MBtu

(b) Reheat from 650 to 2250 F in 5 hours.

Energy used = 145 MBtu

(c) Hold at 2250 F for 1 hour.

Energy used = 10.4 MBtu

Total Energy used = 155.4 MBtu

If that furnace had idled at 2250 F for 24 hours,

Energy used = 24 h × 10.4 MBtu/h
= 249.6 MBtu

Energy saved = 249.6 MBtu—155.4 MBtu
= <u>94.2</u> MBtu

Fuel oil saved at 144,000 Btu/gal heating value
= <u>650</u> gal

Temp F	Cooling Time, h	Reheat Time, h	Total Time Time, h	Idling Power MBtu/h	Reheat Energy MBtu
2250	0	0	0	10.4	0
2050	1.3	1.1	2.4	9.5	23
1850	2.8	1.8	4.6	8.5	45
1650	4.4	2.5	6.9	7.5	65
1450	6.3	3.0	9.3	6.6	84
1250	8.3	3.5	11.8	5.7	101
1050	11.0	4.0	15.0	4.7	116
850	14	4.5	18.5	3.8	130
650	18	5.0	23	2.8	145
450	23	5.5	28.5	1.9	159
250	32	6.0	38	0.9	174
50	60	6.5	66.5	0	188

The use of such a tabulation may be illustrated by two examples.

(1) The furnace operator is told, "We'll be down for 24 hours. Be ready to go at this time tomorrow." From the above table he sees that in this time period he can let the furnace cool to 650 F and have it reheated to 2250 F. His action is to:

(2) There is a shut-down of indeterminate length, but the furnace must be ready for production on a two hour notice. Reference to the table above shows that a reheat time of 1.8 hours corresponds to 1850 F, and that this would be a proper idling temperature. The energy saving would, of course, depend on the actual shut-down time If this turned

... be six hours, the following program would ...e.

(a) Cool at no power for 2.8 hours.
Energy used = 0

(b) Idle at 1850 F for 1.4 hours.
Energy used = 1.4 × 8.5 MBtu/h
= 11.9 MBtu

(c) Reheat in 1.8 hours to 2250 F
Energy used = 45.0 MBtu

Total Energy used = 56.9 MBtu

If the furnace was idled six hours at 2250 F,

Energy used = 6 h × 10.4 MBtu/h
= 62.4 MBtu

Energy saved = 62.4 MBtu — 56.9 MBtu
= 5.5 MBtu

Fuel oil saved at 144,000 Btu/gal
= 38 gal

SUGGESTED ACTION

Obtain heating and cooling rate data on major heating equipment and use it to schedule stand-by periods.

Energy consumption data (last two columns of table) is also necessary if it is desired to calculate the amount of energy saving.

Note that there can be considerations other than energy savings which affect the choice of the optimum stand-by temperature. In the present example, a low temperature prevents excessive scaling of the slabs and saves steel, in addition to saving energy.

In some cases, damage to equipment or deterioration of the product can result if the temperature is allowed to fall too far. See ECO 3.9.2 on Shut Down Idle Heating Equipment.

SOURCE Based on L. A. Wood—"Energy Conservation Through Scheduling and Process Changes," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

EXAMPLE

Savings in energy can always be achieved by shutting down heating equipment which is not in use, even after making allowance for the energy used in reheating.

1. The graph, Figure 1, plots down time (total time out of service) versus energy saving for a small laboratory oven rated at 5 kW. The oven normally operates at 180 C, and draws 592 watts when idling at this temperature. From ambient, it will come up to temperature in 9½ minutes using energy at an average rate of 3470 watts. Turning this oven off when it is out of use for 48 hours, saves 27.9 kWh. If the utility consumes fuel at the rate of 10,000 Btu/kWh, the fuel saved is 0.279 MBtu.

   Some ovens of the above type are left on continuously, even though they are in use only 8 hours a day and 5 days a week. The possible annual saving for the above described oven by turning it on only when necessary amounts to approximately 3900 kWh or 39 MBtu of fuel at the utility.
2. Larger units show correspondingly greater savings. Figure 2 shows a similar plot for a large oil burning furnace used to reheat steel slabs for a rolling mill. The furnace operates at 2250 F and requires fuel oil at the rate of 72 gal/h to idle at this temperature When cooled to ambient temperature, it can be reheated in 6.5 hours while burning oil at an average rate of 200 gallons per hour.

   Shutting this furnace down for 48 hours over a single weekend, will save approximately 2160 gallons of fuel oil, or 313 MBtu at 145,000 Btu/gal.

Both of the graphs are plots of the equation

$$ES = E_i t_d - E_w t_w$$

Where: ES is the amount of energy saved by a shut-down.
E_i is the energy input rate needed to idle the unit at operating temperature
t_d is the down-time; time at no power plus heat-up time.
E_w is the average energy input rate needed during heat-up.
t_w is the time required for heating up from ambient.

Referring to Figure 2, E_i is 72 gallons of oil per hour, E_w is 200 gal/h, and t_w is 6.5 hours. Thus, at a down time (t_d) of 48 hrs,

$$\begin{aligned} ES &= (72 \text{ gal/h} \times 48 \text{ h}) - (200 \text{ gal/h} \times 6.5 \text{ h}) \\ &= 2160 \text{ gal of fuel oil} \end{aligned}$$

If the oil has a heating value of 145,000 Btu/gal, the saving is equivalent to 313 MBtu.

Note that at short down times, the energy saving curve departs from a straight line and gradually approaches zero. At shorter and shorter times the energy saving becomes quite small, but it never becomes negative.

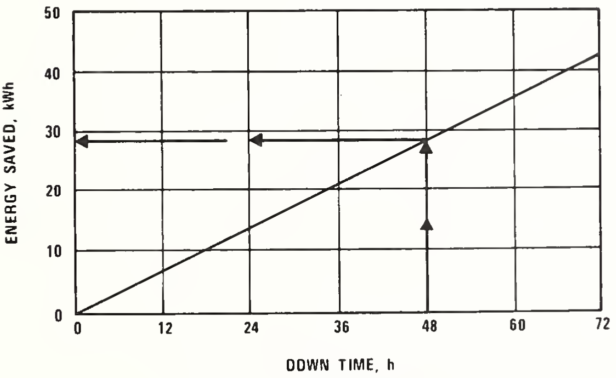


Figure 1 – Energy Saved For Oven Down Time

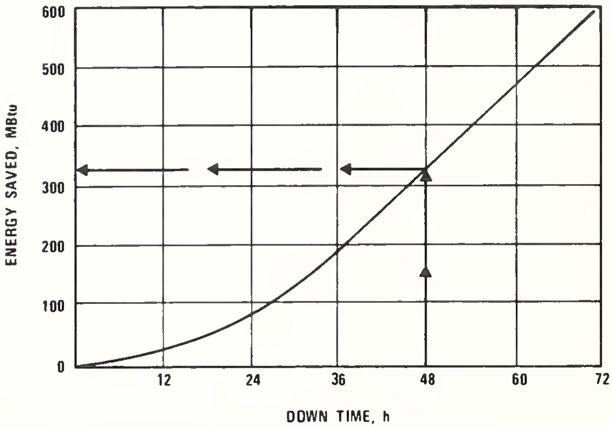


Figure 2 – Energy Saved For Furnace Down Time

SUGGESTED ACTION

Arrange to shut down heating equipment that is not being used.

In some cases there may be an inherent cost which makes a very short shut down financially disadvantageous. See ECO 3.9.1 on Standby at Reduced Temperature.

SOURCE Based on L. A. Wood—"Energy Conservation Through Scheduling and Process Changes," Energy Conservation Through Effective Energy Utilitization, National Bureau of Standards Special Publication No. 403, Vol. II

EXAMPLE

An electronic unit consisted of four sub-assemblies, each of which required a cleaning and drying cycle before final assembly. Three of these sub-assemblies needed only a 10 or 12 minute bake at 125 C to drive off the moisture; the fourth required an hour of baking to completely cure some plastic adhesive. The published specifications called for a one hour bake on all four units. As a result the manufacturing plant purchased two new ovens instead of the one required, and wasted energy at the rate of 24,000 kWh yearly.

$$= 7.5 \text{ kW} \times 16 \text{ h/d} \times 200 \text{ d/yr}$$
$$= \underline{24{,}000} \text{ kWh per year}$$

If the utility consumes fuel at the rate of 10,000 Btu/kWh, the annual waste of fuel

$$= 24{,}000 \text{ kWh/yr} \times 10{,}000 \text{ Btu/kWh}$$
$$= \underline{240} \text{ MBtu per year}$$

Such specification "errors" are not uncommon and are sometimes the result of confusion. In this case, confusion started during the construction of the first prototype when a technician in the model shop mistakenly baked all four units for an hour instead of the 12 minutes called for on three of them. He caught his own error, but the design engineer told him no harm was done, and to go ahead with the final assembly. Some months later the technician was asked to help write up the process specifications, and wrote "bake for one hour at 125 C" for each of the four sub-assemblies. The design engineer approved the documents without noting the discrepancy. Since no one questioned the specifications, both capital funds and energy were wasted.

SUGGESTED ACTION

Re-examine specifications for baking, drying or heat-treating for possible energy reduction changes.

For some examples of energy wastage due to over-specification in the field of heat treating steel parts, see *Iron Age,* Sept. 13, 1973, pp. 43–44.

SOURCE Based on L. A. Wood—"Energy Conservation Through Scheduling and Process Changes," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

EXAMPLE

A small electronics plant operated a group of equipment which drew 28.5 kW for the cleaning of complex assemblies. Careful scheduling permitted the operation of this cleaning line for only one shift instead of two and resulted in an energy saving of 570 MBtu of fuel, or 57,000 kWh per year.

This line had a capacity, with four operators, of 2 to 2.5 times the production rate of the rest of the plant. It was the practice, however, to run it for two shifts like the rest of the plant, but with only two operators per shift. In this way, it was always available so units needed for a rush order would not be held up.

A detailed scheduling system was installed, making sure that no unit needed in a hurry was held up in a queue in the process. With this system it was possible to operate the cleaning line on the first shift only, using all four operators, and still cause no delay on rush orders There was no change in labor cost for the cleaning operation.

Annual power saving

$$= 28.5 \text{ kW} \times 40 \text{ h/wk} \times 50 \text{ wk/yr}$$
$$= 57{,}000 \text{ kWh per year}$$

If the utility uses 10,000 Btu fuel per kWh,

Energy saving

$$= 57{,}000 \text{ kWh/yr} \times 10{,}000 \text{ Btu/kWh}$$
$$= \underline{570} \text{ MBtu per year}$$

At a power cost of $0.02 per kWh

Annual cost saving

$$= 28.5 \text{ kW} \times 2000 \text{ h/yr} \times 0.02 \text{ \$/kWh}$$
$$= \underline{\$1140} \text{ per year}$$

SUGGESTED ACTION

Check the possibility of better scheduling for equipment which must normally be left turned on but is not used to capacity.

Note that in a labor intensive plant, the vagaries of cost accounting may hide power costs in "overhead." A foreman or supervisor can thus fail to receive the credit he deserves for a power saving of this type.

SOURCE Based on L. A. Wood—"Energy Conservation Through Scheduling and Process Changes," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

ECO's under this heading are in preparation and will be available at a later date.

SHIPPING, DISTRIBUTION AND TRANSPORTION

ECO's under this heading are in preparation and will be available at a later date.

Large amounts of energy can be saved if furnace or kiln firing schedules are held to the minimum time necessary, and if the supporting kiln furniture is designed for minimum heat capacity.

EXAMPLE

Such process changes were implemented by a firm to reduce the energy requirement for firing computer memory cores from 120 kWh per million cores to slightly less than 0.9 kWh per million. Exact data are not available, but since the computer industry uses between 100 and 200 billion cores per year, the total yearly savings potential is 10 million to 20 million kWh, or 100,000 to 200,000 MBtu based on 10,000 Btu/kWh.

The original process consisted of spreading out the small (.030" o.d.) green cores on heavy aluminum oxide plates, loading a stack of such plates into a large batch type furnace, and firing for 18 to 24 hours. Although the cores themselves required only a second or two at some precise temperature, usually about 1000 C, the long cycle was necessitated by the characteristics of the furnaces and of the plates which supported the cores. First, it was difficult to be sure that the cores reached the right temperature without any over-shoot; second, the plates were sensitive to temperature shock and had to be heated and cooled slowly.

In the improved process the cores were spread on a woven belt of platinum wire which carried them continuously through a small tube furnace about four feet long. The cores were exposed to high temperature for only 15 to 20 seconds.

The continuous process permitted frequent sample testing of the cores, with feed-back of information for any desired adjustment in temperature, oxygen content of the furnace atmosphere, etc. As a result, the yield of good cores at the final 100% test station was more than doubled.

SUGGESTED ACTION

(1) Keep firing schedules as short as possible.
(2) Reduce to the minimum the amount of heat lost through heating and cooling kiln furniture.
(3) Use continuous firing where possible.

SOURCE Based on L. A. Wood—"Energy Conservation Through Scheduling and Process Changes," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II

EXAMPLE

By rescheduling the way in which its outdoor lights were used, a shopping center realized a reduction in electric power usage of 56,600 kWh per month which was equivalent to a cost savings of $350 per month.

The shopping center includes a total of 83 acres of which approximately 67 are used for outside customer parking and material and equipment storage. The outside area has a total of 2250 lights, ranging in type from floodlights to 35 foot pole lights. The existing lights were the subject of a thorough study over a considerable period of time which considered such factors as the distribution of the lights, which lights were wired on time clocks, which on photo-cells, which were wired singly, in pairs, or in clusters. As a result of this study, only 1401 of the total 2250 lights are now normally used. Of these 1401 lights; 1230 operate from dusk until 10:00 PM, a half hour after the shops close; 38 operate to 11:00 PM; and 133 operate all night. This plan provides adequate, but not uniform, lighting for night time operation and security. There have been no complaints from customers or merchants nor has there been an increase in accident frequency or vandalism.

Method for Calculating Lighting Requirements

The amount of light received from any arrangement of standard lighting fixtures and known wattage can be calculated as follows:

$$F = \frac{N \times L \times D}{A}$$

where: F = foot-candles of illumination
N = number of lighting units of same type and wattage
L = light in lumens for a given type and wattage lighting unit (refer to "IES Lighting Handbook" —1972)
D = depreciation factor for installed lights—use 0.7
A = lighted area, sq. ft.

$$\text{Power Usage (kWh)} = \frac{N \times W \text{ (watts)} \times \text{Usage (hours)}}{1000 \text{ watts/kW}}$$

Power Cost ($) = usage (kWh) × unit cost from local rate schedule ($/kWh)

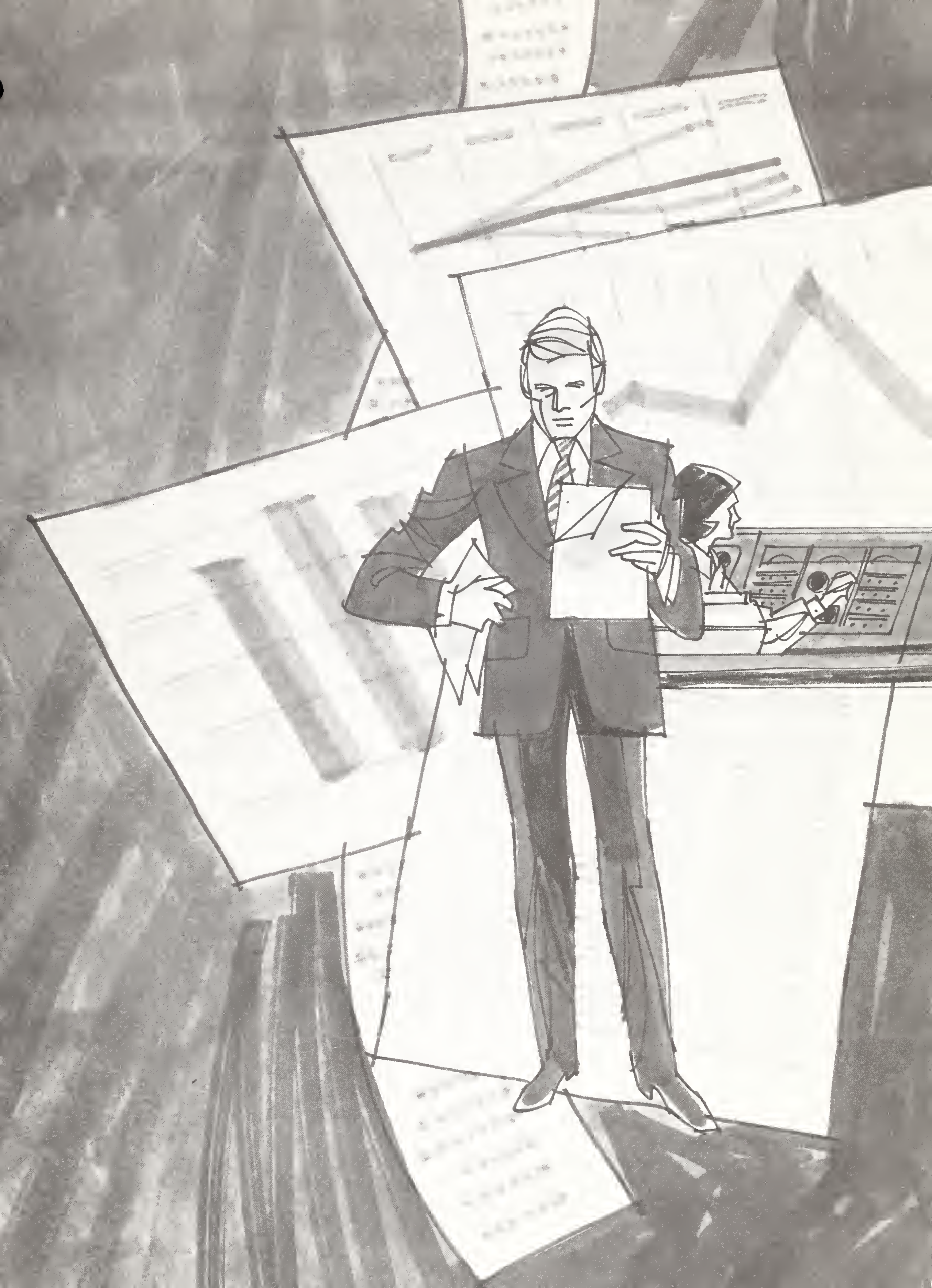
Recommended illumination for parking lots is 1 to 2 foot-candles (Ref. Figure 9–80, "IES Lighting Handbook"—1972).

SUGGESTED ACTION

1. Analyze your outdoor lighting to determine whether use of some lights can be eliminated, or rescheduled, without going below adequate, safe lighting levels.
2. Consult your power company or lighting consultant.

REFERENCE IES Lighting Handbook—1972—5th Edition
Illuminating Engineering Society
345 E. 47th Street
New York, N.Y. 10017

SOURCE Based on J. R. Kernan—"Examples of Energy Conservation," Energy Conservation Through Effective Energy Utilization, National Bureau of Standards Special Publication No. 403, Vol. II



Section 4

ENGINEERING DATA AND FACTORS

TABLE OF CONTENTS

4. ENGINEERING DATA AND FACTORS

4.0 INTRODUCTION

The data reproduced in this section has been selected for use as supplemental information to the preceeding Energy Conservation Opportunities. It is not intended as an exhaustive or complete collection of engineering data and factors. Additional data may be found in the references listed in Section 10, "Bibliography." For those readers who prefer or are more familiar with the modern metric system (SI), reference is made to such publications as:

"E 380-72 ASTM Metric Practice Guide"
"ISO International Standard - 1,000 (1973 ed.), SI Units and Records for the use of their multiples".

4.1 LIST OF SOME CONVERSION FACTORS USED IN EPIC

1 U.S. barrel	= 42 U.S. gallons
1 atmosphere	= 14.7 pounds per square inch absolute (psia)
1 atmosphere	= 760 mm (29.92 in) mercury with density of 13.6 grams per cubic centimeter
1 pound per square inch	= 2.04 inches head of mercury
	= 2.31 feet head of water
1 inch head of water	= 5.20 pounds per square foot
1 foot head of water	= 0.433 pound per square inch
1 British thermal unit (Btu)	= heat required to raise the temperature of 1 pound of water by 1F
1 therm	= 100,000 Btu
1 kilowatt (kW)	= 1.341 horsepower (hp)
1 kilowatt-hour (kWh)	= 1.341 horsepower-hour
1 horsepower (hp)	= 0.746 kilowatt (kW)
1 horsepower-hour	= 0.746 kilowatt hour (kWh)
1 horsepower-hour	= 2545 Btu
1 kilowatt-hour (kWh)	= 3412 Btu
To generate 1 kilowatt-hour (kWh) requires 10,000 Btu of fuel burned by average utility	
1 ton of refrigeration	= 12,000 Btu per hr
1 ton of refrigeration requires about 1 kW (or 1.341 hp) in commercial air conditioning	
1 standard cubic foot is at standard conditions of 60F and 14.7 psia	
1 degree day	= 65F minus mean temperature of the day, F
1 year	= 8760 hours
1 year	= 365 days
1 MBtu	= 1 million Btu

NOTE: In these conversions, inches and feet of water are measured at 62F (16.7 C) and inches and millimeters of mercury at 32F (0 C).

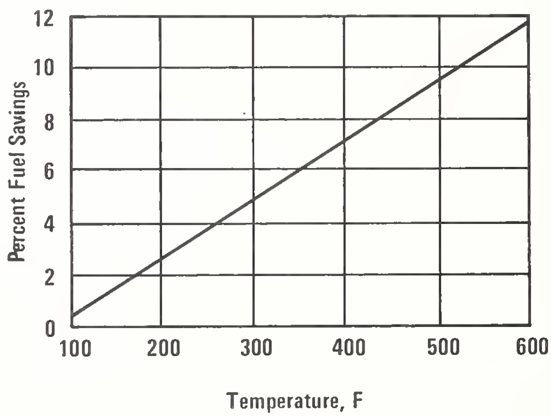
4.2 USUAL AMOUNT EXCESS AIR SUPPLIED TO FUEL-BURNING EQUIPMENT

Fuel	Type of Furnace or Burners	Excess Air Percent by Weight
Pulverized coal	Completely water-cooled furnace for slag-tap or dry-ash-removal	15-20
	Partially water-cooled furnace for dry-ash-removal	15-40
Crushed coal	Cyclone Furnace–pressure or suction	10-15
Coal	Spreader stoker	30-60
	Water-cooled vibrating-grate stoker	30-60
	Chain-grate and traveling-grate stokers	15-50
	Underfeed stoker	20-50
Fuel oil	Oil burners, register-type	5-10
	Multifuel burners and flat-flame	10-20
Acid sludge	Cone and flat-flame type burners, steam-atomized	10-15
Natural, coke-oven, and refinery gas	Register-type burners	5-10
	Multifuel burners	7-12
Blast-furnace gas	Intertube nozzle-type burners	15-18
Wood	Dutch oven (10-23% through grates) and Hofft-type	20-25
Bagasse	All furnaces	25-35
Black liquor	Recovery furnaces for kraft and soda-pulping processes	5-7

Source: *Steam–Its Generation and Use*, 38th edition, 1972; Reprinted with permission of the Babcock and Wilcox Co., New York, N.Y.

4.3 FUEL SAVING COMBUSTION AIR TEMPERATURE

Source: *Steam–Its Generation and Use*, 38th edition, 1972.



Approximate improvement in efficiency when heated combustion air is used in boiler units.

4.4 FUEL HEATING VALUES

Fuel	Higher Heating Value
Coal	
anthracite	13,900 Btu/lb
bituminous	14,000 Btu/lb
sub-bituminous	12,600 Btu/lb
lignite	11,000 Btu/lb
Heavy Fuel Oils and Middle Distillates	
kerosene	134,000 Btu/gallon
No. 2 burner fuel oil	140,000 Btu/gallon
No. 4 heavy fuel oil	144,000 Btu/gallon
No. 5 heavy fuel oil	150,000 Btu/gallon
No. 6 heavy fuel oil, 2.7 % sulfur	152,000 Btu/gallon
No. 6 heavy fuel oil, 0.3% sulfur	143,800 Btu/gallon
Gas	
natural	1,000 Btu/cu ft
liquefied butane	103,300 Btu/gallon
liquefied propane	91,600 Btu/gallon

Source: *Brick and Clay Record*, October 1972; reprinted with permission of the Cahner's Publishing Co. Chicago, Ill.

4.5 TYPICAL PROPERTIES OF FUEL OILS

	Kerosene	No. 2 Burner Fuel	No. 4 Fuel Oil	No. 4 Fuel Oil 1.0% Sulfur	No. 4 Fuel Oil 0.4% Sulfur	No. 5 Fuel Oil	No. 5 Fuel Oil 1.0% Sulfur	No. 6 Fuel Oil 2.7% Sulfur	No. 6 Fuel Oil 1.0% Sulfur	No. 6 Fuel Oil 0.5% Sulfur	No. 6 Fuel Oil 0.3% Sulfur
Gravity, °API	41.4	36.3	23.3	26.1	27.3	22.0	24.1	14.1	22.9	24.8	26.0
Pounds per Gallon	6.814	7.022	7.612	7.476	7.420	7.676	7.573	8.082	7.632	7.539	7.401
Flash Point, °F	133	165	170	194	189	180	193	176	200+	200+	200+
Btu/gal	134,000	140,000	144,000	143,800	143,000	150,000	144,500	152,000	145,500	144,000	143,800
Viscosity, SSU at 100°F	31.5	35.0	96	78	91	180	160	160(1)	400	235	164
Pour Point, °F	-30	0	-10	-20	+15	0	0	+25	+55	+55	+55
Sulfur, weight percent	0.04	0.18	1.62	0.93	0.37	1.43	0.91	2.71	0.96	0.44	0.28
Carbon Residue, weight percent	0.01	0.05	2.9	1.9	1.8	3.5	3.9	12.4	7.0	5.4	4.8
BS&W, percent	–	1.30(2)	0.10	0.10	0.10	0.20	0.20	0.40	0.40	0.30	0.30

Vapor Pressure, psig at 100°F	188	Sulfur, Volatile, g/100 cu ft vapor	4
Distillation, 95% point, °F	-40	Water Contant	dry
Residue, vol %	0.05	Dew Point. °F	-30
Oil-ring test	none	Specific Gravity, 60/60°F	0.501

[1] Saybolt Furol Viscosity at 122°F.
[2] mg/100 ml.

Source: *Brick and Clay Record*, Oct. 1972; Reprinted with permission of the Cahner's Publishing Co. Chicago, Ill.

4.6 FUEL OIL GRADES

Fuel oil (CS-12-48) Grade No.	Gravity, °API	Sp gr	Lb per gal	Btu per lb	Net Btu per gal
6	3	1.0520	8.76	18,190	152,100
6	4	1.0443	8.69	18,240	151,300
6	5	1.0366	8.63	18,290	149,400
6	6	1.0291	8.57	18,340	148,800
6	7	1.0217	8.50	18,390	148,100
6	8	1.0143	8.44	18,440	147,500
6	9	1.0071	8.39	18,490	146,900
6	10	1.0000	8.33	18,540	146,200
6	11	0.9930	8.27	18,590	145,600
6	12	.9861	8.22	18,640	144,900
6, 5	14	.9725	8.10	18,740	143,600
6, 5	16	.9593	7.99	18,840	142,300
5	18	.9465	7.89	18,930	140,900
4, 5	20	.9340	7.78	19,020	139,600
4, 5	22	.9218	7.68	19,110	138,300
4, 5	24	.9100	7.58	19,190	137,100
4, 2	26	.8984	7.49	19,270	135,800
4, 2	28	.8871	7.39	19,350	134,600
2	30	.8762	7.30	19,420	133,300
2	32	.8654	7.21	19,490	132,100
2	34	.8550	7.12	19,560	130,900
1, 2	36	.8448	7.04	19,620	129,700
1, 2	38	.8348	6.96	19,680	128,500
1	40	.8251	6.87	19,750	127,300
1	42	0.8156	6.79	19,810	126,200

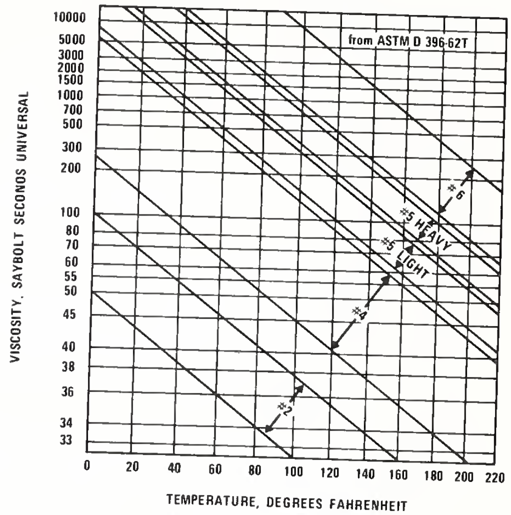
The relation between specific gravity and degrees API is expressed by the formula:

$$\frac{141.5}{131.5 + {}^{\circ}\text{API}} = \text{sp gr at 60 F.}$$

For each 10°F above 60 F add 0.7° API
For each 10° F below 60 F subtract 9.7° API

Source: *Gas Engineers Handbook, 1966;* reprinted with permission of the Industrial Press, New York, N.Y.

4.7 VISCOSITY-TEMPERATURE RELATIONS FOR TYPICAL FUEL OILS



Viscosity-temperature relations for typical fuel oils

Source: *Gas Engineers Handbook, 1966;* reprinted with permission of the Industrial Press, New York, N.Y.

4.8 COMBUSTION CONSTANTS

No.	Substance	Formula	Molecular Weight	Lb per Cu Ft	Cu Ft per Lb	Sp Gr Air = 1.0000	Heat of Combustion: Btu per Cu Ft Gross (High)	Heat of Combustion: Btu per Cu Ft Net (Low)	Heat of Combustion: Btu per Lb Gross (High)	Heat of Combustion: Btu per Lb Net (Low)	For 100% Total Air, Moles per mole of Combustible or Cu Ft per Cu Ft of Combustible: Required for Combustion O_2	Required for Combustion N_2	Required for Combustion Air	Flue Products CO_2	Flue Products H_2O	Flue Products N_2	For 100% Total Air, Lb per Lb of Combustible: Required for Combustion O_2	Required for Combustion N_2	Required for Combustion Air	Flue Products CO_2	Flue Products H_2O	Flue Products N_2
1	Carbon●	C	12.01	–	–	–	–	–	14,093	14,093	1.0	3.76	4.76	1.0	–	3.76	2.66	8.86	11.53	3.66	–	8.86
2	Hydrogen	H_2	2.016	0.0053	187.723	0.0696	325	275	61,095	51,623	0.5	1.88	2.38	–	1.0	1.88	7.94	26.41	34.34	–	8.94	26.41
3	Oxygen	O_2	32.00	0.0846	11.819	1.1053	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	Nitrogen (atm)	N_2	28.01	0.0744	13.443	0.9718	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	Carbon monoxide	CO	28.01	0.0740	13.506	0.9672	321	321	4,347	4,347	0.5	1.88	2.38	1.0	–	1.88	0.57	1.90	2.47	1.57	–	1.90
6	Carbon dioxide	CO_2	44.01	0.1170	8.548	1.5282	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Paraffin series																						
7	Methane	CH_4	16.04	0.0425	23.552	0.5543	1012	911	23,875	21,495	2.0	7.53	9.53	1.0	2.0	7.53	3.99	13.28	17.27	2.74	2.25	13.28
8	Ethane	C_2H_4	30.07	0.0803	12.455	1.0488	1773	1622	22,323	20,418	3.5	13.18	16.68	2.0	3.0	13.18	3.73	12.39	16.12	2.93	1.80	12.39
9	Propane	C_3H_8	44.09	0.1196	8.365	1.5617	2524	2322	21,669	19,937	5.0	18.82	23.82	3.0	4.0	18.82	3.63	12.07	15.70	2.99	1.63	12.07
10	n-Butane	C_4H_{10}	58.12	0.1582	6.321	2.0665	3271	3018	21,321	19,678	6.5	24.47	30.97	4.0	5.0	24.47	3.58	11.91	15.49	3.03	1.55	11.91
11	Isobutane	C_4H_{10}	58.12	0.1582	6.321	2.0665	3261	3009	21,271	19,628	6.5	24.47	30.97	4.0	5.0	24.47	3.58	11.91	15.49	3.03	1.55	11.91
12	n-Pentane	C_5H_{12}	72.15	0.1904	5.252	2.4872	4020	3717	21,095	19,507	8.0	30.11	38.11	5.0	6.0	30.11	3.55	11.81	15.35	3.05	1.50	11.81
13	Isopentane	C_5H_{12}	72.15	0.1904	5.252	2.4872	4011	3708	21,047	19,459	8.0	30.11	38.11	5.0	6.0	30.11	3.55	11.81	15.35	3.05	1.50	11.81
14	Neopentane	C_5H_{12}	72.15	0.1904	5.252	2.4872	3994	3692	20,978	19,390	8.0	30.11	38.11	5.0	6.0	30.11	3.55	11.81	15.35	3.05	1.50	11.81
15	n-Hexane	C_6H_{14}	86.17	0.2274	4.398	2.9704	4768	4415	20,966	19,415	9.5	35.76	45.26	6.0	7.0	35.76	3.53	11.74	15.27	3.06	1.46	11.74
Olefin series																						
16	Ethylene	C_2H_4	28.05	0.0742	13.475	0.9740	1604	1503	21,636	20,275	3.0	11.29	14.29	2.0	2.0	11.29	3.42	11.39	14.81	3.14	1.29	11.39
17	Propylene	C_3H_6	42.08	0.1110	9.007	1.4504	2340	2188	21,048	19,687	4.5	16.94	21.44	3.0	3.0	16.94	3.42	11.39	14.81	3.14	1.29	11.39
18	n-Butene	C_4H_8	56.10	0.1480	6.756	1.9336	3084	2885	20,854	19,493	6.0	22.59	28.59	4.0	4.0	22.59	3.42	11.39	14.81	3.14	1.29	11.39
19	Isobutene	C_4H_8	56.10	0.1480	6.756	1.9336	3069	2868	20,737	19,376	6.0	22.59	28.59	4.0	4.0	22.59	3.42	11.39	14.81	3.14	1.29	11.39
20	n-Pentene	C_5H_{10}	70.13	0.1852	5.400	2.4190	3837	3585	20,720	19,359	7.5	28.23	35.73	5.0	5.0	28.23	3.42	11.39	14.81	3.14	1.29	11.39
Aromatic series																						
21	Benzene	C_6H_6	78.11	0.2060	4.852	2.6920	3752	3601	18,184	17,451	7.5	28.23	35.73	6.0	3.0	28.23	3.07	10.22	13.30	3.38	0.69	10.22
22	Toluene	C_7H_8	92.13	0.2431	4.113	3.1760	4486	4285	18,501	17,672	9.0	33.88	42.88	7.0	4.0	33.88	3.13	10.40	13.53	3.34	0.78	10.40
23	Xylene	C_8H_{10}	106.16	0.2803	3.567	3.6618	5230	4980	18,650	17,760	10.5	39.52	50.02	8.0	5.0	39.52	3.17	10.53	13.70	3.32	0.85	10.53
Miscellaneous gases																						
24	Acetylene	C_2H_2	26.04	0.0697	14.344	0.9107	1477	1426	21,502	20,769	2.5	9.41	11.91	2.0	1.0	9.41	3.07	10.22	13.30	3.38	0.69	10.22
25	Naphthalene	$C_{10}H_8$	128.16	0.3384	2.955	4.4208	5854	5654	17,303	16,708	12.0	45.17	57.17	10.0	4.0	45.17	3.00	9.97	12.96	3.43	0.56	9.97
26	Methyl alcohol	CH_3OH	32.04	0.0846	11.820	1.1052	868	767	10,258	9,066	1.5	5.65	7.15	1.0	2.0	5.65	1.50	4.98	6.48	1.37	1.13	4.98
27	Ethyl alcohol	C_2H_5OH	46.07	0.1216	8.221	1.5890	1600	1449	13,161	11,917	3.0	11.29	14.29	2.0	3.0	11.29	2.08	6.93	9.02	1.92	1.17	6.93
28	Ammonia	NH_3	17.03	0.0456	21.914	0.5961	441	364	9,667	7,985	0.75	2.82	3.57	–	1.5	3.32	1.41	4.69	6.10	–	1.59	5.51
														SO_2						SO_2		
29	Sulfur●	S	32.06	–	–	–	–	–	3,980	3,980	1.0	3.76	4.76	1.0	–	3.76	1.00	3.29	4.29	2.00	–	3.29
30	Hydrogen sulfide	H_2S	34.08	0.0911	10.979	1.1898	646	595	7,097	6,537	1.5	5.65	7.15	1.0	1.0	5.65	1.41	4.69	6.10	1.88	0.53	4.69
31	Sulfur dioxide	SO_2	64.06	0.1733	5.770	2.2640	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32	Water vapor	H_2O	18.02	0.0476	21.017	0.6215	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33	Air	–	–	0.0766	13.063	1.0000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

●Carbon and sulfur are considered as gases for molal calculations only.

All gas volumes corrected to 60 F and 30 in. Hg dry.

Source: *Gas Engineers Handbook*, 1965; Reprinted with the permission of The Industrial Press, New York, N.Y.

4.9 TEMPERATURE OF WASTE-HEAT GASES

Source of Gas	Temp. F
Ammonia oxidation process	1350-1475
Annealing furnace	1100-2000
Cement kiln (dry process)	1150-1500
Cement kiln (wet process)	800-1100
Copper reverberatory furnace	2000-2500
Diesel engine exhaust	1000-1200
Forge and billet-heating furnaces	1700-2200
Gas turbine exhaust	850-900
Garbage incenerator	1550-2000
Open-hearth steel furnace, air blown	1000-1300
Open-hearth steel furnace, oxygen blown	1300-2100
Basic-oxygen furnace	3000-3500
Petroleum refinery	1000-1100
Sulfur ore processing	1600-1900
Zinc-fuming furnace	1800-2000

Source: *Steam-Its Generation and Use,* 38th edition, 1972;

4.10 PROPERTIES OF SATURATED STEAM AND SATURATED WATER (TEMPERATURE)

Temp F	Press. psia	Volume, ft³/lb Water v_f	Evap v_{fg}	Steam v_g	Enthalpy, Btu/lb Water h_f	Evap h_{fg}	Steam h_g	Entropy, Btu/lb x F Water s_f	Evap s_{fg}	Steam s_g	Temp F
32	0.08859	0.01602	3305	3305	-0.02	1075.5	1075.5	0.0000	2.1873	2.1873	32
35	0.09991	0.01602	2948	2948	3.00	1073.8	1076.8	0.0061	2.1706	2.1767	35
40	0.12163	0.01602	2446	2446	8.03	1071.0	1079.0	0.0162	2.1432	2.1594	40
45	0.14744	0.01602	2037.7	2037.8	13.04	1068.1	1081.2	0.0262	2.1164	2.1426	45
50	0.17796	0.01602	1704.8	1704.8	18.05	1065.3	1083.4	0.0361	2.0901	2.1262	50
60	0.2561	0.01603	1207.6	1207.6	28.06	1059.7	1087.7	0.0555	2.0391	2.0946	60
70	0.3629	0.01605	868.3	868.4	38.05	1054.0	1092.1	0.0745	1.9900	2.0645	70
80	0.5068	0.01607	633.3	633.3	48.04	1048.4	1096.4	0.0932	1.9426	2.0359	80
90	0.6981	0.01610	468.1	468.1	58.02	1042.7	1100.8	0.1115	1.8970	2.0086	90
100	0.9492	0.01613	350.4	350.4	68.00	1037.1	1105.1	0.1295	1.8530	1.9825	100
110	1.2750	0.01617	265.4	265.4	77.98	1031.4	1109.3	0.1472	1.8105	1.9577	110
120	1.6927	0.01620	203.25	203.26	87.97	1025.6	1113.6	0.1646	1.7693	1.9339	120
130	2.2230	0.01625	157.32	157.33	97.96	1019.8	1117.8	0.1817	1.7295	1.9112	130
140	2.8892	0.01629	122.98	123.00	107.95	1014.0	1122.0	0.1985	1.6910	1.8895	140
150	3.718	0.01634	97.05	97.07	117.95	1008.2	1126.1	0.2150	1.6536	1.8686	150
160	4.741	0.01640	77.27	77.29	127.96	1002.2	1130.2	0.2313	1.6174	1.8487	160
170	5.993	0.01645	62.04	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170
180	7.511	0.01651	50.21	50.22	148.00	990.2	1138.2	0.2631	1.5480	1.8111	180
190	9.340	0.01657	40.94	40.96	158.04	984.1	1142.1	0.2787	1.5148	1.7934	190
200	11.526	0.01664	33.62	33.64	168.09	977.9	1146.0	0.2940	1.4824	1.7764	200
210	14.123	0.01671	27.80	27.82	178.15	971.6	1149.7	0.3091	1.4509	1.7600	210
212	14.696	0.01672	26.78	26.80	180.17	970.3	1150.5	0.3121	1.4447	1.7568	212
220	17.186	0.01678	23.13	23.15	188.23	965.2	1153.4	0.3241	1.4201	1.7442	220
230	20.779	0.01685	19.364	19.381	198.33	958.7	1157.1	0.3388	1.3902	1.7290	230
240	24.968	0.01693	16.304	16.321	208.45	952.1	1160.6	0.3533	1.3609	1.7142	240
250	29.825	0.01701	13.802	13.819	218.59	945.4	1164.0	0.3677	1.3323	1.7000	250
260	35.427	0.01709	11.745	11.762	228.76	938.6	1167.4	0.3819	1.3043	1.6862	260
270	41.856	0.01718	10.042	10.060	238.95	931.7	1170.6	0.3960	1.2769	1.6729	270
280	49.200	0.01726	8.627	8.644	249.17	924.6	1173.8	0.4098	1.2501	1.6599	280
290	57.550	0.01736	7.443	7.460	259.4	917.4	1176.8	0.4236	1.2238	1.6473	290
300	67.005	0.01745	6.448	6.466	269.7	910.0	1179.7	0.4372	1.1979	1.6351	300
310	77.67	0.01755	5.609	5.626	280.0	902.5	1182.5	0.4506	1.1726	1.6232	310
320	89.64	0.01766	4.896	4.914	290.4	894.8	1185.2	0.4640	1.1477	1.6116	320
340	117.99	0.01787	3.770	3.788	311.3	878.8	1190.1	0.4902	1.0990	1.5892	340
360	153.01	0.01811	2.939	2.957	332.3	862.1	1194.4	0.5161	1.0517	1.5678	360
380	195.73	0.01836	2.317	2.335	353.6	844.5	1198.0	0.5416	1.0057	1.5473	380
400	247.26	0.01864	1.8444	1.8630	375.1	825.9	1201.0	0.5667	0.9607	1.5274	400
420	308.78	0.01894	1.4808	1.4997	396.9	806.2	1203.1	0.5915	0.9165	1.5080	420
440	381.54	0.01926	1.1976	1.2169	419.0	785.4	1204.4	0.6161	0.8729	1.4890	440
460	466.9	0.0196	0.9746	0.9942	441.5	763.2	1204.8	0.6405	0.8299	1.4704	460
480	566.2	0.0200	0.7972	0.8172	464.5	739.6	1204.1	0.6648	0.7871	1.4518	480
500	680.9	0.0204	0.6545	0.6749	487.9	714.3	1202.2	0.6890	0.7443	1.4333	500
520	812.5	0.0209	0.5386	0.5596	512.0	687.0	1199.0	0.7133	0.7013	1.4146	520
540	962.8	0.0215	0.4437	0.4651	536.8	657.5	1194.3	0.7378	0.6577	1.3954	540
560	1133.4	0.0221	0.3651	0.3871	562.4	625.3	1187.7	0.7625	0.6132	1.3757	560
580	1326.2	0.0228	0.2994	0.3222	589.1	589.9	1179.0	0.7876	0.5673	1.3550	580
600	1543.2	0.0236	0.2438	0.2675	617.1	550.6	1167.7	0.8134	0.5196	1.3330	600
620	1786.9	0.0247	0.1962	0.2208	646.9	506.3	1153.2	0.8403	0.4689	1.3092	620
640	2059.9	0.0260	0.1543	0.1802	679.1	454.6	1133.7	0.8686	0.4134	1.2821	640
660	2365.7	0.0277	0.1166	0.1443	714.9	392.1	1107.0	0.8995	0.3502	1.2498	660
680	2708.6	0.0304	0.0808	0.1112	758.5	310.1	1068.5	0.9365	0.2720	1.2086	680
700	3094.3	0.0366	0.0386	0.0752	822.4	172.7	995.2	0.9901	0.1490	1.1390	700
705.5	3208.2	0.0508	0	0.0508	906.0	0	906.0	1.0612	0	1.0612	705.5

4.10 PROPERTIES OF SATURATED STEAM AND SATURATED WATER (TEMPERATURE) *(Continued)*

Press. psia	Temp F	Volume, ft^3/lb			Enthalpy, Btu/lb			Entropy, Btu/lb x F			Energy, Btu/lb		Press. psia
		Water v_f	Evap v_{fg}	Steam v_g	Water h_f	Evap h_{fg}	Steam h_g	Water s_f	Evap s_{fg}	Steam s_g	Water u_f	Steam u_g	
0.0886	32.018	0.01602	3302.4	3302.4	0.00	1075.5	1075.5	0	2.1872	2.1872	0	1021.3	0.0886
0.10	35.023	0.01602	2945.5	2945.5	3.03	1073.8	1076.8	0.0061	2.1705	2.1766	3.03	1022.3	0.10
0.15	45.453	0.01602	2004.7	2004.7	13.50	1067.9	1081.4	0.0271	2.1140	2.1411	13.50	1025.7	0.15
0.20	53.160	0.01603	1526.3	1526.3	21.22	1063.5	1084 7	0.0422	2.0738	2.1160	21.22	1028.3	0.20
0.30	64 484	0.01604	1039.7	1039.7	32 54	1057.1	1089.7	0.0641	2.0168	2.0809	32.54	1032.0	0.30
0.40	72.869	0.01606	792.0	792.1	40.92	1052.4	1093.3	0.0799	1.9762	2.0562	40.92	1034.7	0.40
0.5	79.586	0.01607	641.5	641.5	47.62	1048.6	1096.3	0.0925	1.9446	2.0370	47.62	1036.9	0.5
0.6	85.218	0.01609	540.0	540.1	53.25	1045.5	1098.7	0.1028	1.9186	2.0215	53.24	1038.7	0.6
0.7	90.09	0.01610	466.93	466.94	58.10	1042.7	1100 8	0.3	1.8966	2.0083	58.10	1040.3	0.7
0.8	94.38	0.01611	411.67	411.69	62.39	1040.3	1102.6	0.1117	1.8775	1 9970	62.39	1041.7	0.8
0.9	98.24	0.01612	368.41	368.43	66.24	1038.1	1104.3	0.1264	1.8606	1.9870	66.24	1042.9	0.9
1.0	101.74	0.01614	333.59	333.60	69.73	1036.1	1105.8	0.1326	1.8455	1 9781	69.73	1044 1	1.0
2.0	126.07	0.01623	173.74	173.76	94.03	1022.1	1116.2	0.1750	1.7450	1.9200	94 03	1051.8	2.0
3.0	141.47	0.01630	118.71	118.73	109.42	1013.2	1122.6	0.2009	1.6854	1.8864	109.41	1056.7	3.0
4.0	152.96	0.01636	90.63	90.64	120.92	1006.4	1127.3	0.2199	1.6428	1.8626	120.90	1060.2	4.0
5.0	162.24	0.01641	73.515	73.53	130.20	1000.9	1131.1	0.2349	1.6094	1.8443	130.18	1063.1	5.0
6.0	170.05	0.01645	61.967	61.98	138.03	996.2	1134.2	0.2474	1.5820	1.8294	138.01	1065.4	6.0
7.0	176.84	0.01649	53.634	53.65	144.83	992.1	1136.9	0.2581	1.5587	1.8168	144.81	1067.4	7.0
8.0	182.86	0.01653	47.328	47.35	150.87	988.5	1139.3	0.2676	1.5384	1.8060	150.84	1069.2	8.0
9.0	188.27	0.01656	42.385	42.40	156.30	985.1	1141.4	0.2760	1.5204	1.7964	156.28	1070.8	9.0
10	193.21	0.01659	38.404	38.42	161.26	982.1	1143.3	0.2836	1.5043	1.7879	161.23	1072.3	10
14.696	212.00	0.01672	26.782	26.80	180.17	970.3	1150.5	0.3121	1.4447	1.7568	180.12	1077.6	14.696
15	213.03	0.01673	26.274	26.29	181.21	969.7	1150.9	0.3137	1.4415	1.7552	181.16	1077.9	15
20	227.96	0.01683	20.070	20.087	196.27	960.1	1156.3	0.3358	1.3962	1.7320	196.21	1082.0	20
30	250.34	0.01701	13.7266	13.744	218.9	945.2	1164 1	0.3682	1.3313	1.6995	218.8	1087.9	30
40	267.25	0.01715	10.4794	10.497	236.1	933.6	1169.8	0.3921	1.2844	1.6765	236.0	1092.1	40
50	281.02	0.01727	8.4967	8.514	250.2	923.9	1174.1	0.4112	1.2474	1.6586	250.1	1095.3	50
60	292.71	0.01738	7.1562	7.174	262.2	915 4	1177.6	0.4273	1.2167	1.6440	262.0	1098.0	60
70	302.93	0.01748	6.1875	6.205	272.7	907.8	1180.6	0.4411	1.1905	1.6316	272.5	1100.2	70
80	312.04	0.01757	5.4536	5.471	282.1	900.9	1183.1	0.4534	1 1675	1.6208	281.9	1102.1	80
90	320.28	0.01766	4.8777	4 895	290.7	894.6	1185.3	0.4643	1.1470	1.6113	290.4	1103.7	90
100	327.82	0.01774	4 4133	4.431	298.5	888.6	1187.2	0.4743	1.1284	1 6027	298.2	1105.2	100
120	341.27	0.01789	3.7097	3.728	312.6	877.8	1190.4	0.4919	1.0960	1.5879	312.2	1107.6	120
140	353.04	0.01803	3.2010	3.219	325.0	868.0	1193.0	0.5071	1.0681	1.5752	324.5	1109.6	140
160	363.55	0.01815	2.8155	2.834	336.1	859.0	1195.1	0.5206	1.0435	1.5641	335.5	1111.2	160
180	373.08	0.01827	2.5129	2.531	346.2	850.7	1196.9	0.5328	1.0215	1.5543	345.6	1112.5	180
200	381.80	0.01839	2.2689	2.287	355.5	842.8	1198.3	0.5438	1.0016	1.5454	354.8	1113.7	200
250	400.97	0.01865	1.8245	1.8432	376.1	825.0	1201.1	0.5679	0.9585	1.5264	375.3	1115.8	250
300	417.35	0.01889	1.5238	1.5427	394.0	808 9	1202.9	0.5882	0.9223	1.5105	392.9	1117.2	300
350	431.73	0.01913	1.3064	1.3255	409.8	794.2	1204 0	0.6059	0.8909	1.4968	408.6	1118.1	350
400	444 60	0.0193	1.14162	1.1610	424.2	780.4	1204.6	0.6217	0.8630	1.4847	422.7	1118.7	400
450	456.28	0.0195	1.01224	1.0318	437.3	767.5	1204.8	0.6360	0.8378	1.4738	435.7	1118.9	450
500	467.01	0.0198	0.90787	0.9276	449.5	755.1	1204.7	0.6490	0.8148	1 4639	447.7	1118.8	500
550	476.94	0.0199	0.82183	0.8418	460.9	743.3	1204.3	0.6611	0.7936	1.4547	458 9	1118.6	550
600	486.20	0.0201	0.74962	0.7698	471.7	732.0	1203.7	0.6723	0.7738	1.4461	469.5	1118.2	600
700	503.08	0.0205	0.63505	0.6556	491.6	710.2	1201 8	0.6928	0.7377	1 4304	488 9	1116.9	700
800	518.21	0.0209	0.54809	0.5690	509.8	689.6	1199.4	0.7111	0.7051	1.4163	506 7	1115.2	800
900	531.95	0.0212	0.47968	0.5009	526.7	669.7	1196.4	0.7279	0.6753	1.4032	523.2	1113.0	900
1000	544.58	0.0216	0.42436	0.4460	542.6	650.4	1192 9	0.7434	0.6476	1.3910	538.6	1110.4	1000
1100	556.28	0.0220	0.37863	0.4006	557.5	631.5	1189.1	0.7578	0.6216	1.3794	553.1	1107.5	1100
1200	567.19	0.0223	0.34013	0.3625	571.9	613.0	1184.8	0.7714	0.5969	1.3683	566.9	1104.3	1200
1300	577.42	0.0227	0.30722	0.3299	585.6	594.6	1180.2	0.7843	0.5733	1.3577	580.1	1100.9	1300
1400	587.07	0.0231	0.27871	0.3018	598.8	576.5	1175.3	0.7966	0.5507	1.3474	592.9	1097.1	1400
1500	596.20	0.0235	0.25372	0.2772	611.7	558.4	1170.1	0.8085	0.5288	1 3373	605.2	1093.1	1500
2000	635.80	0.0257	0.16266	0.1883	672.1	466.2	1138.3	0.8625	0.4256	1.2881	662.6	1068.6	2000
2500	668.11	0.0286	0.10209	0.1307	731.7	361.6	1093.3	0.9139	0.3206	1.2345	718.5	1032.9	2500
3000	695.33	0.0343	0.05073	0.0850	801.8	218.4	1020.3	0.9728	0.1891	1.1619	782.8	973.1	3000
3208.2	705.47	0.0508	0	0.0508	906.0	0	906.0	1.0612	0	1 0612	875.9	875.9	3208.2

Source: *Thermodynamic and Transport Properties of Steam*, 1967; reprinted with permission of the American Society of Mechanical Engineers, New York, N Y

4.11 PROPERTIES OF SUPERHEATED STEAM AND COMPRESSED WATER (TEMPERATURE AND PRESSURE)

Abs press. lb/sq in. (sat. temp)		Temperature, F 100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
	v	0.0161	392.5	452.3	511.9	571.5	631.1	690.7								
1	h	68.00	1150.2	1195.7	1241.8	1288.6	1336.1	1384.5								
(101.74)	s	0.1295	2.0509	2.1152	2.1722	2.2237	2.2708	2.3144								
	v	0.0161	78.14	90.24	102.24	114.21	126.15	138.08	150.01	161.94	173.86	185.78	197.70	209.62	221.53	233.45
5	h	68.01	1148.6	1194.8	1241.3	1288.2	1335.9	1384.3	1433.6	1483.7	1534.7	1586.7	1639.6	1693.3	1748.0	1803.5
(162.24)	s	0.1295	1.8716	1.9369	1.9943	2.0460	2.0932	2.1369	2.1776	2.2159	2.2521	2.2866	2.3194	2.3509	2.3811	2.4101
	v	0.0161	38.84	44.98	51.03	57.04	63.03	69.00	74.98	80.94	86.91	92.87	98.84	104.80	110.76	116.72
10	h	68.02	1146.6	1193.7	1240.6	1287.8	1335.5	1384.0	1433.4	1483.5	1534.6	1586.6	1639.5	1693.3	1747.9	1803.4
(193.21)	s	0.1295	1.7928	1.8593	1.9173	1.9692	2.0166	2.0603	2.1011	2.1394	2.1757	2.2101	2.2430	2.2744	2.3046	2.3337
	v	0.0161	0.0166	29.899	33.963	37.985	41.986	45.978	49.964	53.946	57.926	61.905	65.882	69.858	73.833	77.807
15	h	68.04	168.09	1192.5	1239.9	1287.3	1335.2	1383.8	1433.2	1483.4	1534.5	1586.5	1639.4	1693.2	1747.8	1803.4
(213.03)	s	0.1295	0.2940	1.8134	1.8720	1.9242	1.9717	2.0155	2.0563	2.0946	2.1309	2.1653	2.1982	2.2297	2.2599	2.2890
	v	0.0161	0.0166	22.356	25.428	28.457	31.466	34.465	37.458	40.447	43.435	46.420	49.405	52.388	55.370	58.352
20	h	68.05	168.11	1191.4	1239.2	1286.9	1334.9	1383.5	1432.9	1483.2	1534.3	1586.3	1639.3	1693.1	1747.8	1803.3
(227.96)	s	0.1295	0.2940	1.7805	1.8397	1.8921	1.9397	1.9836	2.0244	2.0628	2.0991	2.1336	2.1665	2.1979	2.2282	2.2572
	v	0.0161	0.0166	11.036	12.624	14.165	15.685	17.195	18.699	20.199	21.697	23.194	24.689	26.183	27.676	29.168
40	h	68.10	168.15	1186.6	1236.4	1285.0	1333.6	1382.5	1432.1	1482.5	1533.7	1585.8	1638.8	1992.7	1747.5	1803.0
(267.25)	s	0.1295	0.2940	1.6992	1.7608	1.8143	1.8624	1.9065	1.9476	1.9860	2.0224	2.0569	2.0899	2.1224	2.1516	2.1807
	v	0.0161	0.0166	7.257	8.354	9.400	10.425	11.438	12.446	13.450	14.452	15.452	16.450	17.448	18.445	19.441
60	h	68.15	168.20	1181.6	1233.5	1283.2	1332.3	1381.5	1431.3	1481.8	1533.2	1585.3	1638.4	1692.4	1747.1	1802.8
(292.71)	s	0.1295	0.2939	1.6492	1.7134	1.7681	1.8168	1.8612	1.9024	1.9410	1.9774	2.0120	2.0450	2.0765	2.1068	2.1359
	v	0.0161	0.0166	0.0175	6.218	7.018	7.794	8.560	9.319	10.075	10.829	11.581	12.331	13.081	13.829	14.577
80	h	68.21	168.24	269.74	1230.5	1281.3	1330.9	1380.5	1430.5	1481.1	1532.6	1584.9	1638.0	1692.0	1746.8	1802.5
(312.04)	s	0.1295	0.2939	0.4371	1.6790	1.7349	1.7842	1.8289	1.8702	1.9089	1.9454	1.9800	2.0131	2.0446	2.0750	2.1041
	v	0.0161	0.0166	0.0175	4.935	5.588	6.216	6.833	7.443	8.050	8.655	9.258	9.860	10.460	11.060	11.659
100	h	68.26	168.29	269.77	1227.4	1279.3	1329.6	1379.5	1429.7	1480.4	1532.0	1584.4	1637.6	1691.6	1746.5	1802.2
(327.82)	s	0.1295	0.2939	0.4371	1.6516	1.7088	1.7586	1.8036	1.8451	1.8839	1.9205	1.9552	1.9883	2.0199	2.0502	2.0794
	v	0.0161	0.0166	0.0175	4.0786	4.6341	5.1637	5.6831	6.1928	6.7006	7.2060	7.7096	8.2119	8.7130	9.2134	9.7130
120	h	68.31	168.33	269.81	1224.1	1277.4	1328.1	1378.4	1428.8	1479.8	1531.4	1583.9	1637.1	1691.3	1746.2	1802.0
(341.27)	s	0.1295	0.2939	0.4371	1.6286	1.6872	1.7376	1.7829	1.8246	1.8635	1.9001	1.9349	1.9680	1.9996	2.0300	2.0592
	v	0.0161	0.0166	0.0175	3.4661	3.9526	4.4119	4.8585	5.2995	5.7364	6.1709	6.6036	7.0349	7.4652	7.8946	8.3233
140	h	68.37	168.38	269.85	1220.8	1275.3	1326.8	1377.4	1428.0	1479.1	1530.8	1583.4	1636.7	1690.9	1745.9	1801.7
(353.04)	s	0.1295	0.2939	0.4370	1.6085	1.6686	1.7196	1.7652	1.8071	1.8461	1.8828	1.9176	1.9508	1.9825	2.0129	2.0421
	v	0.0161	0.0166	0.0175	3.0060	3.4413	3.8480	4.2420	4.6295	5.0132	5.3945	5.7741	6.1522	6.5293	6.9055	7.2811
160	h	68.42	168.42	269.89	1217.4	1273.3	1325.4	1376.4	1427.2	1478.4	1530.3	1582.9	1636.3	1690.5	1745.6	1801.4
(363.55)	s	0.1294	0.2938	0.4370	1.5906	1.6522	1.7039	1.7499	1.7919	1.8310	1.8678	1.9027	1.9359	1.9676	1.9980	2.0273
	v	0.0161	0.0166	0.0174	2.6474	3.0433	3.4093	3.7621	4.1084	4.4505	4.7907	5.1289	5.4657	5.8014	6.1363	6.4704
180	h	68.47	168.47	269.92	1213.8	1271.2	1324.0	1375.3	1426.3	1477.7	1529.7	1582.4	1635.9	1690.2	1745.3	1801.2
(373.08)	s	0.1294	0.2938	0.4370	1.5743	1.6376	1.6900	1.7362	1.7784	1.8176	1.8545	1.8894	1.9227	1.9545	1.9849	2.0142
	v	0.0161	0.0166	0.0174	2.3598	2.7247	3.0583	3.3783	3.6915	4.0008	4.3077	4.6128	4.9165	5.2191	5.5209	5.8219
200	h	68.52	168.51	269.96	1210.1	1269.0	1322.6	1374.3	1425.5	1477.0	1529.1	1581.9	1635.4	1689.8	1745.0	1800.9
(381.80)	s	0.1294	0.2938	0.4369	1.5593	1.6242	1.6776	1.7239	1.7663	1.8057	1.8426	1.8776	1.9109	1.9427	1.9732	2.0025
	v	0.0161	0.0166	0.0174	0.0186	2.1504	2.4662	2.6872	2.9410	3.1909	3.4382	3.6837	3.9278	4.1709	4.4131	4.6546
250	h	68.66	168.63	270.05	375.10	1263.5	1319.0	1371.6	1423.4	1475.3	1527.6	1580.6	1634.4	1688.9	1744.2	1800.2
(400.97)	s	0.1294	0.2937	0.4368	0.5667	1.5951	1.6502	1.6976	1.7405	1.7801	1.8173	1.8524	1.8858	1.9177	1.9482	1.9776
	v	0.0161	0.0166	0.0174	0.0186	1.7665	2.0044	2.2263	2.4407	2.6509	2.8585	3.0643	3.2688	3.4721	3.6746	3.8764
300	h	68.79	168.74	270.14	375.15	1257.7	1315.2	1368.9	1421.3	1473.6	1526.2	1579.4	1633.3	1688.0	1743.4	1799.6
(417.35)	s	0.1294	0.2937	0.4307	0.5665	1.5703	1.6274	1.6758	1.7192	1.7591	1.7964	1.8317	1.8652	1.8972	1.9278	1.9572
	v	0.0161	0.0166	0.0174	0.0186	1.4913	1.7028	1.8970	2.0832	2.2652	2.4445	2.6219	2.7980	2.9730	3.1471	3.3205
350	h	68.92	168.85	270.24	375.21	1251.5	1311.4	1366.2	1419.2	1471.8	1524.7	1578.2	1632.3	1687.1	1742.6	1798.9
(431.73)	s	0.1293	0.2936	0.4367	0.5664	1.5483	1.6077	1.6571	1.7009	1.7411	1.7787	1.8141	1.8477	1.8798	1.9105	1.9400
	v	0.0161	0.0166	0.0174	0.0162	1.2841	1.4763	1.6499	1.8151	1.9759	2.1339	2.2901	2.4450	2.5987	2.7515	2.9037
400	h	69.05	168.97	270.33	375.27	1245.1	1307.4	1363.4	1417.0	1470.1	1523.3	1576.9	1631.2	1686.2	1741.9	1798.2
(444.60)	s	0.1293	0.2935	0.4366	0.5663	1.5282	1.5901	1.6406	1.6850	1.7255	1.7632	1.7988	1.8325	1.8647	1.8955	1.9250
	v	0.0161	0.0166	0.0174	0.0186	0.9919	1.1584	1.3037	1.4397	1.5708	1.6992	1.8256	1.9507	2.0746	2.1977	2.3200
500	h	69.32	169.19	270.51	375.38	1231.2	1299.1	1357.7	1412.7	1466.6	1520.3	1574.4	1629.1	1684.4	1740.3	1796.9
(467.01)	s	0.1292	0.2934	0.4364	0.5660	1.4921	1.5595	1.6123	1.6578	1.6990	1.7371	1.7730	1.8069	1.8393	1.8702	1.8998

4.11 PROPERTIES OF SUPERHEATED STEAM AND COMPRESSED WATER (TEMPERATURE AND PRESSURE) *(Continued)*

Abs press. lb/sq in. (sat temp)		Temperature, F 100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
600	*v*	0.0161	0.0166	0.0174	0.0186	0.7944	0.9456	1.0726	1.1892	1.3008	1.4093	1.5160	1.6211	1.7252	1.8284	1.9309
	h	69.58	169.42	270.70	375.49	1215.9	1290.3	1351.8	1408.3	1463.0	1517.4	1571.9	1627.0	1682.6	1738.8	1795.6
(486.20)	*s*	0.1292	0.2933	0.4362	0.5657	1.4590	1.5329	1.5844	1.6351	1.6769	1.7155	1.7517	1.7859	1.8184	1.8494	1.8792
700	*v*	0.0161	0.0166	0.0174	0.0186	0.0204	0.7928	0.9072	1.0102	1.1078	1.2023	1.2948	1.3858	1.4757	1.5647	1.6530
	h	69.84	169.65	270.89	375.61	487.93	1281.0	1345.6	1403.7	1459.4	1514.4	1569.4	1624.8	1680.7	1737.2	1794.3
(503.08)	*s*	0.1291	0.2932	0.4360	0.5655	0.6889	1.5090	1.5673	1.6154	1.6580	1.6970	1.7335	1.7679	1.8006	1.8318	1.8617
800	*v*	0.0161	0.0166	0.0174	0.0186	0.0204	0.6774	0.7828	0.8759	0.9631	1.0470	1.1289	1.2093	1.2885	1.3669	1.4446
	h	70.11	169.88	271.07	375.73	487.88	1271.1	1339.2	1399.1	1455.8	1511.4	1566.9	1622.7	1678.9	1735.0	1792.9
(518.21)	*s*	0.1290	0.2930	0.4358	0.5652	0.6885	1.4869	1.5484	1.5980	1.6413	1.6807	1.7175	1.7522	1.7851	1.8164	1.8464
900	*v*	0.0161	0.0166	0.0174	0.0186	0.0204	0.5869	0.6858	0.7713	0.8504	0.9262	0.9998	1.0720	1.1430	1.2131	1.2825
	h	70.37	170.10	271.26	375.84	487.83	1260.6	1332.7	1394.4	1452.2	1508.5	1564.4	1620.6	1677.1	1734.1	1791.6
(531.95)	*s*	0.1290	0.2929	0.4357	0.5649	0.6881	1.4659	1.5311	1.5822	1.6263	1.6662	1.7033	1.7382	1.7713	1.8028	1.8329
1000	*v*	0.0161	0.0166	0.0174	0.0186	0.0204	0.5137	0.6080	0.6875	0.7603	0.8295	0.8966	0.9622	1.0266	1.0901	1.1529
	h	70.63	170.33	271.44	375.96	487.79	1249.3	1325.9	1389.6	1448.5	1504.4	1561.9	1618.4	1675.3	1732.5	1790.3
(544.58)	*s*	0.1289	0.2928	0.4355	0.5647	0.6876	1.4457	1.5149	1.5677	1.6126	1.6530	1.6905	1.7256	1.7589	1.7905	1.8207
1100	*v*	0.0161	0.0166	0.0174	0.0185	0.0203	0.4531	0.5440	0.6188	0.6865	0.7505	0.8121	0.8723	0.9313	0.9894	1.0468
	h	70.90	170.56	271.63	376.08	487.75	1237.3	1318.8	1384.7	1444.7	1502.4	1559.4	1616.3	1673.5	1731.0	1789.0
(556.28)	*s*	0.1289	0.2927	0.4353	0.5644	0.6872	1.4259	1.4996	1.5542	1.6000	1.6410	1.6787	1.7141	1.7475	1.7793	1.8097
1200	*v*	0.0161	0.0166	0.0174	0.0185	0.0203	0.4016	0.4905	0.5615	0.6250	0.6845	0.7418	0.7974	0.8519	0.9055	0.9584
	h	71.16	170.78	271.82	376.20	487.72	1224.2	1311.5	1379.7	1440.9	1449.4	1556.9	1614.2	1671.6	1729.4	1787.6
(567.19)	*s*	0.1288	0.2926	0.4351	0.5642	0.6868	1.4061	1.4851	1.5415	1.5883	1.6298	1.6679	1.7035	1.7371	1.7691	1.7996
1400	*v*	0.0161	0.0166	0.0174	0.0185	0.0203	0.3176	0.4059	0.4712	0.5282	0.5809	0.6311	0.6798	0.7272	0.7737	0.8195
	h	71.68	171.24	272.19	376.44	487.65	1194.1	1296.1	1369.3	1433.2	1493.2	1551.8	1609.9	1668.0	1726.3	1785.0
(587.07)	*s*	0.1287	0.2923	0.4348	0.5636	0.6859	1.3652	1.4575	1.5182	1.5670	1.6096	1.6484	1.6845	1.7185	1.7508	1.7815
1600	*v*	0.0161	0.0166	0.0173	0.0185	0.0202	0.0236	0.3415	0.4032	0.4555	0.5031	0.5482	0.5915	0.6336	0.6748	0.7153
	h	72.21	171.69	272.57	376.69	487.60	616.77	1279.4	1358.5	1425.2	1486.9	1546.6	1605.6	1664.3	1723.2	1782.3
(604.87)	*s*	0.1286	0.2921	0.4344	0.5631	0.6851	0.8129	1.4312	1.4968	1.5478	1.5916	1.6312	1.6678	1.7022	1.7344	1.7657
1800	*v*	0.0160	0.0165	0.0173	0.0185	0.0202	0.0235	0.2906	0.3500	0.3988	0.4426	0.4836	0.5229	0.5609	0.5980	0.6343
	h	72.73	172.15	272.95	376.93	487.56	615.58	1261.1	1347.2	1417.1	1480.6	1541.1	1601.2	1660.7	1720.1	1779.7
(621.02)	*s*	0.1284	0.2918	0.4341	0.5626	0.6843	0.8109	1.4054	1.4768	1.5302	1.5753	1.6156	1.6528	1.6876	1.7204	1.7516
2000	*v*	0.0160	0.0165	0.0173	0.0184	0.0201	0.0233	0.2488	0.3072	0.3534	0.3942	0.4320	0.4680	0.5027	0.5365	0.5695
	h	73.26	172.60	273.32	377.19	487.53	614.48	1240.9	1353.4	1408.7	1447.1	1536.2	1596.9	1657.0	1717.0	1777.1
(635.80)	*s*	0.1283	0.2916	0.4337	0.5621	0.6834	0.8091	1.3794	1.4578	1.5138	1.5603	1.6014	1.6391	1.6743	1.7075	1.7389
2500	*v*	0.0160	0.0165	0.0173	0.0184	0.0200	0.0230	0.1681	0.2293	0.2712	0.3068	0.3390	0.3692	0.3980	0.4259	0.4529
	h	74.57	173.74	274.27	377.82	487.50	612.08	1176.7	1303.4	1386.7	1457.5	1522.9	1585.9	1647.8	1709.2	1770.4
(668.11)	*s*	0.1280	0.2910	0.4329	0.5609	0.6815	0.8048	1.3076	1.4129	1.4766	1.5269	1.5703	1.6094	1.6456	1.6796	1.7116
3000	*v*	0.0160	0.0165	0.0172	0.0183	0.0200	0.0228	0.0982	0.1759	0.2161	0.2484	0.2770	0.3033	0.3282	0.3522	0.3753
	h	75.88	174.88	275.22	378.47	487.52	610.08	1060.5	1267.0	1363.2	1440.2	1509.4	1574.8	1638.5	1701.4	1761.8
(695.33)	*s*	0.1277	0.2904	0.4320	0.5597	0.6796	0.8009	1.1966	1.3692	1.4429	1.4976	1.5434	1.5841	1.6214	1.6561	1.6888
3200	*v*	0.0160	0.0165	0.0172	0.0183	0.0199	0.0227	0.0335	0.1588	0.1987	0.2301	0.2576	0.2827	0.3065	0.3291	0.3510
	h	76.4	175.3	275.6	378.7	487.5	609.4	800.8	1250.9	1353.4	1433.1	1503.8	1570.3	1634.8	1698.3	1761.2
(705.08)	*s*	0.1276	0.2902	0.4317	0.5592	0.6788	0.7994	0.9708	1.3515	1.4300	1.4866	1.5335	1.5749	1.6126	1.6477	1.6806
3500	*v*	0.0160	0.0164	0.0172	0.0183	0.0199	0.0225	0.0307	0.1364	0.1764	0.2066	0.2326	0.2563	0.2784	0.2995	0.3198
	h	77.2	176.0	276.2	379.1	487.6	608.4	779.4	1224.6	1338.2	1422.2	1495.5	1563.3	1629.2	1693.6	1757.2
	s	0.1274	0.2899	0.4312	0.5585	0.6777	0.7973	0.9508	1.3242	1.4112	1.4709	1.5194	1.5618	1.6002	1.6358	1.6691
4000	*v*	0.0159	0.0164	0.0172	0.0182	0.0198	0.0223	0.0287	0.1052	0.1463	0.1752	0.1994	0.2210	0.2411	0.2601	0.2783
	h	78.5	177.2	277.1	379.8	487.7	606.9	763.0	1174.3	1311.6	1403.6	1481.3	1552.2	1619.8	1685.7	1750.6
	s	0.1271	0.2893	0.4304	0.5573	0.6760	0.7940	0.9343	1.2754	1.3807	1.4461	1.4976	1.5417	1.5812	1.6177	1.6516
5000	*v*	0.0159	0.0164	0.0171	0.0181	0.0196	0.0219	0.0268	0.0591	0.1038	0.1312	0.1529	0.1718	0.1890	0.2050	0.2203
	h	81.1	179.5	279.1	381.2	488.1	604.6	746.0	1042.9	1252.9	1364.6	1452.1	1529.1	1600.9	1670.0	1737.4
	s	0.1265	0.2881	0.4287	0.5550	0.6726	0.7880	0.9153	1.1593	1.3207	1.4001	1.4582	1.5061	1.5481	1.5863	1.6216
6000	*v*	0.0159	0.0163	0.0170	0.0180	0.0195	0.0216	0.0256	0.0397	0.0757	0.1020	0.1221	0.1391	0.1544	0.1684	0.1817
	h	83.7	181.7	281.0	382.7	488.6	602.9	736.1	945.1	1188.8	1323.6	1422.3	1505.9	1582.0	1654.2	1724.2
	s	0.1258	0.2870	0.4271	0.5528	0.6693	0.7826	0.9026	1.0176	1.2615	1.3574	1.4229	1.4748	1.5194	1.5593	1.5962
7000	*v*	0.0158	0.0163	0.0170	0.0180	0.0193	0.0213	0.0248	0.0334	0.0573	0.0816	0.1004	0.1160	0.1298	0.1424	0.1542
	h	86.2	184.4	283.0	384.2	489.3	601.7	729.3	901.8	1124.9	1281.7	1392.2	1482.6	1563.1	1638.6	1711.1
	s	0.1252	0.2859	0.4256	0.5507	0.6663	0.7777	0.8926	1.0350	1.2055	1.3171	1.3904	1.4466	1.4938	1.5355	1.5735

Source *Thermodynamic and Transport Properties of Steam*, 1967, reprinted with permission of the American Society of Mechanical Engineers, New York, N.Y.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Section 5

FINANCIAL EVALUATION PROCEDURES

TABLE OF CONTENTS

5. FINANCIAL EVALUATION PROCEDURES

5.1 INTRODUCTION

Energy conservation opportunities (ECO's) which generate benefits greater than costs without sacrificing product quality are generally profitable and therefore attractive. Those which require little more than operational changes that can be made at negligible cost clearly fall into this category. Many ECO's, however, require an initial capital outlay which must be amortized by the energy savings generated over their expected lifetime. Many ECO's which might have been unprofitable or merely marginal investments before the price of fuels and electricity began their rapid increase are now economically justifiable. The purpose of this section is to review some of the basic tools of financial analysis which may be useful in the economic evaluation of such ECO's, whether outlined in Section 3 or suggested elsewhere.

Sound, consistent economic criteria for evaluating energy conservation opportunities are quite important. Before any investment is undertaken some quantitative measure of profitability is desirable so that the investment's expected return can be compared with that for alternate investment opportunities. Because true economic cost includes opportunity costs of foregone investments, ECO's should be considered to be profitable only when their expected rate of return is greater than that which could be realized from alternative investment opportunities, whether in energy conservation or elsewhere.

In reality, investment decisions are generally based on more than simple rates of return. Factors such as risk, cash flow, taxation schedules, preference between long- and short-term investments, and others should be considered as well. Since these factors may vary greatly among firms they will not be considered directly here. The outcome of any economic evaluation may be considerably affected by them, however, so they should not be overlooked in actual applications but used in conjunction with the measurement criteria presented here.

5.2 FIRST LEVEL MEASURES OF PERFORMANCE

While many energy conservation opportunities may be found during a close examination of plant and operations, some can be quickly rejected because of a low or negative return on investment. First level measures of performance can be useful in screening out such ECO's without the application of more sensitive second-level measures. In general, however, first-level measurements should not be used for justifying major investments for energy conservation projects since these measures do not reflect the time value of money.* Because first level measurements, such as "payback period" and "return on investment", are often referenced and useful for screening candidate investments, it is desirable to show how they are computed and why they are not complete.

The information needed to calculate these performance measures is as follows:

—First Cost, FC

—Annual Operating Cost (if any due to investment), AOC

—Annual Fuel Savings, AFS

—Projected Fuel Price, PFP

—Estimated Lifetime, EL

First cost is the estimated dollar cost of labor and materials required to implement the scheme. The other four items determine the annual benefit stream. (Salvage value of the investment is disregarded here.)

Projected fuel price represents an average fuel price during the estimated lifetime of the investment. The use of current fuel prices will result in lower total savings than can be reasonably expected, inducing a bias against energy conservation investments.

At this point, the net annual saving is defined for application in forthcoming equations and discussion:

$$\text{Net Annual Savings, } S = (AFS \times PFP) - AOC$$

5.2.1 Payback period (PP) is defined as the first cost divided by the net annual savings, or

$$PP = \frac{FC}{(AFS \times PFP) - AOC} \quad \text{or} \quad \frac{FC}{S}$$

The payback period is then compared to the expected lifetime of the investment in order to make some rough judgment as to its potential for recoupment. A payback period of less than one-half the lifetime of an investment would generally be considered profitable where the lifetime is ten years or less.

* This will be discussed in the next section.

The payback period as a measure of performance gives rise to problems, however. For instance, dollars saved in future years are credited the same as dollars saved in current years and comparisons between alternative investment opportunities of different lifetimes cannot be made.

5.2.2 Return on Investment (ROI) is somewhat superior to the above because it takes into account the depletion of the investment over its economic life by providing for renewal through a depreciation charge. Using a straight line depreciation charge (DC) where

$$DC = \frac{FC}{EL}$$

the percent return on investment can be calculated using

$$\text{ROI, \%/yr} = \frac{S-DC}{FC} \times 100\%$$

ROI has the advantage of putting investments with different life expectancies on a comparable basis. It is frequently used in the financial analysis of potential investments because of its simplicity of calculation. Where the rate of return appears small, however (say less than 20%), second level measurements are called for.

5.3 SECOND LEVEL MEASURES OF PERFORMANCE

Second level measures of performance are those which incorporate an allowance for the time value of money, generally in the form of a discount factor. Because of alternative investment opportunities, a dollar held today is worth more than a dollar held in some future time period. The internal rate of return on the best available investment alternative is generally considered to be the appropriate discount rate for evaluating new investment opportunities, unless this rate is below the true borrowing rate when a new investment needs to be financed. In this case, the discount rate must be at least as high as the borrowing rate.

While appropriate discount rates may differ widely in different industries and even among firms within the same industry, corporate discount rates usually run between 10 to 20% or higher. This, again, is equivalent to saying that such a return can be realized elsewhere and thus for a new investment to be justified it must yield a return somewhat greater than this. It should be noted that profits generated by energy savings are generally taxed at the same rate as profits earned elsewhere within or outside of the firm, affirming the need for an equivalent discount rate for energy saving projects.

Several second-level measurements for evaluating ECO's are available. The following three will be presented and discussed:

1) Benefit/cost analysis
2) Time to recoup capital investment
3) Internal rate of return

5.3.1 Benefit/cost analysis requires the direct comparison of the present value benefits (savings) generated by a given investment with its costs. Generally this is formulated in terms of a benefit/cost ratio (B/C). A ratio greater than unity implies that the expected net benefits (properly discounted and summed over the lifetime of the investment) will exceed the initial costs and therefore such an investment is profitable. Likewise, a benefit/cost ratio less than unity implies that such an investment is not profitable. As an absolute measure of the profitability of an investment this is generally considered superior to all others.

The stream of benefits, or net savings (S), when constant in each time period, can be expressed in terms of present value (PV) by using a discount rate (D) and summing the benefits over the expected lifetime (EL) of the project. The present value can be easily estimated using the present worth factors (PWF) in Table 1. By finding the appropriate factor (PWF) for the discount rate (D) and expected lifetime (EL) of the investment and multiplying the factor (PWF) by the net annual savings (S), the present value (PV) of the future savings can be determined. If this present value is greater than the first cost of the investment, the project is profitable.

5.3.2. Time to recoup capital investment, or the "breakeven" period, is similar in concept to the payback period (PP) discussed earlier, except that the breakeven period takes discount rates into consideration. Again, the chief disadvantage of such a measurement is that investments of unequal lifetimes cannot be compared. However, this measurement of performance is often useful to financial planners and budget analysts.

The breakeven period (BP) can be quickly approximated using Table 1. Locate in the column for the appropriate discount rate (D) the present worth factor (PWF) on either side of the payback period (PP) calculated as shown previously. The breakeven period (BP) will be between these two years; interpolation will allow a closer approximation.

C. **The Internal Rate of Return (IRR)** is defined as that discount rate, (D), which reduces the stream of net returns associated with the investment to a present value of zero. While in general the IRR is not always a good measurement of economic performance, IRR will give good results when evaluating a project which has a fixed first cost followed by a stream of positive net benefits.

Unfortunately, the calculation of IRR is not a straightforward exercise but requires an iterative approach converging on the solution. Many computerized financial analysis programs can estimate this quite easily. While the IRR does not require that a discount rate be used in its determination (we are solving for the discount rate), it will be explicitly compared to the appropriate discount rate for the firm in justifying the investment. IRR, like the benefit/cost ratio, is useful when comparing the expected rates of return for alternative investments.

5.4 EXAMPLE OF CALCULATION

Management is considering a capital investment in its manufacturing process for energy conservation purposes which will cost $100,000 to design and install but will involve no new recurring costs. This project is expected to save an average of 27,500 MBtu of natural gas per year for the next 10 years. The projected average cost of this fuel during the time period is assumed to be $1.00 per MBtu. Assuming that management feels that a 20% discount rate is appropriate, will this be a profitable investment?

First Cost	(FC)	= $100,000
Annual Fuel Savings	(AFS)	= 27,500 MBtu/yr
Projected Fuel Price	(PFP)	= $1.00/MBtu

$$\text{Net Annual Savings (S)} = (\text{AFS} \times \text{PFP}) - \text{AOC} = 27{,}500 \text{ MBtu/yr} \times 1.00 \text{ \$/MBtu} - 0 = \$27{,}500 \text{ per yr}$$

5.4.1 First Level Measures of Performance

A. *Payback period (no discounting)*

$$\text{PP} = \frac{\text{FC}}{\text{S}} = \frac{\$100{,}000}{\$27{,}500/\text{yr}} = 3.6 \text{ yr}$$

B. *Return on Investment*

$$\text{DC} = \frac{\text{FC}}{\text{EL}} = \frac{\$100{,}000}{10 \text{ yr}} = \$10{,}000 \text{ per yr}$$

$$\text{ROI}, \frac{\%}{\text{yr}} = \frac{\text{S} - \text{DC}}{\text{FC}} \times 100\% = \frac{(\$27{,}500 \text{ \$/yr} - \$10{,}000 \text{ \$/yr})}{\$100{,}000} \times 100\% = 17.5\% \text{ per yr}$$

Using return on investment (ROI) as an approximation of the profitability of this project, we see that even after an allowance for depreciation this appears to be an attractive investment. Second level measurements of performance are needed, however, if we wish to incorporate the time value of money into the analysis.

5.4.2 Second Level Measures of Performance

A. *Benefit/Cost Analysis*

In order to formulate a benefit/cost ratio we must find the present value of the future savings.

Using the present worth factor (PWF) from Table 1 for 20% discount rate (D) and 10 year lifetime (EL) we find that the present value (PV) of the net annual savings (S) is

$$\text{PV} = \text{S} \times \text{PWF} = \$27.500 \times 4.192 = \$115{,}280$$

This will result in a benefit/cost ratio (B/C) equal to

$$\text{B/C} = \frac{\text{PV}}{\text{FC}} = \frac{\$115{,}280}{\$100{,}000} \text{ or } 1.15$$

Now it becomes apparent that this is a profitable investment even when the time value of money is considered.

B. *Time to Recoup Investment* can be quickly approximated by using Table 1 and the payback period (PP) estimated earlier as 3.6 years. In the 20% discount rate column one can find that the present worth factor closest to 3.6 is 3.605 which indicates that the investment will be entirely recouped in about 7 years when taking the time value of money into consideration. While this is considerably longer than the payback period without discounting, it provides a much better indication of the profitability of this investment because it includes the cost of foregone investment opportunities. If the proper discount rate has been used any investment which is recouped in a period less than its lifetime should be considered profitable.

TABLE 1

PRESENT WORTH FACTORS (PWF)

LIFETIME (EL)	DISCOUNT RATE (D)				
	5%	10%	15%	20%	25%
1	0.952	0.909	0.870	0.833	0.800
2	1.859	1.736	1.626	1.528	1.440
3	2.723	2.487	2.283	2.106	1.952
4	3.546	3.170	2.855	2.589	2.362
5	4.329	3.791	3.352	2.991	2.689
6	5.076	4.355	3.784	3.326	2.951
7	5 786	4.868	4.160	3.605	3.161
8	6.463	5.335	4.487	3.837	3.329
9	7.108	5.759	4.772	4.031	3.463
10	7.722	6.145	5.019	4.192	3.571
11	8.306	6.495	5.234	4.327	3.656
12	8.863	6.814	5.421	4.439	3.725
13	9.394	7.103	5.583	4.533	3.780
14	9.899	7.367	5.724	4.611	3.824
15	10.380	7.606	5.847	4.675	3.859
16	10.838	7.824	5.954	4.730	3.887
17	11.274	8.022	6.047	4.775	3.910
18	11.690	8.201	6.128	4.812	3.928
19	12.085	8.365	6.198	4.843	3.942
20	12.462	8.514	6.259	4.870	3.954
21	12.821	8.649	6.312	4.891	3.963
22	13.163	8.772	6.359	4.909	3.970
23	13.489	8.883	6.399	4.925	3.976
24	13.799	8.985	6.434	4.937	3.981
25	14.094	9.077	6.464	4.948	3.985

The above table is calculated from the following equation:

$$PWF = \frac{1 - (1 + D)^{-EL}}{D}$$

where D is discount rate expressed as a fraction and EL is the expected lifetime of the project in years.

5.5 MARGINAL ANALYSIS

Typical of many investments are those energy conservation opportunities whose rates of return decrease as the levels of investment increase. An example is the application of insulation, where each additional increment generates less savings than the last. In considering such investments, one may wish to estimate the optimal level of application, in the sense that no other level will generate greater net savings (savings minus costs).

The following equality will be useful in estimating such an optimal investment size for any given ECO with variable application levels:

$$MS = MC$$

Where:

MS = marginal savings, the present value savings generated by the last increment of the project, and

MC = marginal cost, the present value cost of this last increment.

This can be shown to hold true by referring to Figure 1. The upper part of Figure 1 shows total cost (TC) and total savings (TS) as a function of investment size. While any level of investment between Q and Q_1 is profitable (since TS > TC), the most profitable level is at that point where the distance between TS and TC is maximized, at Q_o. This

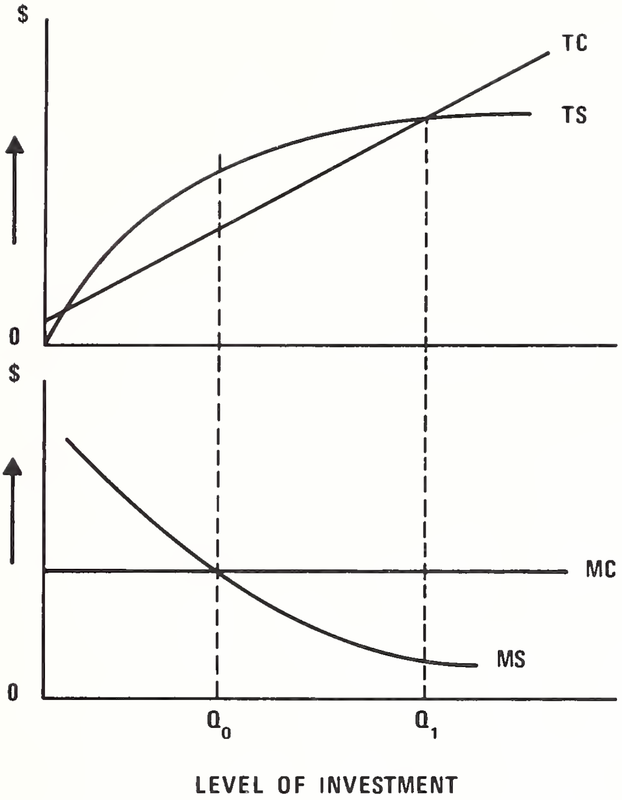


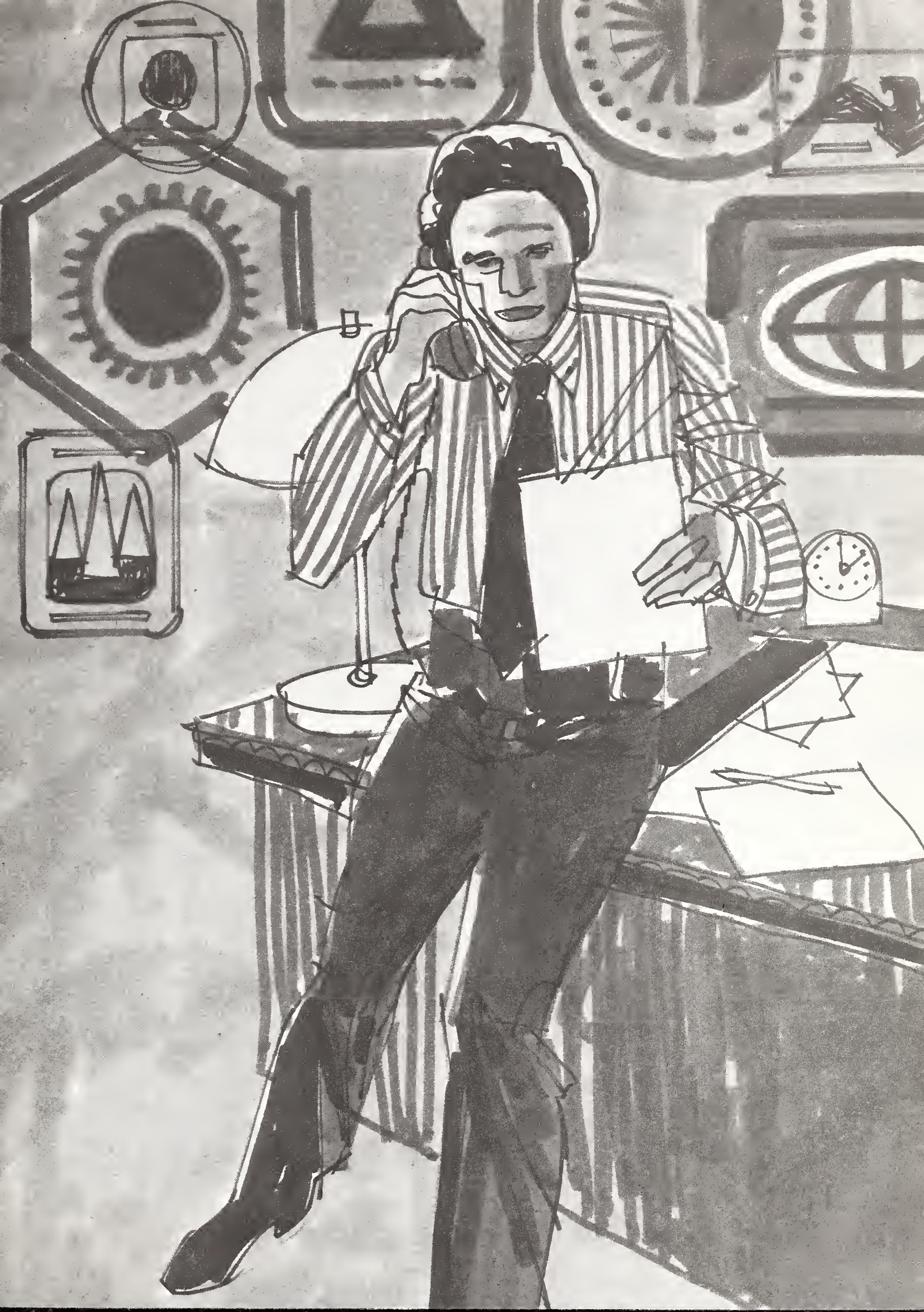
Figure 1 – Determination of Optimal Investment Size Based on the Marginal Savings – Marginal Cost Relationship.

occurs when the slope (or rate of change) of the TC and TS functions are equal. Directly below this point, on the lower diagram, we see that MS = MC.

That this point, Q_0 is indeed the optimal level of investment can be shown as follows. At any investment level less than Q_0, further profit can be earned by expanding investment since the additional savings generated are greater than their cost. At any point beyond Q_0, however, increased savings are not covered by their costs and thus profits will be decreased by adding investment beyond point Q_0. This leaves only that point where MS = MC as the true optimal investment level.

It should be noted that the use of marginal analysis not only will aid in determining the point at which adding investment ceases to be profitable, it may also be used in the reverse sense. That is, marginal analysis may also indicate that by reducing the level of investment in a proposed project that appears to be unprofitable to the point where MS = MC, the project may indeed be made profitable.

For a more comprehensive discussion of marginal analysis techniques and application, consult any basic economics text, such as *Price Theory and Its Use*, D.S. Watson, Houghton-Mifflin Company, (1963); and *Economics*, P. A. Samuelson, McGraw-Hill, (1973).



Section 6

SOURCES OF ASSISTANCE

TABLE OF CONTENTS

6. SOURCES OF ASSISTANCE

6.0 INTRODUCTION

This section contains lists of organizations and individuals who can provide additional guidance and assistance in implementing or operating an energy conservation program. The individuals listed have volunteered to serve in a "steering role." That is, if contacted, they will supply information on energy conservation available from the organization and/or they may provide names of other organizations or individuals who can be contacted regarding specific problems.

Contacts listed in Tables 1 and 2 are all at the national level. Some organizations will have additional contacts available at chapter or regional locations; these would be furnished through the national contact. Table 1 lists trade, business, and commercial associations. Table 2 lists technical societies.

The Office of Energy Programs, Department of Commerce, Washington, D.C. 20230, (202) 967–3535 and Department of Commerce field offices, Table 3, are also sources of information on energy.

Additional sources of assistance will be added in future revisions of this section.

6.1 TRADE, BUSINESS AND COMMERCIAL ASSOCIATIONS

TABLE 1.

American Concrete Pipe Associaion
Cyril I. Malloy, Jr.
Director of Public Affairs
1501 Wilson Boulevard, Suite 908
Arlington, VA 22209
(703) 524-3939

American Dry Milk Institute Whey Products Institute
John T. Walsh
Executive Director
130 North Franklin Street
Chicago, IL 60606
(312) 782–4888 or 5455

American Hotel and Motel Association
Albert E. Kudrle
Director of Public Relations
888 Seventh Avenue
New York, NY 10019
(212) 265–2000

American Institute of Food Distribution Incorporated
John F. Rengstorff
Executive Vice President
P.O. Box 523
Fair Lawn, NJ 07410
(202) 971–5570

American Institute of Timber Construction
Paul R. Beattie
Executive Vice President
333 West Hampden Avenue
Englewood, CO 80110
(303) 761–3212

American Petroleum Institute
Ms. Barbara J. Bland
Senior Manager Public Communications
1801 K Street, N.W.
Washington, DC 20006
(202) 833–5756

American Plywood Association
L. A. Whitman
Treasurer
119 A Street
Tacoma, WA 98401
(206) 272–2283

American Trucking Association
Edward V. Kiley
Vice President, Research & Technical Services Div.
1616 P Street, N.W.
Washington, DC 20036
(202) 797–5221

Brick Institute of America
D. C. Patterson
Asst. Chief Engineer
1750 Old Meadow Road
McLean, VA 22101
(703) 893–4010

Chemical Specialities Manufacturers Association
Ralph Engel
Executive Director
1001 Connecticut Avenue, N.W.
Washington, DC 20036
(202) 872–8110

Concrete Reinforcing Steel Institute
Paul F. Rice
Technical Director
180 N. LaSalle Street, Room 2110
Chicago, IL 60601
(312) 372–5059

Forging Industry Association
George W. Weinfurtner
Staff Specialist, Plant Engineering Services
55 Public Square
Cleveland, OH 44113
(216) 781–6260

Independent Battery Manufacturers Association, Incorporated
Dan A. Noe
Executive Secretary
100 Larchwood Drive
Largo, FL
(813) 584–5540

International Association of Business Communicators
Energy Communication Advisory Committee
Henry Bachrach, Chairman
c/o General Electric Company
570 Lexington Ave.
New York, NY 10022
(212) 750–2621

International Association of Ice Cream Manufacturers and/or Milk Industry Foundation
Robert M. Mulligan
Administrative Assistant
910 17th Street, N.W.
Washington, DC 20006
(202) 296–4250

International Mobile Air Conditioning Association, Incorporated
L. T. Merrill, Secretary-Manager
6166 North Central Expressway, Suite 909
Dallas, TX 75206
(214) 361–7014

Manufacturing Jewelers and Silversmiths of America
Bernard W. Russian
Chairman Energy Committee
236 Chapman Street
Providence, RI 02905
(401) 467–5800

Metal Poster Industries Federation
Kempton H. Roll
Executive Director
Box 2054
Princeton, NJ 08540
(609) 799–3300

Motor and Equipment Manufacturers Association
Ronald M. Landau
Coordinator of Technical Services
222 Cedar Lane
P.O. Box 439
Teaneck, NJ 07666
(201) 836–9500

National Asphalt Pavement Association
Charles R. Foster
Director of Engineering & Research
6811 Kenilworth Avenue, Suite 620
P.O. Box 517
Riverdale, MD 20840
(301) 779–4880

National Association of Building Manufacturers
William T. Eggbeer
Vice President/Technical Services
1619 Massachusetts Avenue, NW
Washington, DC 20036
(202) 234–1374

National Association of Photographic Manufacturers, Inc.
Thomas J. Dufficy
600 Mamaroneck Avenue
Harrison, NY 10528
(914) 698–7603

National Association of Engine and Boat Manufacturers
George Rounds
Secretary
Box 583
Greenwich, CT 06830
(203) 661–4800

National Association of Recycling Industries, Incorporated
Howard Ness
Technical Vice President
330 Madison Avenue
New York, NY 10017
(212) 867–7330

National Automatic Laundry and Cleaning Council
Julius Hovany
National Legislative Director
7 South Dearborn Street, Room 1038
Chicago, IL 60603
(312) 263–3368

National Canners Association
R. P. Farrow
Vice President and Director Washington Laboratory
1133 20th Street, NW
Washington, DC 20036
(202) 331-5958

National Clay Pipe Institute
E. J. Newbould
Vice President—Government Relations
1130 17th Street, N.W.
Washington, DC 20036
(202) 296-5270

National Crushed Stone Association
F. A. Renninger
Vice President—Operations
1415 Elliot Place, N.W.
Washington, DC 20007
(202) 333-1536

National Electrical Manufacturers Association
Robert Stuart Smith
Director of Public Relations
155 East 44th Street
New York, NY 10017
(212) 682-1500

National Environmental Systems Contractors Association
James P. Norris
Executive Manager
1501 Wilson Boulevard
Arlington, VA 22209
(703) 527-0678

National Federation of Independent Business
Wilson S. Johnson
President
150 West 20th Avenue
San Mateo, CA 94403
(415) 341-7441

National LP-Gas Association
John Hartzell
Manager, Public Information Department
79 West Monroe Street
Chicago, IL 60603
(312) 372-5484

National Oil Fuel Institute
Robert Nespeco
Staff Engineer
60 East 42nd Street
New York, NY 10017
(212) 867-0260

National Roofing Contractors' Association
Dr. Edwin Mertz
Technical Services Manager
1515 North Harlem Avenue
Oak Park, IL 60302
(312) 383-9513

National Soft Drink Association
Thomas A. Daly
Legal Counsel
1101 Sixteenth Street, N.W.
Washington, DC 20036
(202) 833-2450

National Tool, Die and Precision Machining Association
Paul R. Hull
Technical Director
9300 Livingston Road
Washington, DC 20022
(303) 248-6200

National Woodwork Manufacturers Association
John W. Shoemaker
Executive Vice President
400 West Madison Street
Chicago, IL 60606
(312) 782-6232

Optical Manufacturers Association
D. Charles Glinsky
Director of Supply
American Optical Corporation
Southbridge, MA 01550
(617) 765-9711

Pharmaceutical Manufacturers Association
John G. Adams
Vice President, Office of Scientific and Professional Relations
1155 Fifteenth Street, N.W.
Washington, DC 20005
(202) 296-2440

Portland Cement Association
Walter E. Kunze
Group Vice President
Research & Development Laboratories, Cement and Concrete Research Institute
Old Orchard Road
Skokie, IL 60076
(312) 966-6200

Screen Manufacturers Association
Frank S. Fitzgerald
Executive Director
410 North Michigan Avenue
Chicago, IL 60611
(312) 321-1646

The Asphalt Institute
Duane E. Edge
Director of Education
College Park, MD 20740
(301) 927-0422

The Fertilizer Institute
John M. Reynolds, Jr.
Director, Member Services
1015 18th Street, N.W.
Washington, DC 20036
(202) 466-2700

U.S. Brewers Association
Henry B. King
President
1750 K Street, N.W.
Washington, DC 20006
(202) 466-2400

Welded Steel Tube Institute
Robert Boeddener
Executive Secretary
522 Westgate Tower
Cleveland, OH 44116
(216) 333-4550

6.2 TECHNICAL SOCIETIES

TABLE 2

American Chemical Society
Dr. Stephen T. Quigley
Director, Department of Chemistry and Public Affairs
1155 16th Street, N.W.
Washington, DC 20036
(202) 872–4474

American Consulting Engineers Council
Bruce E. Vogelsinger
Assistant Director, Governmental Affairs
1155 15th Street, N.W.
Suite 713
Washington, DC 20005
(202) 296–1780

American Institute of Chemical Engineers
Gerald L. Decker
2339 Peale Drive
Saginaw, MI 48640
(517) 636–1000

American Institute of Mining, Metallurgical, and Petroleum Engineers
Granvill Dutton
Chairman, Technical Information Committee/ Society of Petroleum Engineers of AIME
c/o Sun Oil Company
P.O. Box 2880
Dallas, TX 75221
(214) 744–4411

American Institute of Plant Engineers
Walter A. Schaw
Executive Director
1021 Delta Avenue
Cincinnati, OH 45208
(503) 321–9412

American Society of Agricultural Engineers
Russell H. Hahn
Assistant Secretary of Technical Activities
2950 Niles Road
St. Joseph, MI 49085
(616) 983–6521

American Society of Heating, Refrigeration, and Air Conditioning Engineers
Andrew T. Boggs, III
Executive Director
345 East 47th Street
New York, NY 10017
(212) 752–6800 ext. 360, 361

American Society of Mechanical Engineers
Edward H. Walton
Assistant Executive Director
345 East 47th Street
New York, NY 10017
(212) 752–6800

American Society of Sanitary Engineering
Morton H. Lerner
Chairman of Fuel Energy and Conservation Committee
2401 Architects Building
117 South 17th Street
Philadelphia, PA 19103
(215) 568–5677 or 568–3242

Illuminating Engineering Society
John E. Kaufman
Technical Director
345 East 47th Street
New York, NY 10017
(212) 752–6800 ext. 272

Instrument Society of America
Glenn F. Harvey
Director, Publications and Standards
400 Stanwix Street
Pittsburgh, PA 15222
(412) 281–3171

Society of Automotive Engineers, Incorporated
Joseph Gilbert
General Manager
Two Pennsylvania Plaza
New York, NY 10001
(212) 594–5700

Society of Manufacturing Engineers
Peter L. Blake
Manager, Technical Activities Department
20501 Ford Road
Dearborn, MI 48128
(313) 271–1500

Society of Petroleum Engineers of AIME
Granville Dutton
Chairman, Technical Information Committee
c/o Sun Oil Company
P. O. Box 2880
Dallas, TX 75221

U.S. National Committee of World Energy Conference
Dick E. Hart
Secretary
234 State Street
Room 1000
Detroit, MI 48226
(313) 237–7878

6.3 U.S. DEPARTMENT OF COMMERCE FIELD OFFICES

TABLE 3

Address listed is the local Director, Domestic and International Business Administration. Hours shown are local time.

Alabama, Birmingham
8:30 a.m.—5 p.m.
Suite 200, 908 S. 20th St.
35205 Tel (205) 325-3327

Alaska, Anchorage
8:30 a.m.—5 p.m.
Room 412 Hill Bldg., 632 Sixth Ave.
99501 Tel (907) 272-6531

Arizona, Phoenix
8:30 a.m.—5 p.m.
508 Greater Arizona Savings Bldg.
112 N. Central Ave.
85004 Tel (602) 261-3285

California, Los Angeles
8:30 a.m.—5 p.m.
11th Fl. Federal Office Bldg.
11000 Wilshire Blvd.
90024 Tel (213) 824-7591

California, San Francisco
8:30 a.m.—5 p.m.
Federal Bldg., Box 36013, 450 Golden Gate Ave.
94102 Tel (415) 556-5864

Colorado, Denver
8:30 a.m.—5 p.m.
Room 161, New Custom House, 19th & Stout Sts.
80202 (Tel (303) 837-3246

Connecticut, Hartford
8:30 a.m.—5 p.m.
Room 610B Federal Office Bldg., 450 Main St.
06103 Tel (203) 244-3530

Florida, Miami
8:30 a.m.—5 p.m.
821 City National Bank Bldg., 25 W. Flagler St.
33130 Tel (305) 350-5267

Georgia, Atlanta
8:30 a.m.—5 p.m.
Room 523, 1401 Peachtree St., N.E.
30309 Tel (404) 526-6000

Georgia, Savannah
8:30 a.m.—5 p.m.
235 U.S. Court House & Post Office Bldg.
125-29 Bull St.
31402 Tel (912) 232-4321

Hawaii, Honolulu
8:30 a.m.—5 p.m.
286 Alexander Young Bldg., 1015 Bishop St.
96813 Tel (808) 546-8694

Illinois, Chicago
8:30 a.m.—5 p.m.
1406 Mid Continental Plaza Bldg.
60602 Tel (312) 353-4400

Iowa, Des Moines
8:30 a.m.—5 p.m.
609 Federal Bldg., 210 Walnut St.
50309 Tel (515) 284-4222

Louisiana, New Orleans
8:30 a.m.—5 p.m.
Room 108 Federal Bldg., 707 Florida Blvd.
70801 Tel (504) 527-6546

Maryland, Baltimore
8:30 a.m.—5 p.m.
415 US Customhouse
Gay and Lombard Streets
21202 Tel (301) 962-3560

Massachusetts, Boston
8:30 a.m.—5 p.m.
441 Stuart Street
02116 Tel (617) 223-2312

Michigan, Detroit
8:30 a.m.—5 p.m.
445 Federal Building
230 W. Fort Street
48226 Tel (313) 226-6063

Minnesota, Minneapolis
8:30 a.m.—5 p.m.
306 Federal Building
110 S. Fourth Street
55401 Tel (612) 725-2132

Missouri, Kansas City
8:30 a.m.—5 p.m.
601 E. 12th Street
64106 Tel (816) 374-3142

Missouri, St. Louis
8:30 a.m.—5 p.m.
Chromalloy Building
120 S. Central Avenue
63105 Tel (314) 622-4243

Nevada, Reno
2028 Federal Building
300 Booth Street
89502 Tel (702) 784–5203

New Jersey, Newark
8:30 a.m.—5 p.m.
24 Commerce Street
07102 Tel (201) 645–6214

New Mexico, Albuquerque
8:30 a.m.—5 p.m.
U.S. Courthouse, Room 316
87101 Tel (505) 843–2386

New York, Buffalo
8:30 a.m.—5 p.m.
910 Federal Bldg.
1111 West Huron Street
14202 Tel (716) 842–3208

New York, New York City
8:45 a.m.—5:15 p.m.
41st Floor, Federal Bldg.
26 Federal Plaza
10007 Tel (212) 264–0600

North Carolina, Greensboro
8:30 a.m.—5 p.m.
258 Federal Bldg.
West Market Street
P.O. Box 1950
27402 Tel (919) 275–9345

Ohio, Cincinnati
8:30 a.m.—5 p.m.
8020 Federal Office Bldg.
550 Main Street
45202 Tel (513) 684–2944

Ohio, Cleveland
8:30 a.m.—5 p.m.
666 Euclid Avenue
44114 Tel (216) 522–4750

Oregon, Portland
8:30 a.m.—5 p.m.
521 Pittock-Block
921 S.W. Washington Street
97205 Tel (503) 221–3001

Pennsylvania, Philadelphia
8:30 a.m.—5 p.m.
20112 Federal Building
600 Arch Street
19106 Tel (215) 597–2850

Pennsylvania, Pittsburgh
8:30 a.m.—5 p.m.
431 Federal Building
1000 Liberty Avenue
15222 Tel (412) 644–2850

Puerto Rico, San Juan
7:30 a.m.—4 p.m.
Room 100 Post Office Building
00902 Tel (809) 723–4640

South Carolina, Columbia
8:30 a.m.—5 p.m.
2611 Forest Drive
29404 Tel (803) 765–5345

Tennessee, Memphis
8:30 a.m.—5 p.m.
Room 710, Jefferson Avenue
38103 Tel (901) 534–3214

Texas, Dallas
8:30 a.m.—5:30 p.m.
Room 3E7, 1100 Commerce Street
75202 Tel (214) 749–3287

Texas, Houston
8:30 a.m.—5 p.m.
1017 Old Federal Building
201 Fannin Street
77002 Tel (713) 226–4231

Virginia, Richmond
8:30 a.m.—5 p.m.
8010 Federal Building
400 N. 8th Street
23240 Tel (703) 782–2246

Washington, Seattle
8:30 a.m.—5 p.m.
706 Lake Union Building
1700 Westlake Avenue, North
98109 Tel (206) 442–5615

West Virginia, Charleston
8:30 a.m.—5 p.m.
3000 New Federal Office Building
500 Quarrier Street
25301 Tel (304) 343–1375

Wisconsin, Milwaukee
8:30 a.m.—5 p.m.
Straus Building
238 W. Wisconsin Avenue
52303 Tel (414) 272–3473

Wyoming, Cheyenne
8:30 a.m.—5 p.m.
6022 O'Mahoney Federal Center
2120 Capitol Avenue
82001 Tel (307) 778–2151

Section 7

SAFETY, HEALTH AND POLLUTION CONSIDERATIONS

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7. SAFETY, HEALTH AND POLLUTION CONSIDERATIONS

7.1 INTRODUCTION

As the energy conservation program progresses it will inevitably begin to interface with the plant pollution control program and certain energy conservation actions will affect the safety and health conditions in the plant.

In the vast majority of cases the energy conservation program will enhance the pollution control for a manufacturing facility and many energy saving steps have been taken under in-plant pollution control programs. In a very few cases, however, measures designed to conserve or recover energy may create a local pollution problem if the appropriate measures are not taken as the changes are made.

In so far as energy conservation steps result in better control of processes, better insulation of equipment with elimination of hot surfaces, and containment of energy losses in escaping hot fluids, there may be a real gain in plant safety. In certain other cases where closer attention to process equipment requires more frequent operator or maintenance actions, opportunities for accidents may be increased.

The following discussions point out some specific advantages and emphasize some specific precautions. They are not comprehensive but illustrate the need to review proposed energy conserving opportunities for possible advantages or disadvantages in terms of safety, fire prevention and protection, health, and pollution control. Advantages may in some cases be directly credited as a cost savings and disadvantages may require extra expense in appropriate countermeasures. When such savings or costs are identified they should be included in evaluating the economics of energy conserving alternatives.

References of interest for this section will be found in the Bibliography (Section 10).

7.2 POLLUTION CONTROL BENEFITS FROM ENERGY CONSERVATION

A number of the Energy Conservation Opportunities (ECO's) have been selected from the checklist in Section 3 where changes which result in reduced material losses, recovery of heat, or a more optimally run process will also have environmental benefits. The selection is based on expected association and may not always be significant. The selection is not exhaustive and advantages in pollution control will be found in many cases not mentioned below.

A. REPAIR LEAKS IN LINES AND VALVES

The repair of leaks from process equipment should be one of the first steps in any energy conservation or pollution control program. Process leakage results in losses in chemicals and heat, resulting in increases in basic material and fuel costs. In addition, these process leaks will find their way either to the environment or to the waste treatment system, resulting in either environmental degradation or increased cost for waste treatment.

B. REPLACEMENT OF STEAM JETS WITH VACUUM PUMPS

The barometric condensers often associated with steam jets can introduce the pollution problems discussed above. In addition direct discharge steam jets often create a noise problem. The replacement of steam jets with vacuum pumps will eliminate the need for the water required to condense the steam from these jets.

C. THE MINIMIZATION OF LIVE STEAM AS A HEATING FLUID OR AS A STRIPPING GAS

Live steam injected into any process fluid will result in increased waste loads and highly contaminated water as well as eliminating any opportunity for heat recovery. Substituting indirect heating will decrease the plant waste load. The elimination of steam as a stripping fluid or substitution of an inert gas for steam as a stripping medium can have mixed environmental consequences, however. This is discussed under Pollution Control Precautions, Section 7.3.

D. ELIMINATION OF BAROMETRIC CONDENSERS

Barometric condensers bring large amounts of cooling water into contact with process materials. They, therefore, contaminate the cooling water which subsequently must be treated. Indirect condensers, in keeping the cooling water separate from the process fluids, eliminate a large source of waste water. Unless severe fouling of surfaces occurs, indirect condensers are greatly preferred for pollution control, and the replacement of direct condensers can often be justified on water pollution control costs alone.

E. RETURN CONDENSATE TO BOILER PLANT

Many plants still are discharging condensate to their sewers. This results in very high quality water being contaminated and needlessly requiring waste treatment.

F. OPTIMIZE OPERATION OF MULTI-STAGE VACUUM JETS

Where vacuum jets are required, optimization will reduce the steam requirements and hence the water required in the barometric condenser. This will be a direct reduction in the volume of wastewater to be treated.

G. RECOVER AND REUSE COOLING WATER

The reuse of cooling water is generally encouraged as a means of reducing the thermal load on streams. If the installation of a cooling tower is contemplated, however, there are other requirements for protection of the environment These are discussed in Section 7.3.

H. REPLACE WATER COOLING WITH AIR COOLING

There are some areas where thermal pollution of water is considered a problem. In these areas replacement of water cooling with an air cooling system should be investigated. Although generally more expensive than water cooling, air cooling does have the advantage of reducing the need for a cooling tower, with its accompanying blowdown which may require treatment.

I. RECYCLE TREATED WATER

The practice of recycling treated water is being actively encouraged by the United States Environmental Protection Agency as a means for the economical reduction of pollution. In many cases, this can be justified for environmental reasons alone.

J. RECOVER HEAT FROM BURNABLE WASTE INCINERATOR FLUE GASES WITH A WASTE HEAT RECOVERY BOILER

This can have a direct environmental benefit since wastes are directly converted to harmless materials. Some caution is required, however, and will be discussed under "Precautions".

K. IMPROVE COMBUSTION CONTROL

Improvement in combustion controls is an excellent method to reduce pollutants as well as increase the efficiency of fuel utilization. Under certain conditions, however, the optimum conditions for fuel efficiency are not those for minimum pollution, although these differences are usually small.

L. USE WASTE AND BY-PRODUCTS AS FUEL

The practice of using waste and by-products as fuel can have extremely favorable environmental effects if the technical problems are thoroughly investigated. The technical problems which can sometimes result in local environmental problems are discussed under "Precautions".

7.3 POLLUTION CONTROL PRECAUTIONS

Although, as mentioned earlier, the vast majority of modifications to save energy will also have beneficial environmental effects, this is not always the case. ECO's from the checklist in Section 3 have been selected to illustrate how recommended energy conservation practices might have unfavorable local effects if environmental considerations are not taken into account when the changes are being made. It is stressed that if the proper account is taken of these effects, however, the environmental conditions will generally also be improved.

A. REDUCE BUILDING EXHAUSTS AND THUS MAKE-UP AIR

Although this practice can result in decreased air pollution control costs as well as energy savings it must be undertaken only with a firm knowledge of the Occupational Safety and Health Administration requirements for the materials being handled inside the building. OSHA requires that any ventilation system be designed so concentrations of airborne toxic materials are held below the threshold limit value (TLV) or the maximum allowable concentrations (MAC). It is important to stay well on the safe side of these values. This can often be done while reducing the total exhaust air flow by the proper selection and siting of hoods.

B. CONSIDER SWITCHING SELECTED STEAM STRIPPING DISTILLATION UNITS FROM DIRECT STEAM TO INDIRECT STEAM OR "DRY" DISTILLATION

This method can allow recovery of heat not recoverable in direct steam injection and reduction in waste water load, however, air pollutants that would have been removed in the condensation step of the direct steam stripper will pass through the indirect stripper in many cases if sufficient water isn't present. Each case requires a series of calculations to determine if an air pollution problem will result. In many instances other design practices can be used to eliminate these conditions, but this possibility should be investigated.

C. OPERATE DISTILLATION COLUMNS AT NEAR FLOODING CONDITIONS FOR MAXIMUM EFFICIENCY

This will be done in many instances by reducing the pressure of the distillation column, reducing the efficiency of the overhead condenser. Plant engineers should recalculate the performance of the condenser under the reduced pressure to be sure that an air pollution problem won't result. If this is indicated the condenser capacity must be improved through either additional surface or lower cooling fluid temperatures.

D. REPLACE BAROMETRIC CONDENSERS WITH SURFACE CONDENSERS

Although this is definitely recommended as a water pollution control step as well as an energy conservation measure, it can introduce an air pollution problem. Most barometric condensers act as scrubbers for the non-condensible gases in the stream. They usually remove soluble gases, odors, and some particulates. The conditions of a surface condenser may be such that the condensing fluid may not have sufficient capacity to dissolve some of the components in the non-condensible gases. An additional treatment step on the gases might be required. An analysis of the specific conditions existing in the condensing stream is required to determine if problems of this type are likely.

E. CLEAN FOULING FROM WATER LINES REGULARLY

This is of course good practice. Care must be taken, however, that the cleaning compounds used are compatible with the waste treatment system, and that the treatment system will not be overloaded or adversely affected by discharging large amounts of cleaning solutions at one time.

F. RECOVER AND REUSE COOLING WATER

If the installation of a cooling tower will require that the water be treated to inhibit corrosion and fouling, the blowdown from the tower will contain dissolved salts and the treatment chemicals, and a permit will be required if the blowdown is discharged to a stream. Although this does not present a severe problem the application for a new discharge permit from EPA for this stream shouldn't be overlooked.

G. USE WASTE AND BY-PRODUCTS AS FUEL

Significant benefits to the environmental control program can result from the successful burning of waste products as fuel. There are air pollution pitfalls in doing this, however, and the problems associated with efficiently burning wastes should not be minimized. For instance heavy metals, such as mercury and cadmium, occur in many waste products and during the incineration process these are sometimes dispersed into the effluent. Another important factor to remember is the variability of many liquid wastes in comparison to fuels. The oxygen requirements for efficient burning of many wastes will vary radically depending on fuel properties and the incinerator operation must be controlled to respond to these changes. In addition hydrochloric acid or other corrosive combustion products may be formed from wastes containing chlorinated hydrocarbons. Other halides such as fluorine compounds also occur in some modern waste materials. Combustion of these wastes can have a rapid deleterious impact on boiler surfaces causing repair costs which may more than offset any savings in fuel costs. The proper scrubbing and/or particulate control systems must be included on the boiler or incinerator. In addition many of the toxic substances require a minimum flame temperature to completely destroy their toxic properties. It is important for the incinerator or boiler to have refractory material which can withstand both the high temperature and the corrosive materials.

H. OPERATE 3 OR 4 DAYS AROUND THE CLOCK RATHER THAN ONE OR TWO SHIFTS PER DAY

For plants which have their own waste biological treatment system this change in operating schedule may affect the performance of the treatment plant unless special provisions are made. The treatment plant will be faced with an increased load over the period of continuous operation and substantially no load for about one half the time. Although a moderate amount of flow equalization will allow most waste treatment plants to operate satisfactorily on a 1-2 shift per day cycle, a 3 or 4 day continuous operating cycle may require considerable equalization capacity so that food will be available to the biomass during the down time.

I. CONVERT FROM INDIRECT TO DIRECT FIRING

Direct firing means that the combustion gases will be contacting the process materials. There is the possibility of new materials being added to the combustion gases which could become air pollutants. The dilution effect of the combustion will tend to sweep process materials into the stack. This possibility should be carefully evaluated for air pollution potential before converting to direct firing. For example, direct contact evaporation of black liquor in paper mills is largely responsible for the odor problems associated with this industry.

7.4 GENERAL SAFETY CONSIDERATIONS

As energy conservation proceeds, operating and maintenance procedures may be changed for existing equipment and new equipment or modifications may be installed. If this represents an increase in the tempo of such changes it would be appropriate to step up activities normally associated with the plant safety program.

Plant safety engineers or others responsible for identifying unsafe conditions have experience in viewing the plant in a critical manner. For example, a warehouse storing flammable materials is designed for a certain number of air changes per hour which has been arrived at after consideration of health and safety requirements involving a company's insurance carrier, local and state labor department regulations, and state and federal OSHA and MESA requirements, among others. It would be a serious error to arbitrarily reduce the ventilation capacity in any warehouse or manufacturing area to save energy without a plant safety engineer taking all these factors into consideration. The safety engineer may see the operation in a way which helps to spot undesirable features which might be overlooked by one who identifies those features with their contribution to the plant processes. This point of view may be valuable in identifying opportunities for energy conservation.

By including plant safety personnel on the energy conservation team there may be a double advantage, the benefit of having personnel experienced in plant inspection and of including the consideration of plant safety early in the planning for each energy conserving change.

7.5 SPECIAL SAFETY AND HEALTH CONSIDERATIONS

Certain energy conservation actions could result in a conflict with applicable safety and health standards such as the Federal Occupational Safety and Health Act (OSHA) regulations or a company's fire insurance requirements. For example, electricity can be conserved by reducing illumination levels but the OSHA regulations prescribe minimum lighting levels for certain categories of space and activities. The following sections from the OSHA regulations as printed in the *Federal Register* are the pertinent ones related to potential energy conservation measures.

> 1910.94 (c)(7)(iv)(b) ". . . general heating of the building . . . provided that all occupied parts of the building are maintained at not less than 65°F. . . ."

This section which applies to the ventilation of spray paint booths suggests that it is not necessarily a good idea to take warm air from a building to ventilate a spray booth because the equivalent make-up air must be heated for the building.

> 1910.141 (d)(ii) "Each lavatory shall be provided with hot and cold running water, or tepid running water."

The degree of "hot" is subject to interpretation, but can be a source of energy waste if hot water cannot be used without cooling.

> 1910.142(f)(4) "Every service building shall be provided with equipment capable of maintaining a temperature of at least 70°F during cold weather."

This section applies to temporary labor camps and especially to "laundry, handwashing and bathing facilities" and suggests a warmer environment where people are to take baths. Potential energy savings in meeting this regulation should be considered.

> 1910.142 (g) ". . . Light levels in toilet and storage rooms shall be at least 20 foot-candles 30 inches from the floor. Other rooms, including kitchens and living quarters, shall be at least 30 foot-candles 30 inches from the floor."

This section also refers to temporary labor camps, and may be understood to be no less than the requirements in more permanent installations. The levels correspond to those found in ANSI Std A11.1—1965 which is the reference cited.

> 1910.143 (b)(2)(vii) ". . . lighting shall be provided with an intensity of not less than 10 foot-candles, 30 inches above the floor."

This minimum cited for non-water privy installations is probably a more realistic practical minimum requirement.

> 1910.178 (h) and

> 1910.219 (c)(5) ". . . Controlled lighting of adequate intensity should be provided in operating areas. (See ANSI A 11.1—1965)"

> 1518.55 "Illumination. (a) General. Construction areas, ramps, runways, corridors, offices, shops, and storage areas shall be lighted to not less than the minimum illumination intensities listed in Table D-3 while any work is in progress."

TABLE D-3—MINIMUM ILLUMINATION INTENSITIES IN FOOT-CANDLES

FOOT-CANDLES	AREA OR OPERATION
5	General construction area lighting.
3	General construction areas, concrete placement, excavation and waste areas, accessways, active storage areas, loading platforms, refueling, and field maintenance areas.
5	Indoors: warehouses, corridors, hallways, and exitways.
5	Tunnels, shafts, and general underground work areas: (Exception: minimum of 10 foot-candles is required at tunnel and shaft heading during drilling, mucking, and scaling. Bureau of Mines approved cap lights shall be acceptable for use in the tunnel heading.)
10	General construction plant and shops (e.g., batch plants, screening plants, mechanical and electrical equipment rooms, carpenter shops, rigging lofts and active storerooms, barracks or living quarters, locker or dressing rooms, mess halls, and indoor toilets and workrooms).
30	First aid stations, infirmaries, and offices.

NOTE: The table indicates very much lower lighting levels for active storage areas, hallways, warehouses, corridors and indoor toilets.

1926.154 (d) "... Solid fuel heaters and oil-fired salamanders are prohibited in buildings and on scaffolds."

This prohibition of the use of solid fuel heaters requires the use of more elaborate heaters using fuels in short supply.

Section 8

EMPLOYEE PARTICIPATION

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8. EMPLOYEE PARTICIPATION

8.1 INTRODUCTION

An energy conservation program in any commercial or industrial company can be successful only if it arouses and maintains the participative interest of its employees. Employees who participate and who feel themselves partners in the planning and implementation of the details of the program will share pride in the results.

One objective of your plan should be to develop employee awareness of the seriousness of the energy situation as it applies to the employee's home, company, and community. The other objective is to motivate each one to practice energy conservation at all times. These objectives can be attained only by communicating with the employees and educating them on all matters relative to the use and conservation of energy, both in their jobs and in their personal lives.

Communicating with employees on the subject of energy can be accomplished in many different ways: face to face discussion, conveniently scheduled seminars and workshops, distribution of informative and descriptive literature, slide presentations and moving pictures, and most important of all, sincere practice of conservation on the part of management at all times. Assistance with the preparation of effective communications on energy conservation throughout your organization can be obtained by contacting the Chairman of the Energy Communication Advisory Committee of the International Association of Business Communicators. See Section 6, Table I.

8.2 ON-THE-JOB CONSERVATION

The use of company newsletters, bulletin boards, or posters for pictorializing energy conservation objectives and accomplishments will help impress employees with the importance of such matters. Exhibits A and B are examples from the Monsanto Company's "Bayou Briefs" and the Union Carbide Corporation's "Forecaster." Employee participation can be enhanced by examples of energy conservation ideas being implemented, photographs of persons who submitted the idea, and information on the savings realized.

Competition between departments, sections, or groups within the company in pursuing conservation of energy can also generate enthusiasm among employees. Competitive programs can be initiated among the employees themselves and should be encouraged. Other competition can be company sponsored and even subsidized. The familiar "suggestion box" technique, with proper incentives, will often produce very worthwhile ideas for energy conservation. Acknowledgement of good ideas is a key to success of this approach. Results in competitive programs can be measured in terms of million Btu equivalent used per unit of product or per standard hour of operation, or some other understandable unit. Current results should be measured against prior comparable periods of time to be meaningful.

Employee education can take many diverse forms —workshops and training courses for supervisory personnel, articles in the company newsletter, and energy conservation checklists given to each employee. It is important that employees realize that energy shortages mean more than long lines at the gas station. They must be made aware that failure to conserve energy at home can affect the energy available to their place of employment. They should know that there are direct and indirect effects of the energy crisis: the direct ones being an inability to get deliveries of oil, or natural gas, or electricity to run the plant, and the indirect ones being an inability for the plant to get raw materials, spare parts, or product components. This effort can help put the "big picture" into the perspective—that energy shortages hundreds of miles away may affect their jobs just as surely as shortages at home. Exhibit C shows some examples of material used for employee education.

A clear, concise list of firm "dos and don'ts" to guide employees in performance of their work can be helpful in achieving energy conservation practices. Such lists should be distributed to all employees whose jobs involve the use or control of energy. The list should be updated as often as necessary. Supervisors should have the responsibility of seeking adherence to all items on the lists. An example of such a list is attached (Exhibit D).

8.3 TRANSPORTATION CONSERVATION

One "off-the-job" area which accounts for a major consumption of energy, and in which practically all employees are involved is personal transportation. The gasoline consumed by automobiles was about 13 percent of our gross energy supply in the United States in 1973.

A typical checklist relating to operation of automobiles is attached (Exhibit E). Such lists will be

	Existing Habits	Using Three-Man Car Pool	Average Savings Per Family
Average Occupants/Trip	1.4	2.8*	—
Average Car Trips/Year	360	180	180 trips
Average Car Miles Traveled/Year	3384 miles	1692	1692 miles
Gas Used (@ 13.3 miles/gallon)	254 gallons	127	127 gallons
Gas Costs (@37.8¢/gallon)	$96	$48	$48/year
Other Costs of Operation (@ 10.16¢/mile)	$344	$172	$172/year
Total Savings Per Family			$220/year

* Assumes a car pool of three persons; allows for average absences of 17 days a year for each person.

helpful to car owners and will result in conservation of energy, as well as considerable cost savings to the individual. Exhibit F is a pictorialized aid prepared by the Environment Center of the University of Tennessee—"16 Easy Ways to Cut Your Transportation Costs." This is typical of many such publications available upon request for distribution to your employees.

Encouragement and assistance should be provided employees in forming car pools for transportation to work. Based on an assumed three-person car pool for transportation to work, the average annual monetary and gasoline savings per family are indicated in the above table prepared in June 1973 by the Citizen's Advisory Committee on Environmental Quality.

Where large groups of employees are working in a common area, but not necessarily for the same employer, assistance in forming transportation pools to work is available through programs prepared by the U.S. Department of Transportation, Federal Highway Administration, Washington, D.C. An example of cooperative implementation of such a program for employees for municipal and state governments in a capital city is attached (Exhibit G). Individual companies should participate in such area-wide car pool programs.

Car pooling, of course, is not the only alternative for reducing employee-related energy usage. For example, flexible work hours can maximize the use of daylight during the winter and staggered shifts can help avoid costly traffic jams. The ten hour, four day work week, when feasible, is a plan which some companies have adopted. This plan not only reduces employee transportation requirements by 20 percent, but may also allow for conservation of heating, air conditioning, lighting, and other employee-supporting energy usage.

Employers should also evaluate public transportation. Where it is limited, or not available, a company shuttle operating from centralized pick-up points is another alternative and could be operated on a non-profit basis by an employee organization.

8.4 HOME ENERGY CONSERVATION

Operation of our homes accounts for the consumption of about 19 percent of our gross national energy supply and is another area which employers should stress in an employee participation program. Many of the conservation economy measures applied on the job are just as important to the employees in the operation of their homes. It is very important that an overall conservation plan developed by your company management include guidance and assistance to the employees in practicing conservation at home and elsewhere, not just on the job.

Literature and helpful checklists are available for distribution to employees to assist them in the conservation of energy and with holding down cost increases in home heating and cooling, lighting, and the purchase and use of home appliances. Such printed material is available in most areas from government agencies and from utility companies. Exhibits H, I, J and K are examples of such literature.

8.5 SUMMARY

In summary, your employees must become energy conscious. The practice of taking the unlimited availability of energy for granted must be changed to one of, "How can I accomplish this task with the minimum use of energy?" The two elements of employee participation—communication and education—must be a continuing commitment of management.

IN–HOUSE EMPLOYEE NEWS LETTERS

ENERGY CONSERVATION BEGINS AT HOME

Did you ever wonder which appliance at home uses the most electricity? The following listing gives a comparison. Would you like to know how much each one cost you last month? If so, follow these steps:

1. From your last month's electric bill, divide the total bill by the kilowatt hours used. This gives your average cost/kilowatt hour.

2. Estimate the number of hours you used an appliance last month.

3. Multiply the hours used ... (from the table), divide by 1000 and multiply th...

Example: Suppose you ... each day last month. ... your t... Kilowa... averag... $.03 :

... saving electri...

MAINTENANCE & THE ENERGY CRISIS

The picture at left shows one of the major steam leak abatement efforts of the Maintenance Department in the recent past. This leak on the top of 3051 steam drum was successfully stopped using a clamp and seacant arrangement and thus averting a total AN II shutdown.

How does this relate to energy con... Simple. Steam leaks cost money. The t... shows how much. Based on our current ... generation costs.

Monthly $s Lost Due to Steam Leak

Opening Size inches	50 psig	150 psig	450 psig
1/16	9	13	24
1/4	146	207	393
1/2	581	1338	2536
3/4	1307	3965	7518
1	2322	8604	16,304

As you can see, small leaks can be expensive over a ... In addition, le... "leak today may be a 1/2" l... month.

The Maint... control progr... Everyone will ... success of th... are first sp...

ECP LOOKS FOR HOT AIR"

Texans are known in some places for their "hot air". The Ethylene and Hydrocarbons Departments at Chocolate Bayou do their part (process-wise) to foster that personal intended ... to ... that is, tion. Millions of BTU's per ... are being discharged into ... from the stacks of the ... heaters operating ...

At left, ... Corky B... ...iamson, and ... in the she... urnace 11H1-1, ... 300 per year in ...

One of the en... the Ethylene and ... ts is to redu...

FURNACE FIRING AND ENERGY CONSERVATION

At left Roy Grantom, PT Specialist, is shown during one of a series of three 82-manhour training sessions recently completed. These sessions were designed to help meet the goals of the plant energy conservation program this year.

Even though the Ethylene Unit is a large producer of fuel gas, their demand is great. The heat requirements for the 18 of 20 furnaces on line is equal to the fuel gas needed for 83,000 three bedroom houses.

Roy's past experience in this field is very valuable when initiating ways to conserve energy and ...

ENERGY CONSERVATION UNDERWAY IN SAB

Energy conservation in the SAB unit is receiving increased emphasis. Improvements have previously been made in nitrogen amounting to $12,000 per year.

As part of the program to reduce ...gy usage even more, each shift foreman has been assigned a utility item such ...am, nitrogen, cooling tower water. ...h of these utilities, each shift is trying to find ways to improve ...mance by: (1) establishing the current usage; (2) developing a ... of continuous measurement; ...

...ggest...

ENERGY CONSERVATION IN POLLUTION ABATEMENT

Wyndal Ellis, pictured at left, is doing his part in Pollution Abatement to ...e energy by stopping steam leaks. ...ng steam leaks is just one ... efforts to conserve energy ... Pollution Abatement serv... This long-range energy ... ...ram has resulted in ... fuel gas usage ... turbines ...

ENERGY CONSERVATION PROGRAM IN FULL SWING

THE CORPORATE ADMINISTRATIVE COMMITTEE RECENTLY ANNOUNCED THE FORMATION OF THE OFFICE OF CORPORATE ENERGY PLANNING, EFFECTIVE APRIL 1, TO BE HEADED BY ROBERT E. LENZ.

THE OFFICE WILL IDENTIFY MO... ENERGY NEEDS AND METHODS TO MEET THE... IT WILL PREPARE AND MAINTAIN PLANS ... ASSURE THE COMPANY'S ENERGY REQUIRE... MENTS, BOTH SHORT- AND LONG-TERM, ... MET. AND IT WILL MONITOR AND CO... ATE ENERGY PURCHASES FOR CONSISTENC... WITH OVER-ALL CORPORATE OBJECTIVES.

IN LINE WITH THE CORPORATE CON... CERN OVER ENERGY PLANNING AND UTILI... ZATION AN ENERGY CONSERVATION PROGRAM WAS INITIATED HERE AT CHOCOLATE BAYOU DURING MARCH (MARCH 21 ISSUE OF BAYOU BRIEFS). SHOWN ABOVE, TWO MEMBERS OF THE COMMITTEE, KEN ATKINS AND BOB PAIR EXPLAIN THE CONSERVATION PROGRAM TO ETHYLENE PROCESSORS. ETHYLENE IS THE FIRST OF THE UNITS TO RECEIVE INFORMATION AND SUGGESTIONS IN CONSERVING ENERGY.

THE COMMITTEE IS CHAIRED BY W. L. BUETTNER AND CONSISTS OF THE FOLLOWING MEMBERS. ALSO SHOWN ARE THEIR AREAS OF CONCENTRATION.

L. C. PEELER AND S. Y. YERETSKY - AN
P. E. TREMONT - CED
J. R. GIBSON, R. ED GRANTOM AND J. O. NYE - ETHY. & HYDRO.
G. B. BARTLEY AND C. B. CRAWFORD - MAINTENANCE
J. B. SIEVERT - MTS., DIST., SCHED., PLT. ENG.

NATURAL GAS AND THE ENERGY CRISIS

Natural gas is another petroleum related product on a growing list affected by the world-wide energy shortage. Industrial and private users face some critical problems in the foreseeable future. No longer do business planners count on an unlimited inexpensive energy supply in their economic forecasts.

In late 1972 Rice University presented a seminar, by Henry Groppe of Mares and Groppe Consultants, that highlighted some sobering facts.

Current usages of natural gas is constituted by 1/3 home and light commerical use (hospitals and schools) and 2/3 by industry (primarily boiler fuel). Since no substitute is readily available for private use, industry can expect to bear the crunch as gas supplies dwindle. In any "shortage" situation, the Federal Government is expected to get extensively involved through the Federal Power Commission, but no one seems sure just what form this involvement will take; everything from conservation to allocation is being examined. Suggestions fall into three major categories of long-term solutions to the shortage: 1. synthetic natural gas from coal or a chemical reaction of heavy hydrocarbons; 2. liquified natural gas imported from Africa, the Middle East and Russia; 3. develop gas reserves on the Alaskan North Slope.

All three would require enormous financial, research, and equipment investment. Energy analysts indicate that ..."the substitution of low sulphur fuel oil for natural gas in boiler fuel use is the most practical and economic solution for the next few years."

In addition, natural gas users must make a major effort to conserve thi...

ETHYLENE CONSERVES ENERGY

Double pumping is one of the many ways in which energy may be wasted in a chemical plant or refinery. When two pumps are used to do a single pump job, the electricity used to run the second pump is wasted. If a situation of this type exists in your unit, it should be reported to your unit supervision for corrective action.

Pro... Jet... be ... ved in an Energy Conservation ...gram has as its main ob... this location, and will ... headed by Skip Buettner.

It's up to you to do your part in conserving energy wherever possible.

PHENOL AND THE ENERGY CRISIS

The photo at left, Maxie Hill checks alignment during a plant test to actual heating needs for acetone in Phenol II. Watching are Phenol Mike Raymer, Milt Vaughn and PT ...erry Sons. ...st showed that substitution of waste lb. steam can be made in the acetone ... of Phenol II. By combining this ... a utilities project for reducing ... turbine drives, it will be possible ... in the steam boilers by ... ...team per hour. ... Phenol plant is ... this type are ...

HAVE YOU DONE YOUR PART TOWARD THE SUCCESS OF THE E...

THE SUCCESS OF THE ENERGY CONSERVATION PROGRAM DEPENDS ON EVERYONE DOING HIS PART TO ELIMINATE WASTE. SOME THINGS TO LOOK FOR IN YOUR AREA ARE STEAM LEAKES, DEFECTIVE STEAM TRAPS, DIRTY HEAT EXCHANGERS, EXCESSIVE VENTING, AND BARE LINES NEEDING INSULATION. DO YOU KNOW THE COST OF HEAT LOSSES IN UNINSULATED LINES? HERE ARE SOME EXAMPLES: A PIPE 10' LONG, 1" IN DIAMETER WHICH IS IMPROPERLY INSULATED CAN COST THE COMPANY $1.09 PER MONTH, WHEREAS A PIPE OF THE SAME LENGTH WHICH IS 12" IN DIAMETE... TO YOUR UNIT SUPERVISION ANY PLACES IN ...IRS. WE ARE DEPENDING ON YOU TO FIND AND ...TED.

...ER AND GENE CARPENTER, UTILITIES. THEY ...URAL GAS METERING STATION. THROUGH ...ICERE EFFORTS TO CONSERVE ENERGY USAGE BY EVERYONE, IT IS BELIEVED WE ...N ACHIEVE THIS YEAR'S OBJECTIVE - REDUCE THE NATURAL GAS FLOW INTO THE PLANT THROUGH THIS METER BY 5%.

EXHIBIT A

BAYOU BRIEFS

IN-HOUSE EMPLOYEE NEWS LETTERS

Energy Systems & Maint. Work Toward Cost Cuts

How much steam does a steam leak leak, if a steam leak does leak steam?

One answer could be $8,000 per year.

Yes, believe it or not a small steam leak at two thousand pounds/hour would cause a loss of 17 MM pounds per year. Based on the figure of $0.47 per thousand pounds (direct cost only) this leak would amount to $8,000 per year.

We have more than just 600# steam lines in the plant -- for instance in the No. 3 Olefins and Ethanol 12 areas we have 1400# lines which come from No. 3 Olefins. This steam is produced at 1700# pressure and reduced to serve the needs of other units.

Just recently a flange on one of the 1400# lines began leaking at No. 3 Powerhouse. (See picture at right) It just so happened this line supplied 1000# steam to Ethanol 12. Shutting down either of these units for repair was prohibitive.

So...the Energy Systems and Maintenance Groups came up with a solution. They welded a steel band around the flange and installed a bleedoff valve. In addition, all the nuts and bolts were welded. Cost of making the ...

'rizes if you do

How Many Ride In Car Pools ?

CAR POOLS come in all shapes and sizes.

Some are all women car pools...others are all men only.. some are mixed.

The Energy Conservation group and The Forecaster are combining forces to find out how many car pools we have driving to and from Carbide every day.

We want to know: 1)how many car pools there are on each shift as well as the daily 5-day-a-week workers; 2)what is the oldest car pool in the plant?; and 3)which car pool drives the most miles to and from work?

And...in order to stimulate some response to these questions we're willing to provide some prizes. We'll have periodic drawings from the answers to our questionaires which will entitle each member of the lucky car pool to $5 worth of E... eady or Prestone ... I-MART--we'll ... balls.

... have five or ... because there ... rs on the road ... nize car pools ... And...if ... area and ... rivers who ... ven call ...

... ntest ... RIZE ... se any ...

... e days ... us ra- ... yone bonded to- ... in c... s to save gasoline, we'd like t... share with you some of the fun ... nd the dollars you can ... pool. ... ure people who ... inity

Sometimes It Is necessary to brush up on your tolerance and understanding when one of your group oversleeps, or his car won't start, or you have a flat on the way to work, but all these things add to the "fun" of being in a car pool.

Some drivers may want to economize to the degree that the air conditioning is not used in the mornings and the ladies may have to resort to wearing head scarfs... and then there are the smokers and non-smokers who have to develop tolerance for each other.

But some of the greatest advantages of car pools are the conversations about what the kids did last night, or who won the Little League ball game, or the dinner theater you've heard about but never attended but someone else in your car pool has...and yes, even the discussions on politics and religion can get very interesting without getting out of hand.

Now for the savings you can glean...figure out how much you spend alone each day driving to and from work. Be sure and calculate the wear and tear on your car and the fact that you must have two cars so the family can also have one every day. Maybe with a car pool one family car would be sufficient -- think of the savings on insurance alone!

And you can work out some kind of an arrangement whereby if a rider is not at the car by ten minutes after the whistle blows you know he or she has made other arrangements so you go on. This actually happened several years ago in a car pool ODE CARLISLE was in. He had the driver's car key and when the driver didn't show up his car pool ...

... on Page 3)

— — Car Pool Contest

(Cont'd. from Page 1)

went on without him.

So you see CAR POOLS ... be fun, save money, cut down on pollution, leave more parking spaces, and save gasoline all at the same time. And we also have a hunch car pooling might even cut down on auto accidents since there will be less traffic.

Let's see if Union Carbide-Texas City can't set some kind of a new record for car pools and at the same time you carpoole ...

... can win some nice prizes.

If you're already in a car pool, fill in this blank. You'll be eligible for the very first drawing for prizes which will be held August 16 at 11:30 in the Cafeteria. Drop blanks in Ad Boxes or mail to Forecaster Office no later than Wednesday, August 15.

If other Industries have a promotion of this kind, we'd be interested in hearing from them or working with them to establish riding pools.

Want To Join A Car Pool ?

If you want to join a car pool and don't know anyone in your immediate vicinity, fill in this blank and we'll try to group you with others in your area:

NAME ____________________

ADDRESS ____________________ PHONE ________

SHIFT ____________________ STRAIGHT DAYS ________

The Energy Crisis

by MILT WILLIAMS, Gulf Coast Fuel Coordinator

What has caused the energy crisis?

There is not one simple answer to our energy dilemna. It ... ral years ... xceeding ... now the ... ncreasing ... y rough- ... loration ... has been ... has been ... ergy. ... imposed ... ssible ... l and ... e way of ... pment. ... e con- ... er our ... fur oil, ... has not ... er new ... cilities ... w on the ...

... I become ... on for- ... This not ... ntenable ... ation but ... the se- ... tes In ... able to ... then of ... the only ...

... try is a ... y. Not ... but also ... ials. As ... raw mate- ... ral gas. ... We ... the ener- ... of three ... s, por- ... years, America has no other way to go. N...

That program not only is behind schedule b... or ther behind because of environmental roc...

... breach? Only oil. ... he worst environmental penalties of all. T... nd most chilling new increment of the pili... l. In the drive for uncompromising air puri... out of its few remaining markets hundreds c... because it contains more sulfur than orbit... n, where do industrial and power companie...

... then? Where are all those extra millions c... stillate, and residual fuels to come from? ... y must come from abroad, and costs of fore... -the-board. U. S. refiners are going to h... U.S. demand and domestic supply h... g a staggering 6 million plus barrels per day."

... the Austin and San Antonio incidents. TCR and Marathon locally have also been curtai... by Coastal. We are forced t... replace the gas with liquid fu... at costs ranging from 4 to 5 ti... as much as well as invest larg... amounts of capital to make th... change. Of course, eventua... these increases have to be fe... In the marketplace and all of ... will be paying more for certa... products; however, money al... may not solve the problem.

Energy in some markets ... replacing gold as a standard ... value. We are beginning to ... suppliers who demand some f... of energy in return for their ... ducts. Allow me to quote p... an editorial that appeared i... Oil and Gas Journal last spr... which addresses itself to our ... idly increasing dependence ...

Energy Savings Contest

How many ENERGY SAVINGS IDEAS can you think of?

The Forecaster Office and the ENERGY CONSERVATION Group will give away three prizes to Carbiders who can come up with the most ENERGY SAVING Ideas within the Texas City plant.

First prize will be an EVEREADY Outdoor/Indoor Fluorescent Light (on display in The Forecaster office -- naturally it is battery operated); second prize will be an EVEREADY Big Jim Camping Lantern; and third prize will be your choice of PRESTONE or EVEREADY Items in the Mini-Mart not to exceed $3, or a Floating Lantern.

Get your thinking caps on -- look for ways to conserve energy throughout the plant. If we have enough participation we may have a contest for "off-the-job" energy conservation.

Make out your list and drop it in the Ad Boxes at any of the gates...or in the plant mail. All entries must be legible, signed, and list an extension or home phone number.

Deadline for entering the ... Is MAY 31 at 4 p.m.

What Is Industry Doing To Conserve Energ...

by Milt Williams

The chemical and refining industries have been taking positive steps to conserve energy. At Union Carbide active energy conservation programs have been in effect for 2½ years at its twelve chemicals and plastics plants. Last year, UCC carried out 238 energy conservation projects that resulted in savings of over $6 million. These savings were sufficient to offset increases in fuel costs (costs are now increasing so rapidly, however, it is doubtful that they can be completely offset by energy conservation projects). These energy conservation projects include savings in steam, direct fuel costs, power and water.

A typical example of a fuel savings is installation of the necessary monitoring equipment to control the excess air to the boiler. An example of steam savings is reduction of excess reflux on the distillation columns. Electrical savings are achieved by operating one pump where formerly two were operating - cutting off unnecessary lights.

Water savings result from more stringent control of condensate (boiler feed water). At the Texas City plant each department head is responsible for energy conservation in his department, assisted by an engineer assigned permanently to that department. In addition, a central ...nergy conservation committee ... ised of representatives from ... ring, maintenance, shift ... and Utilities, suggests ... s for energy conservation, ... otes interest through pub- ... and semi-annual meetings ... e departments, and acts ... rdinating body for tab- ... he results of the energy ... ion program for all de-

... ears the Texas City ... fected energy can- ... ings of over $2 mil- ... within the past six months energy conservation representatives from the local Amoco, Monsanto - both Chocolate Bayou and Texas City plants, and Union Carbide plant began meeting monthly to exchange ideas and discuss common areas of energy conservation. Both Amoco and Monsanto have active energy conservation ideas of their own.

As the energy crisis continues and energy costs escalate, industry will be spending more and more capital on energy conservation. It is, and will continue to be, a vital segment of doing business, particularly in the chemicals and oil refining areas of our economy.

Energy conservation should not, however, be limited to industry. As a recent article stated, "The energy crisis belongs to us all." It behooves everyone to do his part to conserve the use of energy. We need time to develop our energy resources more fully and for other alternative sources of energy to take effect.

Well, what can we do as individual citizens?

We can limit needless and fast driving (it has been widely publicized that a savings of 20% in gasoline can result from driving 50 MPH instead of 70 MPH), keep our cars tuned, encourage car pooling, cut down on air conditioning and other electrical requirements.

We should continue to concentrate on meeting primary air quality standards - those relating to health - however, unrealistic secondary standards must be postponed until cost-effective and energy-conserving technology becomes available.

We must build sensible automobiles that are more efficient, smaller, and consequently use less gasoline (the average weight of cars today is 3500 lbs; if it were 2500 lbs, we'd save 2.1 MM bbls. of gasoline/day). Truly, we must increase the efficiency of all forms of transportation.

On the political scene we must stimulate leasing of potential oil and gas lands, particularly on the outer continental shelf. We must assure adequate crude oil supplies to encourage construction of new refineries, and we must allow the construction of refineries, deep water ports and nuclear power stations so long as they provide satisfactory environmental controls. We must expedite construction of the Trans-Alaska pipeline. We must accept the discomforts of temporary shortages.

Let me repeat, "The energy crisis belongs to us all."

I Belong To A Car Pool

NAME ____________________ EXT. ________

OTHERS IN CAR POOL ____________________

____________________ STRAIGHT DAYS ________

DRIVE FROM ____________________ SHIFT ________

HOW LONG CAR POOL FORMED ____________________

EXHIBIT B

THE FORECASTER

EMPLOYEE EDUCATION

What Is Industry Doing To Conserve Ene

by
Milt Williams

Energy Systems & Maint. Work Toward Cost Cuts

The Energy Crisis

Monsanto CED NEWS

...uels in short supply, prices are zooming out of
...gland, fuel oil by the barrel is currently costing
...es what it did a couple of years ago.
...s all boils down to is a necessity for lowering
...home and on the job - lowering heating and
...nd lowering air-conditioning usage in warm

...rgy usage, the World Headquarters site
...ll locations, and as always, CED is
...ng is going to be the energy-conservation

...Engineers know best the why of the
...nd how to do it. Others are looking
...ethods on the best ways to conserve -
...at the same time maintain comfortable
... levels.
...is busy checking and reducing
...Their objective is to obtain
... The first lighting and
...rector's area on 4-East

ENERGY CONSERVATION - Recently, you have probably noticed lower temperature levels throughout F Building, and within the past few days, lowered levels of lighting in the working areas as well as in hallways. Unless you have been completely out of touch lately, there is no need to tell you that we are experiencing an energy crunch.

Yes, Virginia, THERE IS an energy crisis. Regardless of current arguments among politicians and various shades of attention-getters - broadly featured in the news media - on whether the crisis has come about naturally or was "manufactured", and notwithstanding who was or is at fault, IT IS VERY REAL.

As you know, Monsanto, along with countless other manufacturers, needs a great deal of energy to run its plants - power plants, furnaces, motors, engines, and to provide comfort - lighting, heating, ventilation, air conditioning. Not only this, but the feedstocks we use in a great many of our processes are derived from fossil fuels - the same fuels we use to generate most of our energy.

We were brought up-to-the-minute on this by Monsanto people from all domestic locations at our Monsanto Energy Conservation Workshop, held in St. Louis last week.

- more -

Remove: January 28

EXHIBIT C

CHECKLISTS

PLEASE POST IN CONTROL ROOMS

TEN POINT CHECK LIST – ENERGY SAVINGS

1. TURN OFF UNNECESSARY LIGHTS.

2. MINIMIZE COOLING WATER FLOWS.

3. CLOSELY MONITOR PURGE GAS REQUIREMENTS.

4. MAINTAIN UTILITY METERS.

5. CHECK STEAM TRAPS. REPAIR OR REPLACE DEFECTIVE TRAPS. KEEP BY-PASS VALVES CLOSED.

6. MONITOR AND MINIMIZE REFLUX FLOWS.

7. ELIMINATE UTILITY LEAKS.

8. OPTIMIZE COMBUSTION AIR ON BOILERS AND FURNACES.

9. MINIMIZE RECYCLING IN PUMPS AND COMPRESSOR SYSTEMS.

10. MINIMIZE HEAT TRANSFER EFFICIENCIES BY KEEPING EQUIPMENT CLEAN:

    (A) MECHANICAL OR CHEMICAL CLEANING.

    (B) PERIODIC BACK FLUSHING.

    (C) MAINTAIN PROPER VELOCITIES.

EXHIBIT D

INDIVIDUAL CITIZEN ACTION CHECKLIST
FOR TRANSPORTATION

HOW TO SAVE AUTOMOBILE ENERGY

√ Reduce speed on highways when possible.

√ Drive smoothly, avoid excess braking, slow down if possible before stepping on the brakes.

√ Don't idle your engine unnecessarily.
It should not run longer than 3 minutes while you're waiting. In cold weather, drive slowly for the first quarter-mile instead of idling. Racing the engine also wastes gasoline.

√ Keep your car maintained in good condition.
Have the automobile periodically checked for repairs and upkeep, and keep the engine cleaned and properly tuned. You'll save on gasoline this way.

√ Keep your tires properly inflated.
This helps gasoline mileage. Radial tires also help conserve gasoline.

√ Encourage proper filling of your gasoline tank.
Don't let service station attendants overfill your tank so that gasoline is wasted. This is an appreciable source of air pollution.

√ Use car air conditioners wisely.
Think about how necessary it is to turn it on before you flip that switch. If possible, don't use it. When you do, set the temperature at the warmest level that is still comfortable.

√ Use low or no-lead gas, if possible.
Find out from a mechanic or your salesman if your car can use it before buying. Find out what octane rating your car needs and don't buy a higher one. Gas stations now post this rating on pumps.

EXHIBIT E

TRANSPORATION

10 EASY WAYS TO CUT YOUR TRANSPORTATION COSTS!

SEE THAT YOUR CAR'S ENGINE IS PROPERLY TUNED — check the ignition system particularly well. A poorly tuned engine can waste up to 15% gasoline.

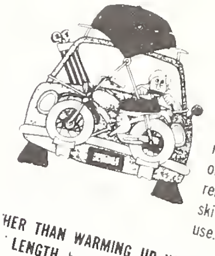
MAINTAIN AS HIGH A TIRE PRESSURE AS SPECIFIED FOR YOUR CAR. This will decrease friction and improve mileage, saving as much as 50 gallons of gas per year. Also, radial tires will cut down on gas expenditures — they pay for themselves in usage alone!

You may have heard about some mechanical alterations to improve gas consumption.

BEWARE!

They may be illegal, dangerous, and very costly in the long run. Consult your car dealer for facts.

DISCONNECT YOUR AIR-CONDITIONING OR DON'T BUY A CAR WITH FACTORY AIR. (Make sure your car has outside air vents). This step will give you a 10% or better mileage increase.



KEEP YOUR CAR'S WEIGHT TO A MINIMUM. Routinely carrying around chains, sandbags, outboard engines, sports equipment, etc. cuts down on gas mileage. Also, remove luggage and ski racks when not in use.

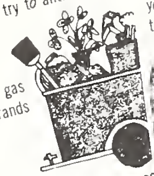
...HER THAN WARMING UP YOUR ENGINE BY IDLING ... LENGTH, begin driving immediately at slow speed.

... have a standard shift, **SAVE GAS BY GETTING ...H GEAR AS SOON AS POSSIBLE.** In second, ...se 25% more gas than in third at the same

DON'T RIDE THE BRAKE!

Even light pressure makes your engine work harder and wastes gasoline in addition to causing extra wear and tear. Use your brake pedal, not your accelerator, to "hold" your car steady on a steep hill.

ERRATIC DRIVING HABITS ARE VERY EXPENSIVE. Steady is the word — accelerate slowly; try to anticipate slow downs and stops.



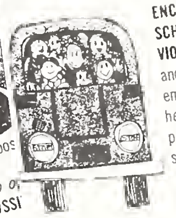
PLAN AHEAD — cut down on gas by combining necessary errands into one trip.

TRAVEL DURING OFF-PEAK TRAFFIC TIMES — use routes with as few traffic lights and stop signs as pos...

Even a small car costs at least 8¢ a mile to o... so **IT MAKES SENSE TO DRIVE AS LITTLE AS POSSI...** use public transportation and participate in ca... whenever you can.

GASOLINE IS POISONOUS!

Don't ever try to siphon gas unless you know what you're doing — even the cheapest hospital bill is likely to be worth more than 50 gallons of gas!



ENCOURAGE YOUR CHURCH AND SCHOOL AUTHORITIES TO PROVIDE BUSES for religious, athletic, and social events. Talk to your employer about the possibility of helping to organize car pools or provide buses through incentive systems.

ENCOURAGE YOUR CHILDREN TO WALK OR RIDE A BICYCLE WHENEVER POSSIBLE — try setting an example! Make ... that children know traffic rules. Encourage sc... help in this. Also, ask your school ... use of parking space ...

NEVER CARRY EXTRA GAS IN YOUR CAR

unless you expect an urgent need for it — and then carry it only in approved cans, strapped securely to the outside of the car. Otherwise you may be sitting inside a fire bomb.

Environment Center
Institute for Public Service
The University of Tennessee
Knoxville, Tennessee 37916

This program is partially financed by a federal grant under Program IMPACT of the Higher Education Act of 1965, Title I Community Service and Continuing Education.

EXHIBIT F

CAR POOLS

JAMES E. HOLSHOUSER JR
GOVERNOR
WILLIAM L. BONOURANT
SECRETARY

STATE OF NORTH CAROLINA
DEPARTMENT OF ADMINISTRATION
RALEIGH 27603

Carpool Matching Program
General Information

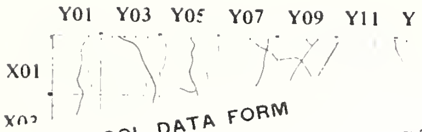
A computerized carpool matching program has been obtained from Federal Highway Administration. This program will match names addresses of employees living in the same area of metropolitan igh who express interest in belonging to a daily carpool. Usinc attached grid map of the county and the Carpool Data Form, yees will code their residence location and enter other required mation about working hours, telephone number, etc. These Carpool orms should be returned to departmental personnel offices by sted employees by January 4, 1974 if possible.

week of January 14, 1974, a computer listing of employees n the same grid location will be furnished by the State to loyee who sent in the completed Data Form. When the computer are received, employees can then contact one another about o a carpool.

arpools are established, reports will be requested of rators so that carpool parking privileges can be extended.

ent you are unable to find your grid location on the rnished with this packet, please see the large maps posted tmental personnel office or on the principle bulletin building.

any questions about the program, please contact your rsonnel office.



CARPOOL DATA FORM

INSTRUCTIONS IF YOU ARE INTERESTED IN PARTICIPATING IN A CARPOOL, PLEASE COMPLETE ALL QUESTIONS AND RETURN ONLY THIS PAGE BY DECEMBER 21 THROUGH INTEROFFICE MAIL TO YOUR DEPARTMENTAL PERSONNEL OFFICER.

3 — 11 SOCIAL SECURITY NUMBER

NAME: 12 (LAST) 25 (FIRST) 35 MI

ADDRESS: 36 (NUMBER) 42 (STREET NAME) 58

59 (CITY) 73 STATE 74 76 (ZIP) 80

12 X Y 14 HOME GRID NUMBER (See Map) — PLEASE LOCATE YOUR RESIDENCE CAREFULLY ON THE ATTACHED MAP AND PLACE THE GRID NUMBERS HERE.

16 X Y 18 WORK GRID NUMBER (See Map) — PLEASE LOCATE YOUR WORK LOCATION CAREFULLY ON THE ATTACHED MAP AND PLACE THE GRID NUMBERS HERE.

20 : 24 AM PM (CHECK ONE) REPORTING TIME (TO WORK)

25 : 29 AM PM (CHECK ONE) DEPARTURE TIME (FROM WORK)

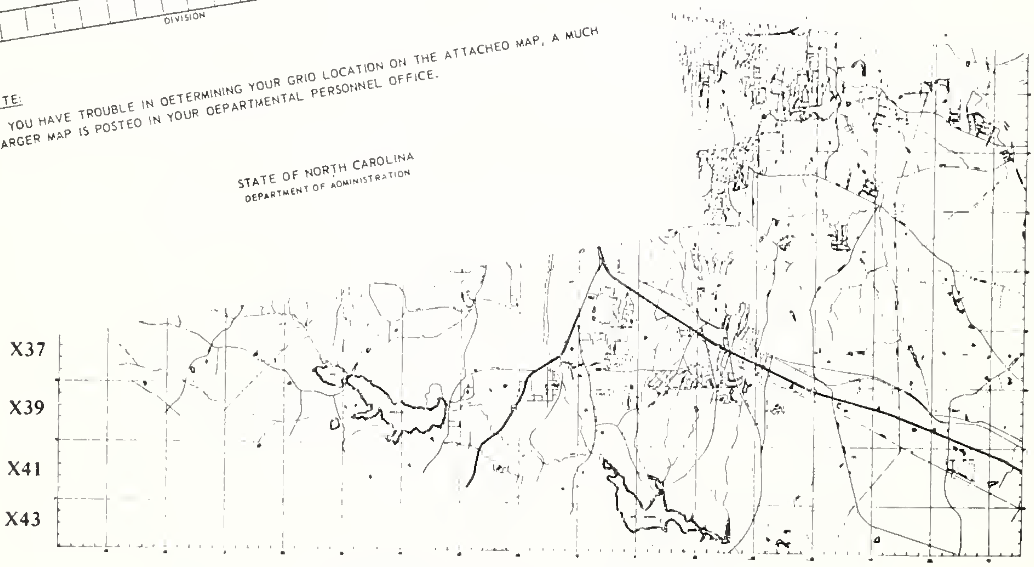
31 BUSINESS TELEPHONE NUMBER

40 DEPARTMENT 55

57 DIVISION 72

NOTE:
IF YOU HAVE TROUBLE IN DETERMINING YOUR GRID LOCATION ON THE ATTACHED MAP, A MUCH LARGER MAP IS POSTED IN YOUR DEPARTMENTAL PERSONNEL OFFICE.

STATE OF NORTH CAROLINA
DEPARTMENT OF ADMINISTRATION



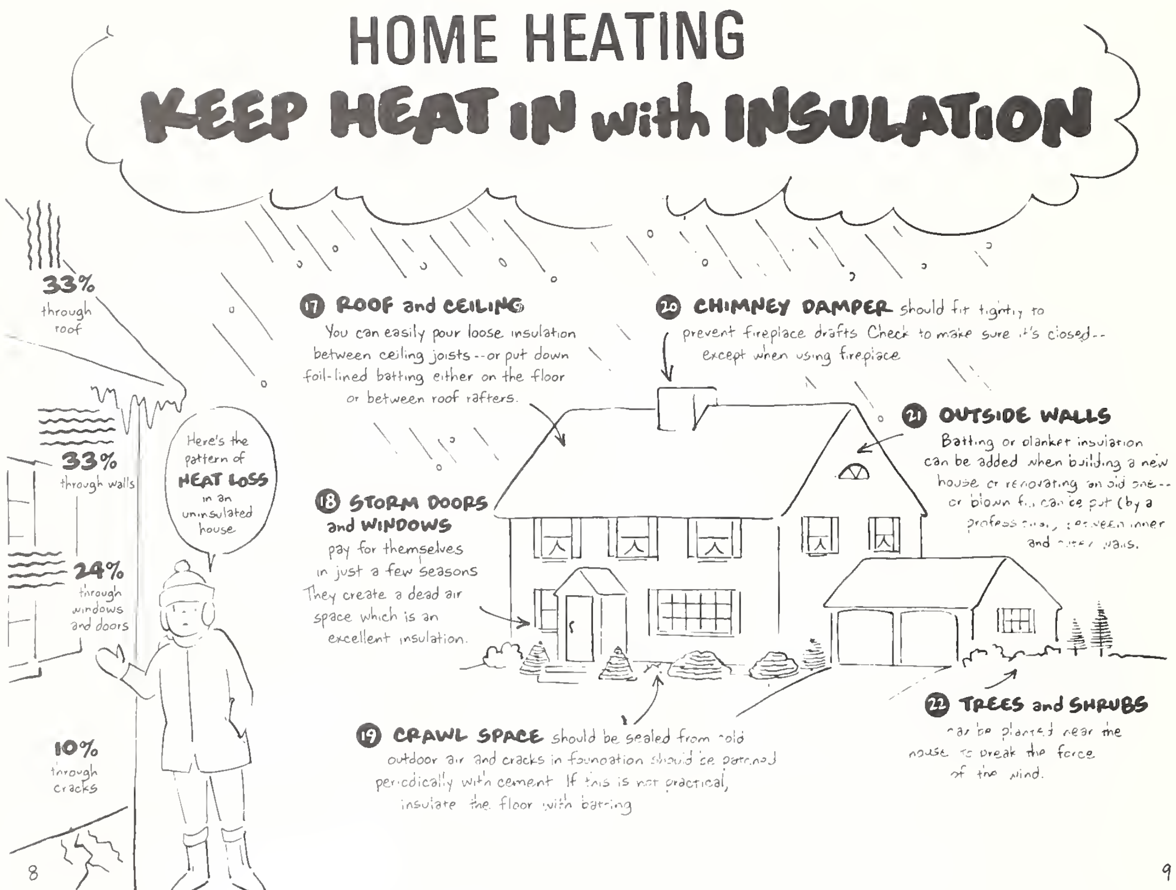
EXAMPLE: — — — — IF YOUR RESIDENCE IS LOCATED IN THE SHADED GRID ABOVE, YOUR GRID LOCATION WOULD BE X23, Y23.

N

EXHIBIT G

CONSERVATION

EXHIBIT H



HOME HEATING
KEEP HEAT IN with INSULATION
33% through roof
33% through walls
24% through windows and doors
10% through cracks
Here's the pattern of HEAT LOSS in an uninsulated house
17 ROOF and CEILING You can easily pour loose insulation between ceiling joists--or put down foil-lined batting either on the floor or between roof rafters.
18 STORM DOORS and WINDOWS pay for themselves in just a few seasons They create a dead air space which is an excellent insulation.
19 CRAWL SPACE should be sealed from cold outdoor air and cracks in foundation should be patched periodically with cement If this is not practical, insulate the floor with batting
20 CHIMNEY DAMPER should fit tightly to prevent fireplace drafts Check to make sure it's closed-- except when using fireplace
21 OUTSIDE WALLS Batting or blanket insulation can be added when building a new house or renovating an old one-- or blown fill can be put (by a professional) between inner and outer walls.
22 TREES and SHRUBS can be planted near the house to break the force of the wind.
8
9

Wouldn't you like to CUT the COST of HEATING YOUR HOME
FUEL BILL
$$$$
SURE-- but what kind of FUEL are you talking about ?
Any kind !
Whether you use coal electricity gas oil or even wood
Some of the tips in this booklet can help you make your fuel bills smaller.
Man is naturally a WARM animal-- usually warmer than the air around him-- So he loses heat.
But if he loses too much, he gets UNCOMFORTABLE
To balance things off, man has invented modern, efficient, convenient HOME HEATING SYSTEMS but still often ends up spending more than he should (i e, BURNING MONEY) to keep WARM.

EXHIBIT I

HOME ENERGY SAVINGS

FLUORESCENT LIGHTING IS CHEAPER THAN INCANDESCENT LIGHTING. A 60-watt fluorescent light bulb gives you as much as a 180-watt incandescent bulb — at 1/3 the cost.

KEEP OUTDOOR ILLUMINATION TO AN ABSOLUTE MINIMUM. Outdoor gas lights are particularly expensive; one may cost you up to $50 or more per year. Four electric spotlights can cost you more than $60 per year at present lowest rates.

A BLACK AND WHITE TELEVISION SET USES ONE HALF TO ONE QUARTER THE ENERGY OF COLOR TV when comparing same picture tube sizes. Remember this if you have a choice in your household, and consider it strongly next time you buy. If your present television set has an "instant on-off" feature, unplug the TV when not in use — it will save you more than $20 a year. **IN ADDITION, SOLID STATE DEVICES CONSUME MUCH LESS ENERGY** than tube type devices.

WHEN BUYING A NEW APPLIANCE INQUIRE CAREFULLY ABOUT ITS EFFICIENCY RATING. Running costs of most appliances are much higher over their lifetimes than the purchasing prices. Extra features, like "frost free" or automatic ice makers, really eat money.

Of course, there is no single setting where one could realize all savings indicated above. But proper actions 'an effect some 25 to 35% reduction in usage costs

Environment Center
Institute for Public Service
The University of Tennessee
Knoxville, Tennessee 37916

m is partially financed by a fede- ... 'rogram IMP/
ation Act of 1965, Title ' ... ' Continuing

HOW YOU COULD MAKE IT CHEAPER AND BETTER THROUGH THE WINTER! 455

EVERY DEGREE

YOU LOWER YOUR THERMOSTAT SAVES YOU 3 CENTS ON EVERY DOLLAR OF YOUR HEATING BILL. If you change your thermostat setting from 75 to 68 degrees, you save 21¢ on the dollar! During the night, set your thermostat even lower than 68 degrees. When you are out for more than a few hours set the thermostat to 55 or 60 degrees, when you leave for some days, try a 50 degree setting . . . Dress warmly, even during the night. Dark-colored clothes are better than light-colored ones. Try several layers of light-weight clothing rather than one thick layer.

CLOSE ALL DOORS AND SHUT OFF ALL HEAT IN UNOCCUPIED ROOMS. Don't forget to seal off registers in these rooms. **DON'T BLOCK HEATING VENTS WHICH ARE IN USE** with rugs, furniture or anything — dogs and cats included! Keep clutter and coverings off radiators and registers. Keep them clean — dirt can reduce transfer of heat to the room air.

KEEP YOUR DRAPERIES CLOSED, except when the sun is shining directly through your windows. Make sure your draperies are betwee ... The more windows you hav ... becomes ... Savings: up to 10

SE ... -RATOR AT ABOU
THE FREEZER AT ZERO TO 5 DEGRI
tures waste power.

DO NOT DELIBERATELY USE ANY OF YOUR APPLIANCES AS ROOM HEATING DEVICES. This is usually a very expensive way to keep warm.

MAKE SURE HOT WATER FAUCETS DO NOT DRIP AND THAT THERE IS NO LEAK ANYWHERE IN YOUR HOT WATER PLUMBING. A steady drip can cost you up to $80 per year. Also, metal valve seats erode much faster when dripping.

OPEN YOUR FRIDI ... LY YOUR FREEZE ... REALLY HAVE TO, ... IT QUICKLY. MAKE ... TOR AND FREEZER D ... TIGHT. If a dollar bil ... ly when door is close ... may be needed.

AVOID EXCESSIVE HOT WATER TEMPERATURES. For instance: washers need hotter water than showers. Set the thermostat of your water heater so that the water is only slightly warmer than need be.

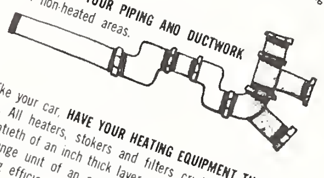
KEEP YOUR FREEZER FULL — even if you stack it with milk cartons full of water. Don't pack too tightly! For efficient freezing, air must circulate.

... YOUR DISHWASHER ONLY WHEN FULLY LOADED. ALSO RUN YOUR AUTOMATIC WASHER AND DRYER ONLY WITH FULL LOADS. KEEP LINT FILTERS CLEAN!

MAKE SURE DRYING TIME IS SET AT NO MORE THAN ABSOLUTELY NECESSARY. Next to your range, the clothes dryer has the highest energy consumption of all appliances. Try drying clothes outside for a change!

CHECK THE INSULATION ABOVE YOUR CEILINGS. You can be losing 25¢ on every dollar of your heating bill because of loosely packed and insufficient insulation. Check that all ceiling insulation is tightly packed and approximately 6 inches thick. In addition, make sure that any attic steps, doors and windows are tightly sealed — try masking tape

INSULATE YOUR PIPING AND DUCTWORK in non-heated areas.



Like your car, **HAVE YOUR HEATING EQUIPMENT TUNED UP.** All heaters, stokers and filters crud up. A one-twentieth of an inch thick layer of soot on the heating exchange unit of an average oil furnace reduces the heating efficiency by 50%.

If you smell gas, call your supplier immediately.

CHECK YOUR OIL TANKS FOR LEAKS. Also, if your tanks are more than 15 years old have them pressure-tested.

Of course, there is no single setting where one could realize all savings indicated above. But proper actions can effect some 25 to 35% reduction in heating costs.

Environment Center
Institute for Public Service
The University of Tennessee
Knoxville, Tennessee 37916

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EXHIBIT J

HOME ENERGY SAVINGS

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EXHIBIT K

Section 9

ENERGY FLOW MEASUREMENTS

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9. ENERGY FLOW MEASUREMENTS

9.1 INTRODUCTION

9.1.1 WHY ENERGY MEASUREMENT

An energy accounting system is essential for control and evaluation of an energy conservation program. The basis of this accounting system will be the determination of the rates of use of energy in the major applications in the plant. Careful consideration should be given to the need for measuring the flow of fuels, process steam, cooling water, condensate, waste liquids, hot air, process fluids, electricity, and all energy-bearing media throughout the plant.

Depending on the number of different applications for using energy and the potential for variation in each application, the need for making measurements may be much different in one plant than in another or even within a single facility. In some small businesses the normal billings for fuels and electrical energy may provide an adequate basis for evaluating and controlling energy use. In many cases periodic or irregular fuel deliveries or meter readings will not provide adequate information to determine the variation of energy use with daily, weekly, or monthly production cycles or with seasonal climate changes. In other cases energy in the form of fuels, electricity, and process steam will be used in two or three or even many different major applications throughout the plant. If the existing delivery networks do not provide for measurement of the rates at which different forms of energy are used at each of the major applications, there may be no way to determine the relative effectiveness of those applications or to evaluate the success of efforts to improve effectiveness.

In some energy applications, such as in combustion processes, measurement and/or control at each point of application may be necessary to ensure efficient use of energy. Effective measuring methods are thus necessary to control, to evaluate, and to manage efforts to conserve energy.

The selection of appropriate energy measurement equipment and the effective use of that equipment are thus important to an energy conservation program and should be addressed early in the development of the program. Measurement equipment can be relatively expensive and if it is not used correctly or adequately maintained, measurement accuracy may badly deteriorate. For example, pressure drops, induced through flow throttling for measurement purposes, can result in a direct energy loss which should be considered.

As a starting point, all fuels, electricity, steam, hot water, hot air, hot fluid, and all other energy containing media used in the plant should be identified and a rough, diagrammatic flow-network sketched for each. These flow networks should show the source and the major points of energy utilization or energy loss for each such media. In many cases the networks will require only a few moments to prepare and can be done from memory. In a complex plant with many points of major energy use the flow networks may require several man-days of engineering effort including plant surveys.

Block diagrams can be used in the flow networks to represent individual applications for which there is potential for energy conservation and for which energy measurement should be provided to evaluate energy savings efforts. Machines such as pumps, blowers, a heat treating furnace, or any unit process are all candidates for representation in an energy network diagram.

The initial definition of the energy flow networks is important because an overly cautious approach will aggregate too many separate applications and overlook needs for evaluation of energy use. An overly ambitious approach may suggest measurement instrumentation which will not be justified. A recommended approach is to show all separately identifiable uses of energy on the flow networks but to carefully study the networks to select those optimum points at which capability for energy measurement should be provided.

One of the steps of the study is to estimate the rate of energy use at each point of use in each flow network including variations due to the production cycle, the day, the week, and the season. Familiarity with the local plant operation will provide a variety of information for these estimates.

This study will form the background for identifying the need to make specific energy rate determinations. Rates of energy cannot be measured directly but must be calculated from measurements of pressure, voltage, temperature, gas composition, or other specific physical properties.

There are, therefore, three important steps in getting to the point where specific measurement equipment can be selected:

1. Sketch the energy flow networks and identify where the energy flows need to be evaluated.

2. Determine what physical properties can be measured to provide the evaluation.

3. Select equipment to measure those properties.

Information on measurement equipment and instrumentation may be found in the references noted in Section 10.

9.1.2 EQUIPMENT SELECTION

The equipment to be selected will include not only the basic measuring device but the instrumentation for direct or remote indication of the measurement. The direct measuring device (sensor) converts some physical property of the flow being evaluated into a pressure, a voltage, or some other output which can be applied to a secondary device. For example: a thermocouple converts temperature to voltage which can be applied to a voltmeter specially adapted for that purpose; an orifice plate converts fluid flow velocity into a pressure differential which can be applied to a pressure gauge (or manometer).

There are a limited number of basic measuring mechanisms which account for the measurements needed in connection with energy conservation. The more common of these are discussed from an introductory point of view later in this section. New developments in basic measurement technology do occur from time to time; for example, remote measurement of surface temperatures from infra-red radiation and recent developments in gas composition measurements. Most of the measurements for energy flow evaluation will continue to be based on established and less expensive methods.

There are commercially available an almost unlimited variety of secondary devices for transmission, display and recording of measurement data. For that reason, no attempt is made here to describe these different secondary devices. An instrumentation applications engineer representing any of the several instrument companies can be of help. The usual procedure of obtaining a few competitive recommendations will narrow the possibilities down to where a selection can be made.

The following general suggestions may be useful in organizing the process of selecting measuring systems.

1. Decide how the results of each energy flow evaluation are to be used, how they will be analyzed, interpreted, and presented, and what course of action may depend on the analysis.
2. Determine the physical measurements which can be most appropriately made as a basis for calculating each energy flow rate which is required.
3. Tentatively select general types of primary measuring devices which could be used.
4. Contact several manufacturers or their local and district representatives to get specific recommendations on devices for your needs. Usually these representatives will be glad to discuss your fundamental energy evaluation problem and make recommendations on physical measurements most suitable as well as the specific measuring equipment.
5. Obtain recommendations in sufficient detail from several suppliers so that costs, maintenance procedures, operating procedures, equipment size, measuring accuracy, and training required for plant personnel are clearly understood.
6. The final selection should include consideration of the following:
   a. Resistance of the measuring device and associated instrumentation to weather, temperature changes, corrosion or abrasion from fluids flowing through the device or from materials spilled or sprayed onto it, vibrations and impact from the operation of process equipment including lift trucks. Compare with conditions in which it is to be used.
   b. Ease of installation and removal of the instrument including whether a process must be shut down.
   c. The accuracy of the device compared to alternatives.
   d. The space required for the measuring device and associated instrumentation and the space available.
   e. The energy required by operation of the measuring device itself; for example, head (pressure) loss due to a fluid meter in a flow system.
   f. All economic factors for the measuring device and the necessary associated instrumentation such as initial cost, installation cost, operator training costs, operating costs, maintenance costs, costs of supplies.
   g. The range of values which can be measured as compared to competitive equipment and as compared to the present and anticipated measuring needs including peak values.
   h. The form in which the data need to be presented to be most useful and whether they should be presented at the point of measurement or remotely. This will be

the basis for selecting secondary devices such as dials or recorders.

i. The nature of the property to be measured, whether steady with only slowly changing magnitude, pulsating, or intermittent (batch).

j The possibility of using measuring devices already within the plant or of using portable measuring devices for two or more applications. This may require moving an existing meter or scheduling the use of portable equipment.

9.2 TEMPERATURE MEASUREMENT

9.2.1 LIQUID-IN-GLASS THERMOMETER

Applications: Very versatile for direct readings because of small size and low cost. Can be used as a probe into a fluid stream.

Useful Range:
Alcohol filled: —125 F to +300 F
Mercury filled: —40 F to +950 F

Principle of Operation: Many liquids display a significant change in volume when heated. A liquid-in-glass thermometer consists of a bulb which holds a quantity of a liquid. This bulb is connected to a stem with a bore approximately equal to the diameter of a human hair. As the bulb is heated, the contained liquid expands into the stem bore. The height of the column of liquid, by accurate calibration, indicates the temperature.

Considerations: A wide range of prices ($1 to $60) and a wide range of accuracies (±5 F to ±0.01 F) are available. Better accuracies are usually accompanied by higher prices. Bore glass thermometers have good response but are fragile. The calibration of better thermometers can be traced to the National Bureau of Standards. Some industrial units have a protective housing and a metal clad sensitive bulb which lengthens the response time. This economical means of measurement is relatively small and very portable. Use is generally limited to on-the-spot readings.

9.2.2 LIQUID FILLED DIAL THERMOMETERS

Applications: One of the most versatile, economical and widely used thermometers. Response time may be a factor. Can be screwed into female pipe threads to be permanently mounted.

Useful Range:
Alcohol filled: —125 F to +300 F
Mercury filled: —40 F to +950 F

Principle of Operation: The principle that some liquids expand when heated is utilized in this type of thermometer just as with liquid-in-glass thermometers. The bulb containing the expanding liquid is metal and larger (i.e., ½ inch diameter x 3 inches long) than glass thermometers. The bulb is connected to a flexible metal tube (capillary) with small bore. The capillary in turn connects to a bourdon tube which is mechanically linked to a pointer. As the temperature at the bulb increases, the filling liquid expands, increasing the pressure in the system. The pressure is transmitted through the capillary to the bourdon tube which tends to uncoil. The resulting mechanical motion is translated to pointer movement which can be calibrated to specific temperatures.

Precautions: The liquid filled thermal systems have bulb configurations which differ for air and water temperature measurements. Improved response for air measurement is achieved by constructing a long and narrow bulb (¼ inch diameter x 5 feet long). The length of the flexible capillary which connects the bulb and dial indicator should not be installed near steam pipes or other high heat sources unless proper temperature compensation is provided in the capillary. The length of this capillary is limited to approximately 100 feet.

9.2.3 BI-METALLIC THERMOMETER

Applications: Direct measurements of gas and liquid temperatures. Output is mechanical signal with a fairly slow response time.

Useful Range: —40 F to +800 F (invar and austenitic alloy)

Principle of Operation: For a given change in temperature, various metals each expand a different amount. If a thin strip of a metal with a high rate of expansion is bonded to a similar strip of metal with a low rate of expansion, a bi-metallic element is formed. With one end of the element firmly anchored, the loose end will deflect as the strip is heated. A bi-metallic element can be formed as a coil, which when heated tends to uncoil. A pointer attached to the coil and a properly calibrated scale provide the basis of a bi-metallic thermometer.

Considerations: The accuracy of these economically priced thermometers ($8 to $50) is 1 to 2 percent of full scale at best. For best accuracy, use as narrow a temperature range as possible for the application. Larger indicating dials improve only the readibility and do not improve accuracy. Because of the bimetallic construction it is important to avoid corrosive environments which easily damage this sensor. Response times vary with application: 3-4 seconds for stirred liquids; 4-5 minues for still air. These thermometers are normally mounted on equipment for on-the-spot readings; however, they are small enough to be hand-carried for insertion into air ducts, open tanks, etc.

9.2.4 CRAYON, LIQUID, AND PELLET TEMPERATURE INDICATORS

Applications: These materials can be applied to hot surfaces and show a change in appearance when a given temperature is reached. They are a "quick and dirty" way of finding the temperature of a surface which may be very large or inconvenient to measure any other way.
Useful Range: 125 F to 1600 F

Principle of Operation: Constant melting point compounds are available in the form of crayons, pellets and liquid suspensions. These indicators cover a wide range of temperatures and are particularly useful for determining within close limits the temperatures of heated bodies to which the compounds are applied. Forty-seven temperatures are available in the range 125 F to 1600 F. The mark made by an indicator changes appearance when the indicated temperature is reached.

Considerations: The application of the crayon, liquid suspension, or pellet does leave a mark which can normally be cleaned with a solvent from steel, etc. The change in appearance may in some cases be rather subtle so that close observation of the spot may be necessary. The spot can be used only once since the appearance of the spot is permanently changed after melting.

9.2.5 RESISTANCE TEMPERATURE DETECTOR (RTD)

Applications: The resistance thermometer is used as a long, narrow probe and is most useful for accurate measurements of gas or liquid temperatures.
Useful Range: −300 F to +1100 F

Principle of Operation: Almost all pure metals undergo a change in resistance which is proportional to the temperature change. Platinum is the most commonly used metal for sensing elements in a resistance temperature detector (RTD); however, copper and nickel are also used. The nominal change in resistance for a 100-ohm platinum RTD is about 0.2 ohms per degree Fahrenheit.

Considerations: Sensors with an accuracy of ±½ percent of temperature being measured are standard. Closer accuracy (±0.02 F) can be obtained with individual calibration of high quality instruments. Long term stability can be excellent also and this instrument is used to define the International Temperature Scale from −300 F to +1100 F. Sensitivity and response time is improved by using a fine wire element. The resistance of the thermometer element is normally determined with a Wheatstone bridge which permits the unknown resistance to be compared to that of a known resistor and a slide wire variable resistor. The resistance of the wire that connects the thermometer to the detecting instrument is important, particularly if more than one sensor is being monitored. Three wire elements provide an external lead wire that, when properly wired into the Wheatstone bridge measuring circuit, automatically compensates for resistance changes in the connecting circuit.

9.2.6 THERMOCOUPLES

Applications: Excellent for surface, gas, and liquid temperature measurements. Wires can be welded on surfaces to measure "average" temperatures. Extremely versatile.

Useful Range:
Type J Iron—Constantan: 0 F to +1400 F
Type T Copper—Constantan: −75 F to +70 F
Type K Chromel—Alumel: 0 F to +2300 F

Other metal pairs are available for higher temperatures.

Principle of Operation: A thermocouple consists of a pair of dissimilar conductors welded or fused together at one end to form the "hot" or measuring junction with the other ends forming the "cold" or reference junction. For this device to function as a thermocouple, there must be a temperature difference between the "hot" and reference junctions. A small voltage is generated at each junction. If the temperature at the "cold" or reference junction is held constant, the measured voltage will be proportional to the temperature at the "hot" junction. Tables are available that list the millivolt output of various types of thermocouples over their useful temperature range. The most common tables use 32 F as the reference temperature; however, tables for other reference temperatures are available.

Considerations: The small voltage generated by a thermocouple must be read by a millivoltmeter or potentiometric indicator or recorder. Direct reading digital indicators are available at moderate cost ($200 to $700). Most measuring devices have built-in "cold" junction compensation which eliminates the need for an external cold junction. Readout units may be located several hundred feet from the thermocouple sensor. Several thermocouples may be read by a single indicator if proper switching is used. The principle of operation should be kept in mind when utilizing thermocouples and care must be taken that no spurious electrical field affects the wires and that the thermocouple bead temperature is not affected by heat flow to or from the wires or surrounding structure. Also, the connecting wires to the pyrometer should be of similar composition, or as the manufacturer specifies, to avoid secondary unwanted voltages. Accuracies of ±2 F to ±4 F are common. Response time and sensitivity of the thermocouple junction are a function of the thermal mass. Bare wire junctions have a very fast response time but are susceptible to mechanical damage, corrosion, and oxidation. Metal clad thermocouple assemblies are more rugged. Grounded assemblies have the thermocouple junction welded or brazed to the tip, which provides faster response. All thermocouples should be calibrated from time to time since chemical or alloying changes can affect their accuracy.

9.2.7 OPTICAL PYROMETERS

Applications: Visual temperature measurement by determining radiation temperatures of hot bodies, such as interiors of furnaces, permits rapid temperature surveys of reactors, furnaces or hot bodies without touching. Temperatures are generally recorded and measured manually.

Useful Range: 1000 F to 5000 F.

Principle of Operation: Optical color pyrometers are used as calibrated comparators. The operator matches the color intensities of the radiation of a hot body to that of a radiating source in the pyrometer. In one type, the operator can vary color temperature of a tungsten lamp filament to match the source; in the other type the incoming radiation color intensity from the body is varied by use of a calibrated optical wedge. Since the pyrometer is calibrated to read equivalent black body radiation from the source, corrections must be made for emissivity from the radiating source.

Considerations: Optical pyrometers are simple to use, requiring no fixtures or wiring and the instrument is portable. However, calibration is very important and must be done carefully and frequently. With ideal conditions for reading the temperature of a black body, accuracies should be ±20 F at 2000 F. However, to achieve black body conditions the operator must observe the inside of a deep cavity which has interior walls of a uniform temperature. The radiation of this "black body radiator" is also affected by any absorbing material in its path such as smoke or glass. Correction factors for absorbance of glass and emissivity are available.

9.2.8 TOTAL RADIATION PYROMETERS

Applications: These optical type pyrometers permit visual measurement of surface temperatures. Both portable and more accurate fixed-in-place instruments can be used. Accurate measurement is assured under black body radiation conditions.

Useful Range: 300 F to 5000 F or higher.

Principle of Operation: All total radiation pyrometers operate on the principle of focusing or concentrating radiant energy of all wave lengths upon a sensitive actuating element, causing a small voltage to be developed therein which is subsequenlty measured. This actuating element is usually a small, sensitive thermocouple appropriately shielded, or in some cases a thermopile. These instruments differ from optical color pyrometers in that a combination of the intensities of light and heat radiation is utilized, rather than the intensity of an approximately single wave length of visible radiation.

Considerations: The pyrometer is pointed at the source of radiation and, after a few seconds time to allow the thermocouple to reach equilibrium, the temperature may be read directly from the measuring instrument. The reading is independent of distance from the source in a high quality instrument if little energy is absorbed by the atmosphere between the source and the instrument. Similar considerations to those mentioned for optical (color) pyrometers are important such as absorbance of smoke or glass or non-black body conditions. In the total radiation pyrometer it is imperative that all optical parts be kept scrupulously clean and that the instrument be calibrated frequently utilizing a standard black body source. These instruments are sensitive to excessive radiation and can be damaged if used improperly.

9.3 FLUID FLOW MEASUREMENT

9.3.1 ROTAMETERS

Application:

Liquids (0 to 20 gal/h smallest sizes), (0 to 400 gal/h largest sizes)

Gases (0 to 2 cu ft/h smallest sizes), (0 to 1800 cu ft/h largest sizes)

Principle of Operation: Fluid flows upward through a tapered vertical tube, usually of circular cross section, which is positioned with its smallest end down, and encloses a weight with a diameter equal to that of the bottom end of the tube. The weight has grooves or vanes which cause it to rotate as fluid flows upward through the tube. This weight or "float" is lifted by the velocity forces (momentum) of the flowing fluid to the point in the tube where these forces just balance the weight of the float. As the flow rate increases the flow rate which will just support the float occurs at larger tube diameters higher in the tube. A calibrated scale converts float position to flow rate. The pressure drop through a rotameter is small and nearly constant regardless of flow rate.

Considerations: They are simple, easy to read and operate. Their accuracy may be as good as ±¼ percent or as poor as ±10 percent of full scale reading. Rotameters have a linear or near-linear scale with a 10 to 1 ratio of measurement range. That is, if the maximum measureable flow is 30 gallons/minute, the minimum accurate flow measurement would be 3 gallons/minute. Rotameters are calibrated to specific fluid conditions (i.e., density and viscosity at operating conditions of temperature and pressure).

Rotameters used on liquids are most sensitive to viscosity changes and gas rotameters are most sensitive to pressure and temperature changes. Float designs can be altered to minimize but not eliminate these effects. All rotameters must be mounted vertically. Glass tube rotameters give visible evidence of proper operation, but are limited to installations where the line pressure is 150 psi or less, depending on tubing size. Metal tube units that utilize a magnetic coupled indicator operate at pressures of 700 to 800 psi. Magnetic coupled recorders or transmitter units are also available. Rotameters can be mounted in parallel to extend the maximum useful range.

Since glass is breakable caution should be exercised in the use of glass rotameters for flammable, corrosive or toxic materials.

Rotameters, although relatively inexpensive, are quite large compared to other flow measuring devices and therefore are not suitable for portable use.

9.3.2 DIFFERENTIAL PRESSURE DEVICES

A. Orifice Plate, Flow Nozzle, Venturi Tube

Application: These devices are applicable to line sizes from ½ inch to 60 inches and for water, steam, air, oil, gas and chemicals. They can be used not only for liquids and gas but also for liquid slurries and liquid-gas combinations. There are many different types each with advantages for certain applications.

Principle of Operation: All of these differential pressure devices are installed to constrict the flow which increases the velocity and reduces the pressure of the fluid while it is passing through the constriction. The difference in pressure between the normal static line pressure and the reduced pressure is related to flow rate through fundamental laws of fluid flow. This relation always includes a coefficient which is usually based on extensive laboratory calibration made by the manufacturer on geometrically similar devices with the fluid flowing in a "standard" condition as it enters the device. This standard condition requires a specified length of straight pipe (often 10 pipe diameters) preceding the device which must also be provided or simulated in the field application.

Considerations: The *orifice plate* is by far the most popular flow element due to ease of manufacture, simplicity of design, and low cost (typically $50.00 for a 3 inch size). It can be mounted in the wall or bottom of a tank or perpendicular to the flow in a pipe. Properly designed and installed, an orifice plate exhibits good accuracy (±1 percent); however, as the usable flow range is raised or lowered accuracy is sacrificed. An orifice plate has a sharp upstream edge. A slight rounding can introduce a 2 to 10 percent error from the original calibration at maximum meter capacity.

There are a number of pressure tap locations used with orifice plates; the three most common are flange taps, vena contracta, and pipe taps. The most commonly used are flange taps located 1 inch upstream and downstream from the orifice plate. Taps at these locations are less sensitive to fluids which may have varying viscosity. Orifices are slightly less accurate (1 to 2 percent) than a venturi and not quite as sensitive to small changes in flow. Cavitation is a possibility at high flow rates. The main disadvantage is a relatively high head loss.

Orifices can be used to measure compressible gas flow with corrections to the equations for compressibility effects. Orifice meters are commonly used for steam flow for which a drain hole should be located at the bottom of the meter to drain off collected moisture (this is also the case for air lines). For liquid measurement a relief hole should be provided at the top of the meter section to release any trapped air. Orifice meters are simple to install, have small space requirement, lower initial cost than a venturi or nozzle, and should receive strong consideration in any program of flow measurement.

The *flow nozzle* has a rounded approach which has a curvature equivalent to the quadrant of an ellipse. There are many designers of flow nozzles; the ISA (Instrument Society of America) nozzle has become an accepted standard form in many countries. The rounded approach improves the efficiency (less head loss) and improves long-term accuracy by reducing erosive effects. Nozzles are easy to install but are more complex in design and more costly ($175 for 3 inch size). Flow nozzles can be used to measure higher velocity fluids because the curved approach reduces cavitation (bubble formation that causes deviation from the calibration and increases nozzle erosion).

The *venturi tube* has a gradually restricting approach section, a short throat section and an even more gradual expanding exit cone. This design insures against cavitation. Because of the approach and exit cones and because venturi tubes are usually made of cast metals such as iron and bronze there is some tendency toward coating. Periodic cleaning is recommended.

The venturi provides excellent downstream pressure recovery which is an advantage where only small head losses can be tolerated. The venturi tube is more accurate and can measure higher velocity flow than the orifice plate or nozzle. The venturi tube design is much more sophisticated and the device is much longer than either the plate or nozzle and has a higher initial cost. ($700.00 for the 3 inch size.)

B. 90 Degree Elbow Elements

Application: Fluid pipe or conduit sizes from ½ inch to 30 or 40 inches. Because they are made from part of the pipe line which may already be in place they can be used in most fluid applications for which pressure connections can be made to the elbow at the appropriate points.

Principle of Operation: The pressure differential that provides the basis of measurement is that existing between the inside and the outside of the elbow due to change in direction of the fluid flowing. Pressure taps through the elbow walls are located at the 45 degree line in the plane of the turn, radially opposed and perpendicular to the elbow interior surface. (Some experiments suggest taps at the 22½ degree point are effective). These taps provide access for the differential pressure measuring device.

Considerations: Elbow meters are usually made from an existing bend in the pipe or conduit and offer no additional flow restriction. The only installation charge is for the pressure taps which must be free from burrs.

Elbow flow-meters are not yet widely used and the discharge equation and coefficient relating pressure differential to flow rate may have to be determined in-house or by a consultant. Where published experimental data are available for the conditions required, elbow meters constructed from commercial pipe elbows have an expected accuracy of better than ±5 percent *without* calibration in place and without accurate data on the exact dimensions of the individual elbows. In-place calibration can be expected to give better accuracy. Elbow meters are particularly sensitive to disturbances in flow and should be preceded by at least 25 diameters of straight pipe and followed by at least 10 diameters of straight pipe.

This type meter is as durable as the existing elbow, requires no maintenance, offers no additional head loss or flow limits beyond that of the existing elbow, is not likely to clog or show effects from wear, and is quite insensitive to viscosity changes or solids to liquid ratios.

The differential pressure is small at low flow velocities or for gas flow necessitating the use of sensitive secondary equipment for these conditions.

9.3.3 POSITIVE DISPLACEMENT DEVICES

Application: Widely used in industry for metering both liquid and gas flow for line sizes ½ inch to 6 inches.

Principle of Operation: This type of meter traps a fixed volume of gas or liquid as it passes through the meter and a counting mechanism records the number of displacements in a convenient unit of volume. Normally this type of meter has no timing equipment but an average rate of flow can be determined by observing the time required for the meter to displace a specified volume of fluid.

Considerations: Relatively low inertia of moving mechanical parts, minimum seal surfaces, and good temperature compensation are characteristics sought in better devices. Positive displacement meters can be made to resist corrosive fluids; are easy to install; require periodic maintenance or replacement as moving parts wear; and calibration may change. Cost is not usually great and no sophisticated secondary equipment is involved. All such meters extract energy and cause a head loss.

Characteristics of several types are briefly described as follows:

1. Reciprocating Piston: Very high torque, mechanical seals, good accuracy at low flow rates, ideal for measuring flow of low pressure gases because of low head losses.
2. Oscillating Piston Meter: Limited driving torque, capillary seal, moderate head loss, good for measuring flow of thin liquids, good accuracy at low flows, available ¾ inch to 6 inch line sizes.
3. Sliding Vane Meter: Low torque, low efficiency, low head loss, better for measuring high flow rates.
4. Rotary Vane Meter: Moderate head loss, low torque, moderate efficiency.
5. Nutating Disk or Wobble Plate: High torque, low head loss, commonly used on water service.
6. Gear or Lobed Impeller: Moderate head loss, low torque, better for measuring higher flow rates.

9.3.4 PITOT TUBES

Application: Commonly used in line sizes over 6 inches for a wide range of fluids.

Principle of Operation: The pitot tube consists of a small diameter tube (¼″ or smaller) with an opening facing into the fluid flow. The pressure developed at this port is the impact pressure caused by stopping the movement of the fluid and is measured against the existing static pressure in the line. A second pressure tap at 90 degrees to the direction of flow measures the static pressure only. Measuring the differential pressure between taps provides a predictable indication of the fluid velocity in the line.

Considerations: Pitot tubes are velocity measuring devices. Because of their small area, they measure the velocity at a point rather than the average across a pipe or duct. Certain precautions must be observed if accuracies as high as ±2 percent are to be obtained with a pitot tube. These conditions are as follows:

1. Provide a duct diameter of 4 inches or greater.
2. Make an accurate traverse across the duct and average the readings.
3. Assure straight-line flow by having at least ten diameters of straight pipe before and after the pitot tube or provide straightening vanes upstream of the tube.

If conditions do not permit a traverse, install the pitot tube in the center of the duct. Then multiply the indicated velocity by 0.9. This method provides answers correct to ±5 percent.

In very large ducts or pipes, deflection of the mast which supports the pitot tube can cause serious errors.

The price of pitot tubes vary widely ($15 to $2500).

9.3.5 TURBINE METERS AND ANEMOMETERS

Application: Most commonly used to meter the flow of gases but also used to meter the flow of liquids as in a gasoline pump. For liquid metering tangential-flow meters are used for small flows, 100 gallons per minute or less; axial or radial flow meters are used for much higher discharges to 10 cubic feet per second. These meters are made liquid proof and are inserted in a pipeline to measure the flow of various fluids under widely varying temperature and corrosion conditions. Air velocities can be measured with cup-type or vane (propeller) type anemometers. Anemometers are available which will measure very low air velocities.

Principle of Operation: These meters are all "inferential meters" because the fluid flow rate is calculated from the speed of rotation of the primary element. Meters of this kind are turbines running with no load other than that required to generate the measurement signal. As the rotor blades turn they are made to pass through a magnetic field and generate an electric voltage which is used as the output signal. Optical tachometers use reflected light to generate the signal for very low velocity anemometers.

Considerations: Accuracy of turbine flow meters is of the order of 1 percent. Calibration may be affected by coating or abrasion of the rotor. A wide range of meters is covered in this category from very expensive fluid turbine meters for small pipeline use to hand-held, room air anemometers.

9.3.6 OPEN CHANNEL WEIRS

Application: Unlimited size for liquid flow in open channels.

Principle of Operation: Any barrier in an open channel over which flow takes place serves as a control which creates a consistent relationship between the volume rate of flow and the weir head (the height of the liquid above the top of the barrier). The height of the liquid must be measured upstream of the barrier. The flow equation relates the dimensions of the weir (barrier) and the height of the water to volume flow. The simplest form of weir is a plate and often the plate has a notch in the vertical face (contracted weir). Rectangular, triangular, or trapezoidal notches are most common. The purpose is usually to amplify the height increment for a flow volume increment, particularly at low flow volume. Often a tank is provided directly upstream from the weir to effectively reduce the liquid flow rate.

Considerations: Commercial weirs are available, aid should be sought when plant staff is not familiar with them. Accuracy depends on the condition of the weir crest and averages perhaps 3 percent but can be as good as 1 percent.

Calibration may change if the weir crest is damaged or if sediment or debris accumulates upstream of the weir plate. The range of flows measurable by a given weir depends on the size and shape of the weir opening.

Triangular notches provide for a wide range of flow. If a weir is carefully constructed, standard formulas can be used without calibration but for more accurate determination of flow rate it is best to calibrate.

To utilize any weir a liquid surface elevation or depth must be measured. For small installations, as in a channel carrying liquids in an industrial plant, the elevation of the liquid upstream of the weir crest is determined relative to the weir elevation using a hook gauge or a float mechanism mounted in a transparent stilling well connected to the channel or weir tank.

9.3.7 MAGNETIC FLOWMETERS

Application: Liquid flow in line sizes from 0.1 inches to 96 inches.

Principle of Operation: A magnetic flow meter produces a strong magnetic field through a non-magnetic section of pipe. As the liquid in the pipe passes through this magnetic field a very small electrical potential is generated. Electrodes mounted in the sides of the pipe detect the potential. Sophisticated electronics amplify the potential into a usable signal. The liquid passing through the pipe must be conductive.

Considerations: High accuracies and the absence of pressure drop within the meter are two important factors in applying this type of meter. There are no projections or restrictions in the meter which means that solids in the liquid or slurries will not clog the meter. There are no wearing parts to change the meter characteristics, however, coating of the electrodes can cause errors in measurement. Magnetic flowmeters are immune to density and viscosity changes and the accuracy is unaffected by upstream piping configurations. The induced voltage is nearly independent of the conductivity of the fluid flowing for conductivity above some threshold value (which is quite low and of the order of tap water). The cost of these units is fairly expensive ($1700 for 1 inch meter and $6000 for a 12 inch meter).

9.4 PRESSURE MEASUREMENT

9.4.1 MANOMETERS

Application: 1 inch Water Column to 100 inches Mercury

Principle of Operation: A piece of glass tubing bent into a U-shape forms a simple manometer. A liquid is added to the manometer until each leg is approximately half filled. With no pressure other than atmospheric, the levels of the liquids in each leg are equal. If a positive pressure is applied to one leg, the liquid column height adjusts to equalize the pressure. The applied pressure is equal to the difference in the two liquid column levels multiplied by the density of the filling liquid (water, mercury, oil). For convenience, pressure terminology has been derived such as inches of water and inches of mercury.

Well-type manometers have a large reservoir of liquid as one leg and a single indicating tube. If the capacity of the well is large compared to that of the tube, the level in the well changes very slightly. This variation can be compensated in the scale calibration. The sensitivity of a manometer can be increased by slanting the indicator tube. This gives the liquid greater movement over a scale for the same vertical distance.

Considerations: Manometers offer a relatively inexpensive, yet accurate method of pressure measurement. A variety of filling liquids provide a wide range of sensitivities. Oil that is less dense than water gives a large column movement for a small pressure change. Mercury, with its very high density, gives a small column movement for a large pressure change.

Manometers are a differential pressure indicator. If one leg is vented to the atmosphere, the pressure applied to the other leg measures relative to atmospheric pressure. This is commonly called "gauge pressure." If, on the other hand, one leg has a near perfect vacuum sealed above it, the pressure measured indicates the total pressure. This includes any pressure that might be contributed by the atmosphere. This type of manometer is used as a barometer which measures variations in atmospheric pressure. Barometric pressure readings are normally read in inches of mercury (30 inches of mercury = 14.7 psi).

Manometers must be mounted carefully and inclined manometers, in particular, should be carefully leveled to insure accurate reading.

9.4.2 LIMP DIAPHRAGM GAUGES

Application: 1 inch water column to 150 inches water column.

Principle of Operation: The pressure to be measured is applied to a pressure plate or piston which is sealed against leaks by a very flexible, limp material which takes almost no force to deform. The force generated by the pressure on the piston compresses a spring. As the spring is deformed, the pointer attached to the pressure plate moves to indicate the correct pressure on a calibrated dial. The spring rate of the range spring and the area of the diaphragm determine the sensitivity of the indicator.

Considerations: Limp diaphragm gauges provide a more rugged means of measuring small pressures than a liquid manometer. They require less room, are fairly durable and are quite inexpensive ($30 to $70). Accuracy may be as good as ±2 percent but at lower ranges (below 1 inch water column) may have accuracies of ±5 percent. Moving a gauge from a vertical position to a horizontal position will require a zero adjustment of the gauge.

9.4.3 BOURDON AND BELLOWS GAUGES

Application:

Bourdon-30 in mercury vac. to 20,000 psi
Bellows-30 in mercury vac. to 50 psi

Principle of Operation: Bourdon tubes and bellows elements that rely on the ability of elastic materials to deform, take many shapes. A partially flattened metallic tube form in a "C" shape is the basis for a simple bourdon tube. The outside curved surface is slightly larger in area than the inside curved surface. When a pressure is applied to the inside of the tube, an unequal force develops which tends to straighten the coil. The coil functions as a spring and the resulting motion is proportional to the pressure force. The small movement of a bourdon is magnified by a frictionless gear mechanism that positions a pointer. The movement of a bourdon can also be amplified by forming a spiral or helical element, eliminating the need for a gear train.

Bellows are normally used for lower pressure devices. The deflection of a bellows is axial only. Since the bellows also acts as a spring, the linear relationship between pressure and motion is maintained. Increasing the number of convolutions in the bellows increases the axial movement. Increasing the diameter of the bellows increases the force generated for a given pressure.

Considerations: When a bourdon or bellows element deforms, it is important that the elastic limit of the material not be exceeded. Permanent damage can result. Gauges that employ these elements are rugged, portable, easy to use, and relatively inexpensive ($5 to $150) depending on dial size and accuracy. Accuracies can be as good as ±¼ percent or as poor as ±5 percent.

9.5 LIQUID LEVEL

9.5.1 SIGHT GAUGES

Application: Any reasonable tank size.

Principle of Operation: Any liquid level in a tank or vessel can be measured by connecting a transparent tube to the tank in such a position to cover the anticipated level variations. The liquid in the tank will reach the same level in the tube that exists in the tank. If the vessel is closed or pressurized, the top of the sight gauge must be connected to sample the reference pressure in the tank.

Considerations: Sight gauges are an inexpensive ($20 to $100) means of level measurement providing reasonable pressures exist in the tank. Indication is restricted to the vicinity of the vessel. Certain conditions can exist that will cause a sight glass to read incorrectly. If a liquid exhibits a radical change in density as its temperature varies, a hot liquid in a well insulated tank might be less dense than the same liquid in a sight glass exposed to cooler ambient temperature conditions. The level in the sight glass would indicate a level lower than truly exists in the tank. Aside from these rare instances, the accuracy of these devices is very good. Since glass is breakable caution should be exercised in the use of glass sight gauges for flammable, corrosive or toxic materials.

9.5.2 BUBBLE TUBE

Application: Any reasonable tank size.

Principle of Operation: A small tube placed vertically in a tank and purged by a gas (air, nitrogen, etc.) will develop a pressure in the tube equal to the liquid pressure at the bottom of the tube. This pressure which changes as the liquid level changes can be read by any suitable pressure indicator.

Considerations: Bubble tubes are a widely used, inexpensive, trouble-free method of level measurement. The following operation conditions must be considered:

1. The supply pressure of the purge must exceed the static liquid pressure by about 3 psi. Commercial devices are available that maintain a constant differential pressure across the purge regulator. This keeps the purge rate constant regardless of level.
2. The purge rate should be adjusted to insure a gas filled tube regardless of the rate that the liquid level changes. The purge rate should be small enough to avoid pressure build-up caused by frictional effects of the gas flowing in the tube.
3. Use a bubble tube approximately ½ inch in diameter. The tube is less likely to plug.
4. Leave an inch or two between the bottom of the tube and the bottom of the tank; three or four inches of sediment is likely to accumulate.
5. A "V" notch on the bottom of the tube decreases the purging bubble size and provides a smoother indication of level.
6. Measure the tube pressure near the tank and frictional effects are avoided.
7. Bubble tubes that supply inerts that must later be removed from a gas via refrigeration, scrubbing, etc. are undesirable.

Bubble tubes can be used in a pressurized tank if the tube pressure measuring device is referenced to the internal tank pressure.

9.5.3 FLOAT/BUOYANCY METERS

Application: Any reasonable tank size.

Principle of Operation: A float rests on the surface of the liquid. As the level changes, the float position also changes. This motion is connected to a pointer by a mechanical linkage, a magnetic coupling, a hydraulic system, or an electrical system.

A buoyancy meter utilizes a float system that does not follow the liquid level. The float is mounted vertically in the tank such that as the level increases the float is further submerged in the liquid. The buoyant force which is developed is converted to a pointer movement.

Considerations: Float gauges vary in price from \$10 to \$200 or \$300 depending on the complexity of design and the range of the indicator. Sophisticated transmitting devices add substantially to the cost.

Float gauges and buoyancy devices should be used in clean liquid that will not coat the float or mechanisms. These units are easy to install and are designed for industrial usage.

9.5.4 CAPACITANCE LEVEL GAUGE

Application: Any tank size.

Principle of Operation: Capacitance is the property of two or more bodies which enables them to store electrical energy in an electrostatic field between the bodies. The capacitance level probe is a metal rod, mounted in the vessel, the contents of which is to be measured. The rod must be electrically insulated from the vessel wall. The capacitance of the system is formed by the rod, the vessel wall and the air space between. As liquid or dry materials alter the gap between the probe and the wall, the electrostatic field changes. High frequency oscillator circuits are sensitive to these small capacitance changes. Amplifying and conditioning circuits provide a useful signal proportional to level.

Considerations: Capacitance probes will not operate properly on all materials. Motor oil has three times the capacitance of air and cannot be measured with level gauges. Highly conductive materials will swamp the high frequency circuits, shorting the probe. If the probe is insulated from the material being measured, (i.e., teflon coated) highly conductive materials can be properly measured.

These units are moderately priced (\$300 to \$500) for units which provide a proportional level signal and they are easily installed in any vessel.

9.6 ELECTRICAL MEASUREMENTS

9.6.1 DIRECT CURRENT METERS

1. Ammeters

Application: All current levels.

Principle of Operation: Direct current ammeters are moving coil instruments of the permanent-magnet type. They operate on the principle of the d'Arsonval galvanometer. In this type of meter, the current to be measured, or a known fraction of it, is established in a lightly constructed rectangular coil of wire which is free to turn on its axis. A radial magnetic field, which surrounds the coil, is maintained by a permanent magnet. The electromagnetic reaction between the coil current and the magnetic field causes the coil to turn against the action of spiral springs, thereby producing a deflection of a needle attached to the coil. The needle moves over a graduated scale on which the current may be read. The actual current passing through the meter coil may be typically 20 milliamperes.

Considerations: A milliammeter can be used to measure currents which are many times larger than the current in the movable coil at full-scale deflection. A resistor of low resistance (shunt) is connected in parallel with the meter circuit. The majority of the current passes through the shunt with only a small fraction passing through the meter. The proportion remains constant and permits a properly calibrated scale to accurately indicate the total current flow in the circuits. Larger ammeters require an external shunt resistor.

Ammeters must be connected in series to properly indicate the current flow in the circuit. Their cost varies with the total current capacity but are generally inexpensive. The meter movement may have jeweled bearings which indicate the delicate construction of these meters.

2. Voltmeters

Application: All voltage levels.

Principle of Operation: Direct current voltmeters are basically milliammeters as described above. Since the meter resistance is constant, the meter deflection is proportional to the current flowing through the meter coil and is, therefore, proportional to the millivolts consumed in the meter circuit. Accordingly, the meter scale may be calibrated to read directly in millivolts. By connecting added resistance in series with the meter and providing a suitable scale, the instrument can be converted into a voltmeter.

Considerations: Voltmeters must be connected in parallel with the circuit load. If low voltages are being measured, a meter with a very high internal resistance should be used. Costs vary with voltage capacity.

3. Wattmeters

(See Wattmeters under Alternating Current Meters.)

9.6.2 ALTERNATING CURRENT METERS

1. Ammeters

Application: All current levels.

Principle of Operation: In this type of meter, a thin strip of iron is fastened to the shaft supporting the pointer. Motion of the pointer is brought about by the interaction of the magnetic field produced by current flowing in a stationary coil and the iron strip or vane. Several different meters have been developed employing this principle in different ways.

Considerations: Ammeters are connected in series with the circuit load and, therefore, must have low resistance coils. The coil has a very few turns of a large cross-section wire.

2. Voltmeters

Applicaion: All voltage levels.

Principle of Operation: Many portable ac voltmeters employ the principle of the electrodynamometer. Two stationary coils are mounted close together on the same axis. The windings of these coils are connected in series, such that the magnetic forces generated are additive. A movable coil is mounted within the stationary coils and is electrically connected in series to the stationary coils. As a small current passes through the coils, a torque is developed which causes the movable coil to deflect. Springs at each end of the movable coil carry current and also resist the coil movement.

Movable vane voltmeters utilize the principle described under ac ammeters. However, the coil is constructed of many turns of very fine wire which results in a high resistance and small current flow.

Considerations: Voltmeters must be connected in parallel with the circuit load. The internal resistance of a voltmeter should be high enough to minimize the current flow through the meter.

3. Wattmeter

Application: All power levels.

Principle of Operation: Power in a dc circuit is equal to the product of the voltage and current. In an ac circuit, however, while the instantaneous power is equal to the product of instantaneous current and voltage, the average power is generally not equal to the product of effective voltage and effective current. The usual type of wattmeter operates on the principle of the electrodynamometer as described under ac voltmeters. In this type of wattmeter, the permanent coils are electrically connected in series to carry the circuit current, while the movable coil is connected in parallel and responds to the voltage level. The moving element has sufficient inertia to prevent the pointer from following the rapid changes in torque generated by the alternating current. Hence, the needle assumes an angular displacement determined by the average torque, and when a calibrated scale is provided, the meter indicates the average power in the circuit.

Considerations: Wattmeters are usually calibrated by applying carefully measured direct current to the stationary winding and direct voltage to the movable winding. When properly calibrated, these meters may be used to measure power in either dc or ac circuits. Power factor for electrical loads may be calculated from wattmeter measurements of real power and voltmeter and ammeter measurements of voltage and current. See local electric utility for information on the effect of power factor on costs of electricity.

9.6.3 MULTIMETERS

Application:

Voltage: Up to 1000 volts.

Current: Up to 5 amperes.

Resistance: 0.1 ohms to 500 megohm.

Principle of Operation: Most modern multimeters utilize sophisticated electronic circuitry. Detailed discussion of these basic circuits is beyond the scope of this publication.

Considerations: Multimeters are commonly used in electronic circuit troubleshooting, yet are handy devices for portable measurements of all electrical parameters. Voltages and resistances are easily read. Large currents are more difficult because of the capacity limitation of lead wire and electronic components. Accuracies vary but can be excellent (typically ±0.1 percent) and cost varies accordingly.

9.7 FLUE GAS ANALYSIS

9.7.1 ORSAT ANALYZER

Application:

Chemical analysis of flue gas for CO_2, O_2 CO, and N_2.

Principle of Operation: A mixture of gases may be analyzed by measuring the volume decrease of the sample when several components are absorbed, one by one, in various solutions. The Orsat apparatus consists of three pipettes and a graduated tube or burette designed to receive and measure volumes of gas at constant temperature. The flue gas sample is measured and then bubbled through potassium hydroxide in the first pipette to extract the carbon dioxide (CO_2). The gas sample is then isolated and the volume remeasured to determine the change due to removal of carbon dioxide. In a similar manner the gas sample is then bubbled through potassium pyrogallate in the second pipette to remove oxygen (O_2), the volume remeasured, then bubbled through cuprous chloride in the third pipette to remove carbon monoxide (CO), and the volume again remeasured. Each successive decrease in the volume of the gas sample is the volume of the component absorbed and the remaining unabsorbed gas is assumed to be nitrogen (N_2).

Considerations: Leaks in gas handling and poor sampling from the flue gas are the most common sources of error. Averaging the results from several simultaneous samples taken from different points in the flue cross section and analyzed separately will provide an accurate procedure.


HEAT
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Section 10

BIBLIOGRAPHY

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10. BIBLIOGRAPHY

10.0 INTRODUCTION

This section presents a sample listing of journal articles and books dealing with various aspects of energy conservation in the industrial field. The material is organized under several general categories similar to those used for the ECO's presented in Section 3.

Representative handbooks and periodicals that contain data and information particularly useful for application to industrial energy conservation activities are presented below:

HANDBOOKS

Chemical Engineers Handbook
Perry, Chilton, and Kirkpatrick, Fourth Edition 1963, McGraw-Hill Book Company, New York, NY

Compressed Air and Gas Handbook
Third Edition 1961 (Revised 1966), Compressed Air and Gas Institute, New York, NY

Engineering Data Book
Gas Processors Suppliers Association and Others, Tulsa, OK

Gas Engineers Handbook
1966, The Industrial Press, New York, NY

Handbook of Applied Instrumentation
Douglas M. Considine, McGraw-Hill Book Company, New York, NY

I.E.S. Lighting Handbook
Fifth Edition, 1972, Illuminating Engineering Society, New York, NY

Handbook of Fundamentals, 1972; *Equipment Volume*, 1972; *Applications Volume*, 1971; *Systems Volume,* 1973
American Society of Heating, Refrigeration, and Air Conditioning Engineers, New York, NY

Standard Handbook for Mechanical Engineers
Theodore Baumeister and Lionel S. Marks, Seventh Edition 1969, McGraw-Hill Book Company, New York, NY

PERIODICALS

ASHRAE Journal
Chemical Engineering
Combustion
Control Engineering
Engineering Journal
Heating/Piping/Air Conditioning
Hydrocarbon Processing
Mechanical Engineering
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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The Energy Conservation Program Guide for Industry and Commerce (EPIC) is a guide to assist business and industry to establish an on-going conservation program. EPIC outlines the steps in an energy conservation program and suggests specific ways to reduce energy use in manufacturing and commercial businesses. EPIC focuses on two aspects of energy conservation:

(1) The key steps in an implementation plan for an energy conservation plan.

(2) Energy Conservation opportunities which have been identified by industry.

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EDGE INDEX

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