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GUIDELINES FOR SAVING ENERGY IN EXISTING BUILDINGS, BUILDING OWNERS AND OPERATORS MANUAL, ECM-1

DUBIN-MINDELL-BLOOME ASSOCIATES

PREPARED FOR

FEDERAL ENERGY ADMINISTRATION

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Building Owners and Operators Manual ECM 1

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16. Abstracts The purpose of this study is to examine national energy usage in existing commercial buildings, design methods of reducing energy consumption through conservation, and analyze the resulting costs and benefits. The conclusions of these studies are compiled in two energy conservation manuals, ECM-1 and ECM-2. ECM-1 is directed primarily to owners, occupants, and operators of buildings. It includes a wide range of opportunities and options to save energy and operating costs through proper operation and maintenance. It also includes minor modifications to the building and mechanical and electrical systems which can be implemented promptly with little if any investment costs. The measures contained in ECM-1 would result in energy and operating cost savings of 15 to 30% based on present fuel costs.

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GUIDELINES FOR SAVING ENERGY IN EXISTING BUILDINGS

Building Owners and Operators Manual
ECM 1

June 16, 1975

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TABLE OF CONTENTS

LIST OF FIGURES

ECM 1 FIGURES PAGE NO.

FOREWORD

The gap between national energy supply and demand and the resulting escalation of operating costs we are now experiencing cannot be reduced or eliminated without a concerted and continuous effort to reduce the national energy consumption through the application of conservation practices. Contrary to common belief energy conservation does not mean sacrificing our living standards or living in a bleak utilitarian society. It can be accomplished without discomfort or sacrifice merely by the more efficient utilization of our non-renewable energy resources.

Buildings consume for heating, air conditioning, lighting, and power more than 33% of all energy used in the United States, the equivalent of 10 million barrels of oil per day at a time when our oil imports are approximately six million barrels per day. Reducing energy used in all buildings by 30% without impairing the indoor environment is a realistic possibility and is the equivalent of cutting our present oil imports by half.

Most of the buildings now in use were designed and constructed when fuels and electric power were readily available and inexpensive and the need for energy conservation was not recognized. The structures and their mechanical and electrical systems were designed to minimize initial costs, not energy usage. Buildings are generally overheated in the winter, overcooled in the summer, overlighted, overventilated year-round, and not operated efficiently. Each year they consume increasing amounts of energy because systems and building components deteriorate as maintenance and service becomes more costly and neglected.

Energy conservation programs which have been undertaken within the past three years in many thousands of existing commercial, institutional and residential buildings have already resulted in a reduction of their annual fuel and electricity consumption of 20 - 50% and indicate the range of potential savings for almost all buildings now in use.

The Federal Energy Administration has been directed by Congress to analyze total national energy usage and formulate policy and stimulate actions which will increase domestic energy supplies and decrease energy demand. To assist in the overall effort to reduce national energy demand, the F.E.A. retained Dubin-Mindell-Bloome Associates, P.C. Consulting Engineers and planners on July 1, 1974 to study national energy usage in existing commercial buildings, together with methods of reducing energy consumption through conservation and the resulting costs and benefits. The conclusions of these studies are compiled in two energy conservation manuals, ECM-1 and ECM-2, for public use.

ECM-1 is directed primarily to owners, occupants, and operators of buildings. It includes a wide range of opportunities and options to save energy and operating costs through proper operation and maintenance. It also includes minor modifications to the building and mechanical and electrical systems which can be implemented promptly with little if any investment costs. The measures contained in ECM-1 would result in energy and operating cost savings of 15 to 30% based on present fuel costs.

ECM-2 is intended for engineers, architects, and skilled building operators who are responsible for analyzing, devising, and implementing comprehensive energy conservation programs which involve additional and more complex measures than those included in ECM-1. ECM-2 includes many energy conservation measures which can result in further energy savings of 15 to 25% with an investment cost that can be recovered within 10 years through lower operating expense.

The urgency of the energy crisis has necessitated the immediate development of these guidelines. They should be used now to conserve energy, reduce operating costs and alleviate hardships as fuel and power supplies become less available.

These guidelines and conservation opportunities will be updated as:

(a) Further studies are made and data is collected from existing buildings in which these guidelines and conservation measures have been implemented.

(b) Further State and Federal Energy Policies evolve.

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DUBIN-MINDELL-BLOOME ASSOCIATES, P.C.
CONSULTING ENGINEERS AND PLANNERS

INTRODUCTION AND SCOPE

Conserving energy means reducing the amount of fuel and electricity which your building or space uses every month. Reducing fuel and electrical consumption saves money. Cost savings made now will be increasingly greater in the future as raw fuel and electricity prices continue to rise.

Fuel and electricity consumption cost savings are important, but by no means the only reasons for you to conserve energy:

- Energy Conservation can extend the useful life of existing equipment and eliminate the need for early replacement costs.
- Energy Conservation can increase the reserve capacity of the existing central plant systems and meet future building extensions without installing extra boilers, chillers or transformers.
- Energy Conservation reduces the likelihood of shutdown or curtailment of operations due to fuel or power shortages-inevitable if demand continues to outstrip supply.
- Energy Conservation reduces airborne pollution resulting from combustion of oil, gas, or coal and may save installation costs of pollution control equipment.
- Energy Conservation means reduction of waste permitting fuel economy without reduction of health and comfort standards, or curtailment of building services and function.
- Energy management, a form of conservation reduces peak electric loads and electric power demand charges while easing the burden on existing power generating and distribution systems.

In addition to the immediate advantages of Energy Conservation for you, there are advantages to the nation as a whole.

- Energy Conservation conserves natural resources.
- Energy Conservation can enhance economic opportunity where materials and labor are required to improve building thermal characteristics.
- Energy Conservation reduces the need for oil imports and the dependency upon external sources for the internal economic well being and security of this country.
- Energy Conservation combats inflation.

Purpose of this Manual

ECM-1 has been prepared to help you, a building owner, manager, operator or occupant, to conserve and manage energy usage now, without the necessity of investing a significant amount of money to do so. In order to conserve energy, you must understand all of the following factors which are included in ECM-1:

- The basis principles of Energy Conservation and the interrelationships between specific climatic conditions, building

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structure, building use, and each of the mechanical and electrical systems.

- The systems, in order of priority, which use the most energy and provide the greatest potential for conservation.
- Methods to identify your building by type, size, function, construction materials and features, mechanical and electrical systems, operation, geographic location (climatic influences) and present energy usage.
- Suggested standards for indoor environmental conditions during occupied and unoccupied periods for spaces with differing functions within the building.
- The opportunities for Energy Conservation with options and guidelines; and the charts, graphs and tables to enable you to quantify the potential savings in fuel and electricity for your own building.

ECM-1 is not strictly a design manual, nor a cost estimating manual, but rather a set of guidelines and procedures to reduce energy usage by reducing waste, and to save energy through more effective operation of the building and its mechanical and electrical systems.

The material, labor and energy costs which are noted or used in the examples throughout the manual are cited to help you gain a perspective of the relative costs and benefits for specific energy conservation measures. The costs are based on specific selected conditions and may vary widely even within the same city. The costs are indications of order of magnitude only. DO NOT ADOPT THEM AS EXACT QUANTITIES.

ECM-1 and ECM-2 were prepared specifically for conservation of energy in existing office buildings, retail stores, and buildings which are generally occupied only a few hours a week such as religious buildings. Many of the examples and analyses refer to these three types of structures. However, most of the measures and operating procedures are equally applicable to other types of existing and new buildings as well, and can be used for hospitals, schools, universities, libraries and other institutional buildings, houses, apartments, warehouses, and industrial buildings (excluding the industrial processes).

ECM-1 and ECM-2 are summations of energy conservation measures which require neither new inventions, new systems, nor exotic solutions. The tables of values, charts, and graphs which are included are based on the authors' analysis, computations, computer programs, judgement and observations.

The opportunities which are described are not universally applicable. Each building is unique, even though others may be of the same type and general appearance. The manuals suggest ideas for consideration with corresponding costs and benefits, but those which are appropriate for any individual building can be determined only after a thorough analysis of the specific building.

Many of the ideas outlined in these guidelines can be executed directly by the building occupants, owners, or managers without delay or the need for further advice; while other measures, even though they do not entail significant capital costs, may require further analysis by an engineer, architect, utility company or service and maintenance organization. Owners should not hesitate to consult these sources. An engineer can complete a preliminary anlysis of energy options to be considered for further analysis, even for a large building in just a few days time.

ECM-1 provides case histories of energy and cost savings for two buildings which have already instituted energy conservation programs, and presents other examples of the calculated savings in energy and dollars for selected major energy conservation options. These two large buildings were able to save $758,000 per year and $434,000 per year respectively, with very little capital costs, by following the recommendations of professional engineers retained by the owners. Small buildings can also show proportionate, but dramatic savings as well.

A partial summary of the procedures we suggest you follow to save energy and operating costs for your building are outlined below. The Federal G.S.A. operates more than 10,000 buildings in the United States and by following many of these procedures, they report an average savings of 30% in energy use last year. (Consult Sections 3 and 4 for a more comprehensive description of major energy conservation opportunities and detailed procedures and guidelines to implement the opportunities.)

1. Walk through your building. Are there areas that are unoccupied, or which can be vacated by making better use of the remaining areas? If so, turn off air conditioning, lights, ventilation and heating (where freezing is not a hazard) permanently. Isolate these areas from other spaces by doors, walls, or other means. If 10 or 15% of the building can be vacated, energy savings will follow almost in the same proportion.

2. Repair broken windows and leaking pipes or ducts; clean filters, radiators, light bulbs and fixtures; caulk leaks around doors, windows, louvers and openings. In many cases, 5 to 15% energy savings are possible, especially in cold climates where infiltration or cold air increases the heating load and causes your heating system to operate longer hours.

3. Shut off lights where not needed. Post colored signs alongside the switch to remind the occupants to do so.

4. Lower thermostats to 68°F in occupied areas during the heating season, and even lower in less critical areas. Lower the relative humidity settings to 20% in the winter. Raise thermostat settings to 78°F* or higher in the summer if your building is air conditioned, and shut off the air conditioner, fans and pumps at night, weekends, and holidays. Savings of 6% to 15% in energy can be realized simply by resetting the control points.

5. Repair all leaky outdoor air dampers, shut off all ventilation systems when the building is unoccupied. Outdoor air which must be heated or cooled often accounts for as much as 30% of the energy used in many buildings. More than half can be saved by night and weekend shutdown since there are more hours in those periods.

6. Have your oil burner and boiler or furnace checked. Clean soot and scale and adjust the firing rate, draft and combustion. 10 to 15% of the heating bill can be saved in many buildings; the colder the climate, the greater the savings.

7. Replace lamps with more efficient ones giving more lumens per watt; remove lamps in unoccupied spaces and disconnect ballasts. Many areas in the building require less illumination than others,reduce lighting levels in less critical areas by removing lamps and disconnecting ballasts. In schools, office buildings, and retail stores, lighting often accounts for up to 40% of all energy used and the heat from the lights also forms a major part of the air conditioning load. 20% to 40% of the energy used for lighting can be saved in many buildings.

8. Clean your windows to let in more natural light. You may find that doing so will permit turning off some of the electric lights near the windows.

9. Set the aquastat lower on your water heater to save energy. In schools, hospitals and housing, domestic hot water often uses from 25 to 40% of the amount of energy required for space heating even in cold climates.

*Exception where terminal reheat systems are installed.

10. There are dozens of other energy conservation opportunities available with little, if any capital costs required (often labor only), depending upon the building orientation, number of windows, the roof and wall materials, the building location and use, and the characteristics of the heating, lighting and air conditioning systems.

In order to take advantage of the opportunities, detailed in Section 4., you must first understand the particular characteristics of your building and the influences which affect fuel and electricity usage; then analyze each of the measures independently and in combination with each other to assure maximum energy savings without adversely affecting the operation, aesthetic quality, the health and comfort of the occupants.

It is suggested that you also read ECM-2, for additional energy conservation opportunities. These entail more capital expenditure, but the investment can be recovered, through reduced operating costs in relatively short periods of time. ECM-2 includes the procedures to estimate energy savings resulting from modification to the building structure and which can be used in altering or replacing elements of the mechanical and electrical systems with more efficient components. Instructions for estimating costs, methods of economic analysis based on life-cycle cost considerations and suggested energy management plans are also included in ECM-2.

SECTION 1

PRINCIPLES OF ENERGY CONSERVATION

Before energy can be conserved, the ways in which it is used must be understood. The building structure - i.e. walls, windows, roof - and the passive components of the mechanical and electrical systems - i.e. ducts, pipes, filters, or lighting fixture louvers - do not directly consume energy but they influence the amount that is finally consumed. The primary energy-conservsion equipments, such as coal, oil or gas burners and boilers/furnaces; refrigeration chillers and compressors; motors; and electric lighting bulbs or tubes, consume energy to supply the "building" load and to compensate for the distribution system load.

The term "building" load, as it is used in this manual, refers to the amount of energy in BTU or KW required to maintain desired indoor space conditions and to operate building equipment if the distribution system and energy-conversion equipment were 100% efficient. The distribution or "parasitic" load is a measure of the energy required to deliver energy from the primary conversion equipment to supply the "building" load. The efficiency of the primary energy-conversion equipment (conversion, since the equipment converts fuel to heat and/or electricity to power or light) ultimately determines the actual amount of energy consumed to supply both loads.

Energy usage, then, depends upon two main factors:

1) The magnitude and duration of the loads.
2) The seasonal efficiency of the primary energy-conversion equipment.

"Building" loads will be reduced if the temperature and relative humidity indoors are maintained at lower levels in the winter and at higher levels in the summer; heat loss, heat gain, and infiltration through the building envelope are decreased; ventilation rates are reduced; domestic hot water temperature and quantity are reduced; the level of illumination by electric lighting is lowered; and the number of hours of operation of elevators, business machines, and cooking equipment is reduced.

The "building" load must be considered on a seasonal basis rather than for peak conditions only. Although two buildings may have the same heating load for any particular hour, one of them may have a considerable higher load, on a seasonal basis, than the other, due to the duration of peak conditions. Or, for instance, a religious building, auditorium or warehouse may have a relatively high energy requirement for lighting during a brief period of time, but if the lights are turned off during unoccupied periods, the annual lighting load may be nominal. Generally, the greater the peak loads for any particular system in an individual building, and the longer their duration, the greater will be the seasonal loads. The distribution loads will be decreased by reducing the amount of power required for pumps and fans, reducing heat loss or gain from ducts and pipes, and by eliminating steam, water and air leaks. Distribution loads are often excessive because systems are designed to operate continuously at the maximum capacity required to meet peak "building" loads, even though these peak loads occur for relatively short periods of time. (usually less than 5% of the year)

Peak efficiency is usually based on a one hour performance. Seasonal efficiency, which reflects the average for the entire season, is a better measure. It is the ratio of useful work (in British Thermal Units - BTU's) performed by the equipment over a period of time, to the BTU value of the fuel or electricity consumed by the equipment over the same period.

Reducing "building" loads, then "distribution" loads, and then improving primary conversion equipment efficiency are most effective when done sequentially, since the latter depends upon the magnitude of the first two and the potential for reducing distribution loads depends upon the magnitude of the building loads and upon the operating conditions of the distribution systems.

Changes implemented for a particular purpose often induce secondary effects which also influence energy usage. For instance, reducing lighting levels and increasing the efficacy of the lighting system also reduces the cooling load. On the other hand, it increases the heating load. Additional heat usually can be supplied more efficiently, however, and at lower energy cost, by the heating system rather than the lighting system. In large offices, schools and stores, where lighting is responsible for a large percentage of the energy which is used for cooling, efforts to reduce energy for lighting are particularly important.

A SUMMARY OF THE PRINCIPLES OF AN ENERGY CONSERVATION PROGRAM

- Identify the specific climatic conditions to which the building is exposed. Make a thorough examination of the mechanical and electrical systems and the building structure and determine the normal use and occupancy of the building to become familiar with existing conditions.

- Identify the magnitude of annual energy usage by quantity of fuel and electricity for each system.

- Set a "goal" or target for reduction in energy usage based upon potential savings for each system.

- Reduce the "building" loads which must be satisfied by the mechanical and electrical systems.

- Reduce thermal losses and the power requirements for the HVAC distribution systems. Improve the seasonal operating efficiency on the basis of the new "building" loads by making adjustments to the distribution systems to reflect the reduced "building" loads.

- Improve the seasonal efficiency of the primary energy-conversion equipment and make adjustments to the systems to reflect the reductions in the "building" and distribution loads.

- Replace worn out and inefficient equipment and systems, which can not be improved, with more efficient ones.

- Maintain records of monthly energy usage, and continuously monitor the systems to assure that the methods which have been adopted are performing as expected, and are meeting or exceeding the energy conservation goals which have been established. As building use and function change, energy conservation measures must be changed accordingly.

SECTION 2

MAJOR ENERGY CONSERVATION OPPORTUNITIES - PRIORITIES, EXAMPLES

INDEX

MAJOR ENERGY CONSERVATION OPPORTUNITIES - PRIORITIES, EXAMPLES

A. BACKGROUND

This Section of the Manual identifies the relative order of energy usage of the environmental systems by building type. It is intended to assist the reader to gain a perspective on the relative importance for each type of the building structural elements and segments of the mechanical and electrical systems which use energy. Before establishing priorities for an energy conservation program which will produce the greatest conservation benefits first, the reader must know the order of magnitude of energy usage in his own building. The case histories of actual buildings, where energy conservation programs have already been started, demonstrate the dramatic energy and cost savings which have been accomplished with minimal capital investment and can be repeated in similar situations.

The major energy conservation opportunities, labeled MECO-1 through 20 and the associated examples of the potential savings in fuel, power and dollars are not all inclusive, but they are a summary of the most important opportunities for energy conservation in many buildings. The savings show in each example were calculated to provide insight into the potential results of conservation efforts under specific conditions. A more comprehensive list of energy conservation opportunities and multiple options for each opportunity are described in Section 4 as guidelines.

Before implementing the options in Section 4, first follow the procedures outlined in Section 3. Identify the particular building structure, its characteristics, and use patterns. Select the options in Section 4 which are applicable to the building; then determine where possible, the potential savings in energy, for those options by using the charts and graphs in that Section.

B. PRIORITIES

Nationwide, the systems that consume the most energy in order of magnitude are: (1) heating and ventilating;

(2) lighting; (3) air conditioning (cooling) and ventilating; (4) equipment and processes; and (5) domestic hot water.

However, depending upon the climate; the building construction; use and mode of operation; and the type, control and efficiency of the mechanical and electrical equipment; the relative order of magnitude of energy use among the first three systems will change.

The amount of energy required for domestic hot water is significant in hospitals, housing, and athletic or cooking facilities in schools and colleges. In many areas of the country the amount of energy to heat water is second only to space heating in the north, and air conditioning in the south in housing. In hospitals the amount of energy to heat hot water may exceed the amount of energy required for lighting.

Religious buildings and public halls which frequently include meeting rooms, offices, and school facilities, are most likely to consume energy in the same pattern as office buildings in the same geographic location—but in smaller quantities per square foot of floor area.

In those retail stores with high levels of general illumination and display lighting, and/or a large number of commercial refrigeration units, electricity consumes the greatest amount of energy.

In climatic zones with mild winters (below 2500 degree days See Fig.4) the seasonal cooling load may be larger than the seasonal heating load and may even consume more energy depending upon the respective efficiencies of each system. In office buildings, schools and retail stores in this zone, the electrical load for lighting, which is relatively independent of climate, may exceed either heating or cooling. Buildings used for only a few hours per week, however, may consume more energy for heating unless indoor temperatures are set back during unoccupied periods and boiler or furance efficiencies are high.

In cold climates, 6000 degree days and above, heating usually consumes the most energy per year in office buildings and schools with lighting and then cooling next. For retail stores in that zone, the most likely order of energy use is lighting-heating-cooling, or lighting-cooling-heating. Generally, heating consumes the most energy for religious buildings or other buildings used for only a few hours/week, in this zone (in fact, in most climatic zones above 3000 degree days), with lighting and cooling following in that order.

In mid-climates 2500 - 6000 degree days, the order of magnitude of energy by systems largely depends upon the type of mechanical and electrical systems and the characteristics of the building structure in which they are installed. The energy required for industrial buildings exclusive of process loads is generally similar in all zones to commercial buildings.

The following Matrix, Table 1, rates the systems by buildings and climates in the general order of annual energy usage with 1 the greatest and 5 the least. However, each building must be analyzed individually to determine its actual annual usage by system. The procedures for determining these values are described in Section 3.

TABLE 1

COMPARATIVE ENERGY USE BY SYSTEM

		Heating & Vent.	Cooling & Vent.	Lighting	Power & Process	Domestic Hot Water
Schools	A	4	3	1	5	*
	B	1	4	2	5	3
	C	1	4	2	5	3
Colleges	A	5	2	1	4	3
	B	1	3	2	5	4
	C	1	5	2	4	3
Office Bldg.	A	3	1	2	4	5
	B	1	3	2	4	5
	C	1	3	2	4	5
Comm.-ercial Stores	A	3	1	2	4	5
	B	2	3	1	4	5
	C	1	3	2	4	5
Reli-gious Bldgs.	A	3	2	1	4	5
	B	1	3	2	4	5
	C	1	3	2	4	5
Hos-pitals	A	4	1	2	5	3
	B	1	3	4	5	2
	C	1	5	3	4	2

Climatic Zone A: Fewer than 2500 degree days
Climatic Zone B: 2500 - 5500 degree days
Climatic Zone C: 5500 - 9500 degree days

The following Pie Diagrams, (Figures 1 and 2) which were produced by Dubin-Mindell-Bloome Associates and the National Bureau of Standards on the basis of a computer analysis, illustrate the relative magnitude of energy consumption for an office building if erected in a cold climate (Manchester, New Hampshire), and the identical building if located in a warm climate (Orlando, Florida). Heating is the single largest user of energy for the office building in New Hampshire, and the amount used for cooling is relatively small. In Florida the energy used for heating has decreased and cooling requires the greater amount.

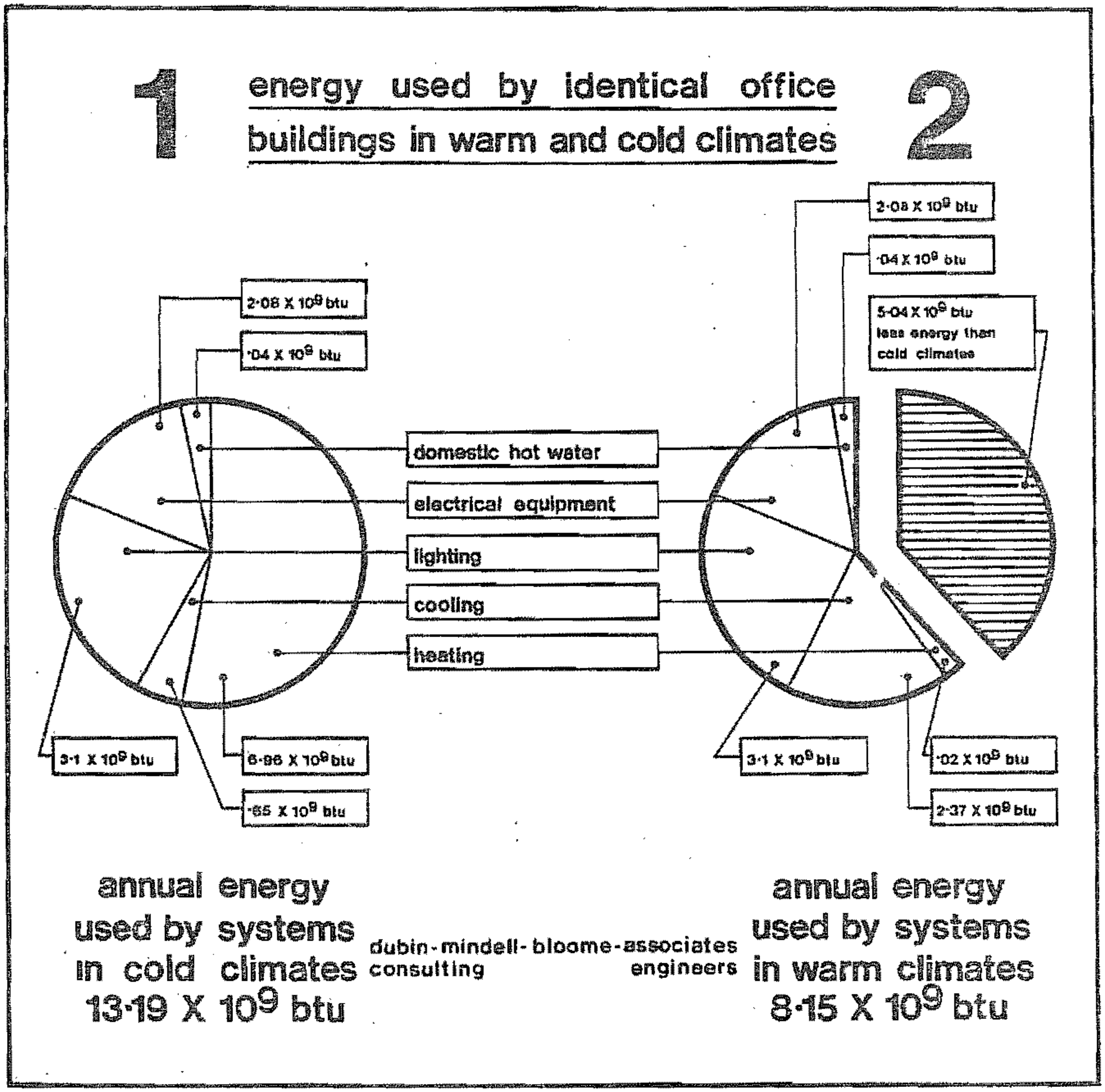
There is no general rule to determine which part of a particular system accounts for the most energy use of that system. The burner-boiler seasonal combustion efficiency can vary from close to 78% down to 30%; for buildings in climatic zones above 2500 degree days, improving the efficiency of the combustion device may be the single most effective measure. However, lighting accounts for a tangible percentage of energy used in all climates and the potential for conservation is high. Savings of 25% to 50% of the energy required for lighting are possible with little initial cost.

HVAC systems which mix hot and cold air together, or simultaneously heat and cool a space, are particularly wasteful and offer a high potential for energy conservation. These systems i.e. dual duct, terminal reheat, and multi-zone are described in Section 4 which also include guidelines for modifying operating modes to minimize energy usage.

In all cases, reducing the "building" load will conserve energy, but for some particular buildings, the savings in energy by decreasing the distribution loads and increasing the seasonal efficiency of the primary energy-conversion equipment are even greater.

C. <u>CASE HISTORIES</u>

Complete data is not available for buildings in which energy usage was measured before and after a conservation program was undertaken, and the results recorded and published, however two such case histories for buildings in New York are included here to show the results of a


1
energy used by identical office buildings in warm and cold climates
2
2·08 X 10⁹ btu
·04 X 10⁹ btu
5·04 X 10⁹ btu less energy than cold climates
2·08 X 10⁹ btu
·04 X 10⁹ btu
domestic hot water
electrical equipment
lighting
cooling
heating
3·1 X 10⁹ btu
6·96 X 10⁹ btu
·85 X 10⁹ btu
3·1 X 10⁹ btu
·02 X 10⁹ btu
2·37 X 10⁹ btu
annual energy used by systems in cold climates 13·19 X 10⁹ btu
dubin-mindell-bloome-associates consulting engineers
annual energy used by systems in warm climates 8·15 X 10⁹ btu

Figures 1 & 2 Engineering Data

Based on the NBSLD program from the National Bureau of Standards which calculated energy consumption for identical buildings in Manchester, New Hampshire and Orlando, Florida.

Gross floor area	- 126,000 $Ft.^2$
Occupants	- 600 people
Operation	- 8 a.m. to 6 p.m. weekdays only
Ventilation	- 15,000 cfm occupied times only
Infiltration	- 4,500 cfm continuous (1/4 air change/hour)
Lighting and power	- 3.4 $Watts/Ft.^2$ occupied times only
Indoor conditions	- Heating 68°F occupied
	58°F unoccupied
	Cooling 78°F occupied only
Outdoor conditions	- Variable - NOAA weathertape

comprehensive energy conservation program only one year after implementation. The energy saved by performing multiple energy conservation options is not always simply the sum of the savings for each individual measure. For instance, reducing the heat loss, or "building" heat load, by a 10% reduction in infiltration, and then increasing seasonal burner-boiler efficiency by 15%, results in a total energy saving for heating of 23 1/2% not 25%. The case histories that follow indicate the net savings achieved through multiple conservation options which were exercised.

For an analysis of the energy savings which are identified for each of a number of individual conservation measures and the net savings due to various combinations refer to Appendix B.

CASE HISTORY 1

A. MAJOR OPERATIONAL CHANGE:

(1) 15°F. NIGHT AND WEEKEND SET BACK. AND INDOOR TEMPERATURES LOWERED DURING OCCUPIED HOURS IN WINTER.

(2) INDOOR TEMPERATURES RAISED TO 78°F. IN SUMMER.

(3) LIGHTING LEVELS REDUCED BY 30%, AND ALL LIGHTS SHUT OFF WHEN NOT NEEDED.

(4) COOLING EQUIPMENT OPERATING HOURS REDUCED BY 20%.

(5) DOMESTIC HOT WATER CIRCULATING PUMPS TURNED OFF AT NIGHT.

B. BUILDING

Office building, New York City
Floor area: 2,000,000 sq. ft. No of stories: 54

C. ANNUAL ENERGY CONSUMPTION BEFORE CONSERVATION PROGRAM:

(1) Purchased steam: 278,464,000 lb. steam/yr. @ $3.20/1000 lbs.*

(2) Electricity: 51,909,000 KWH/yr. @ 4¢/KWH including demand.*

D. ANNUAL ENERGY CONSUMPTION AFTER OPERATIONAL CHANGES:

(1) Steam: 188,017,000 lb. steam, a savings of 32.5%

(2) Electricity: 39,264,000 KWH, a savings of 24.5%.

E. ANNUAL SAVINGS IN DOLLARS;

$758,000

F. COSTS TO IMPLEMENT;

No construction costs. Engineering fees paid are not available.

*Steam and electricity rates as of December 1, 1973.

CASE HISTORY 2

A. MAJOR OPERATIONAL CHANGES:

(1) COMPUTER CONTROL PROGRAM OPTIMIZED TO RESET CHILLED WATER AND TERMINAL REHEAT WATER TEMPERATURES IN ACCORDANCE WITH LOADS.

(2) OUTDOOR AIR OPERATED ON AN ENTHALPY CYCLE

(3) STEAM CONVERTER REPIPED

(4) OPERATIONAL TIME FOR PUMPS AND FANS REDUCED.

(5) 25% OF FLUORESCENT TUBES REMOVED.

B. BUILDING:

Office building, New York City

Floor area: 800,000 sq. ft. No of stories: 22

Occupants: 6,000/day - 1500 at night (Building operated 24 hrs./day - 6 days/week)

C. ANNUAL ENERGY CONSUMPTION BEFORE CONSERVATION:

(1) Purchased steam: 160,000,000 lb. steam/yr (1970) @ $5.30/1000 lbs.*

(2) Electricity: 36,000,000 KWH/yr. @ 5.0¢/KWH including demand.*

D. ANNUAL ENERGY CONSUMPTION AFTER OPERATIONAL CHANGES:

(1) Steam: 97,000,000 lb. steam (1974) a savings of 39%

(2) Electricity: 34,000,000 ** KWH a savings of 6%.

E. ANNUAL SAVINGS IN DOLLARS:

(1) Steam: $334,000

(2) Electricity: $100,000*

F. COSTS TO IMPLEMENT: $12,000 for new steam converter piping (cost to remove bulbs, not available.)

*Steam and electricity rates as of December 30, 1974
**The true savings are unknown, since a substantial amount of new equipment had been installed in 1974.

D. MAJOR ENERGY CONSERVATION OPPORTUNITIES AND EXAMPLES

The following MECO's are only a few of the dozens of opportunities to conserve energy.

There are a large number of options which can be exercised to take advantage of each opportunity. Those which are listed here, in Section 2 , do not, by any means, comprise a complete listing, but hopefully, they will stimulate the reader to study the wider range of choices to conserve energy, which are described in Section 4 .

1. HEATING

The amount of energy or fuel required to heat a building is dependent upon the level of temperature and relative humidity indoors, the amount of ventilation and infiltration air that must be heated, the severity and duration of the outdoor temperature below indoor room conditions, the thermal properties of the building envelope, and the efficiency of the distribution system, burners, boilers and furnaces.

MECO 1 MAINTAIN LOWER INDOOR TEMPERATURES DURING THE HEATING SEASON

Lower indoor temperatures reduce the heating load due to ventilation and infiltration as well as heat loss by conduction through the building envelope.*

Lower the thermostat setting to 68°F or less during occupied hours.**See Section IV, Figure 13, page 103 for "Suggested Heating Season Indoor Temperature Standards."

Lower the thermostat setting to 58°F or less at night, on weekends, and during all other unoccupied periods. See Figure 14, page 105, and example below.

After reducing the heating loads, adjust the distribution system and boiler and burner accordingly to further reduce fuel consumption.**

An Example of Savings by Night Set-Back

1. OPERATIONAL CHANGE: THERMOSTATS LOWERED FROM 68° to 58°F AT NIGHT, WEEKENDS, AND HOLIDAYS.

2. ASSUMPTIONS:

   Office building, Chicago, Illinois (6500 degree days - Fig. 4)

   Floor area: 50,000 Sq. Ft.

   Conditions before operational change: Building occupied 40 hours per week; outside air supplied only during occupied periods; fuel consumption, 64,000 gallons of oil per year, @ 36¢/gal.

3. SAVINGS:

   Energy: 8200 gallons of oil per year; a savings of 12.8%.

   Dollars: $2950/year.

4. IMPLEMENTATION COST; None

* Terminal reheat systems are an exception

** Not included in the example below.

MECO 2 SHUT OFF OUTSIDE AIR DURING ALL UNOCCUPIED PERIODS

Close outside air dampers or shut off outside air fan during unoccupied hours of the heating season, including noon-day periods when buildings may be lightly occupied and periods when areas such as auditoriums, cafeterias, gymnasiums, dormitories and conference rooms are unoccupied.

Reduce or shut off outdoor air entirely in retail stores during periods of the day when occupancy is considerably less than normal.

In religious buildings shut off outdoor air for all days during the week, as well as nights, when the building is unoccupied.

See Section 4 , Figure 16, page 115 for "Suggested Ventilation Standards."

An Example of Savings by Shutting off Ventilation

1. OPERATIONAL CHANGE: SHUT OFF OUTSIDE AIR AT NIGHT AND OTHER UNOCCUPIED PERIODS BY CLOSING OUTSIDE AIR DAMPERS OF AIR HANDLING UNIT.

2. ASSUMPTIONS

   Office building, Minneapolis, Minn. (8400 degree days)

   Floor area: 300,000 Sq. Ft.

   Conditions before operational change: Unoccupied 128 hours per week; outdoor air supplied 24 hours per day @ 30 CFM per person; fuel consumption = 250,000 gallons of oil per year @ 36¢/gal.

3. SAVINGS

   Energy: 68,100 gal. oil per year, a savings of 32.5%

   Dollars: $24,500 per year

4. IMPLEMENTATION COST: None

MECO 3 REDUCE THE QUANTITY OF OUTDOOR AIR FOR VENTILATION DURING OCCUPIED HOURS

1. Reduce the amount of ventilation air during occupied hours by setting outside air dampers and controls. Generally only 5 CFM per person is necessary to maintain proper air quality, but smoking in many areas may raise the average requirements to about 8 CFM per person. See Section 4 , pages 113-118.

An Example of Savings by Reducing Ventilation Rate

1. OPERATIONAL CHANGE: ADJUST DAMPERS TO REDUCE OUTDOOR AIR FROM 22 CFM PER PERSON TO 8 CFM PER PERSON DURING OCCUPIED HOURS.

2. ASSUMPTIONS:

   Office building, Minneapolis Minn. (8400 degree days)

   Floor area: 350,000 Sq. Ft.

   Conditions before operational changes: Occupied 40 hours per week; outdoor air = 30 CFM per person, 2000 occupants = 60,000 CFM; fuel comsumption = 450,000 gallons of oil per year @ 36¢ per gal.

3. SAVINGS:

   Energy: 137,104 gallons of oil per year, a savings of 30%.

   Dollars: $4086/per year

4. IMPLEMENTATION COSTS: None

MECO 4 REDUCE THE RATE OF INFILTRATION

Air infiltrates through cracks around doors and windows, through construction joints, and through doors which are frequently opened. Infiltration occurs whether the building is occupied or not. When exhaust fans are operating and outdoor air ventilation is insufficient to provide makeup air, infiltration rates increase.

Reduce air leakage by sealing and caulking leaks around windows and doors.

Seal construction joints.

Reduce exhaust air volume and operating hours of exhaust systems.

See Section 4 pages 113-122 and Figures 17 and 18.

Example Showing Savings Due to Caulking

1. OPERATIONAL CHANGE: CAULK WINDOWS TO REDUCE INFILTRATION RATE FROM 1 AIR CHANGE PER HOUR TO 1/2 AIR CHANGE PER HOUR.

2. ASSUMPTIONS:

   School, Fargo, North Dakota (9000 degree days)

   Floor area: 300,000 Sq. Ft.

   Conditions before operational changes; Occupied 36 hours per week; average indoor temperature during unoccupied periods = 60°F; existing double windows (26,000 Sq. Ft.) = 1000 windows; present fuel consumption = 225,000 gallons per year @ 36¢ per gallon.

3. SAVINGS:

   Energy: 33,300 gallons of oil per year, a savings of 14.8%

   Dollars: $11,988 per year

4. IMPLEMENTATION COST:

   $10,000 for caulking material and labor.

MECO 5 REDUCE FAN HORSEPOWER

The quantity of air (in cubic feet per minute - CFM), circulated for heating can often be reduced in response to reduced heating loads, or upon an analysis which indicates that the current CFM circulated is not required. Air quantities, set for cooling loads, may often be reduced during the heating season when the same system is used for both heating and cooling. Reducing the air quantity for systems operating against high static pressures, with motors 25 horsepower or larger, can result in significant savings during both the heating and cooling season.

See Section 4 , page 197 and Figures 23 and 24 for savings resulting from reduced air flow with supply and exhaust fans.

Example of Energy Savings by Reducing Air Flow

1. OPERATIONAL CHANGE: REDUCE SUPPLY AIR QUANTITY BY 20% BY REDUCING FAN SPEED 6%. FAN SPEED IS REDUCED BY CHANGING THE DRIVER PULLEY.

2. ASSUMPTIONS:

   Retail Store, New York, New York

   Floor area: 100,000 Sq. Ft.

   Condition before operational change: Air quantity = 1 1/2 CFM/sq. ft., 1 1/2 CFM x 100,000 sq. ft. = 150,000 CFM @ 6" s.p. Fans operate for 2,500 hours/yr. Energy used 360,000 KWH/yr @ 5¢/KWH.

3. SAVINGS:

   Energy: 118,000 KWH/year, a savings of 33%.

   Dollars: $5940/year.

4. IMPLEMENTATION COST:

   Less than $500. for pulley change and labor.

MECO 6 IMPROVE COMBUSTION AND BOILER EFFICIENCY

The efficiency of the boiler/burner unit or furnace decreases rapidly when combustion is improper, when the combustion surfaces accumulate soot and scale, or when excess combustion air increases the stack temperature. Any percentage increase in seasonal boiler/burner efficiency directly reduces fuel consumption in the same proportion.

Test the combustion efficiency with proper instruments and adjust the firing rate and combustion air rate accordingly.

Adjust the automatic damper to control the draft in accordance with the firing rate.

Remove scale and soot from the boiler.

See Section 4, "Heating", pages 124-125 for detailed guidelines for boilers, furnaces, and burners.

An Example of Energy Savings by Improving Combustion Efficiency

1. OPERATIONAL CHANGE: DESCALE BOILER SURFACES, REMOVE SOOT, ADJUST COMBUSTION EFFICIENCY TO IMPROVE BOILER-BURNER EFFICIENCY BY 10%.

2. ASSUMPTIONS:

   Retail store, New York, New York (4800 degree days)

   Floor area: 100,000 sq. Ft.

   Present operation:

   Fuel consumption = 100,000 gallons of oil per year @ 36¢ per gallon; occupied 72 hours per week.

3. SAVINGS:

   Energy: 10,000 gallons of oil per year, a savings of 10%

   Dollars: $3600 per year.

4. IMPLEMENTATION COSTS:

   $500 per year to service burner and boiler at 4-month intervals during the heating season.

2. COOLING

The amount of energy required to cool a building is dependent upon the level of temperature and relative humidity indoors; the amount of ventilation air and infiltration air that must be cooled and dehumidified; the severity and duration of the outdoor temperature and humidity above indoor room conditions; the thermal properties of the building envelope; the heat gain through walls, roof and windows due to solar radiation; and the magnitude and duration of the internal heat gain due to people, and equipment which emits heat and/or moisture.

MECO 7 OPERATING HOURS

Shut off all refrigeration equipment and auxiliaries, including fans, pumps, cooling towers, and condensers during all unoccupied hours-at night, on holidays and weekends.

Delay the operation of the refrigeration system for one or two hours in the morning and shut off prior to closing time except in the severest hot spells.

See Section 4 , "Cooling", page 158.

An Example of Savings Due to Reducing the Number of Hours of Operation of the Cooling System during Occupied Hours

1. OPERATIONAL CHANGE: ENTIRE COOLING SYSTEM OPERATED TWO HOURS LESS PER DAY FOR SIX DAYS PER WEEK.

2. ASSUMPTIONS:

   Retail store (department), New York, New York

   Floor area: 250,000 Sq. Ft.

   Conditions before operational changes:

      Cooling system operated 84 hours per week;
      electric rate = 5¢/KWH

3. SAVINGS:

   Energy: 234,800 KWH per year, a savings of 14%.

   Dollars: $11,700 per year

4. IMPLEMENTATION COST: None

MECO 8 REDUCE THE QUANTITY OF OUTDOOR AIR VENTILATION

Measures to reduce outside air ventilation (and infiltration) to conserve heating energy will also result in decreased summer cooling loads. Where infiltration exceeds 1/2 of an air change per hour for buildings in humid climates, measures to reduce infiltration will provide major energy savings for cooling as well as for heating.

During occupied hours, reduce the amount of air for ventilation as in the measure described in MECO 2.

See Section 4., "Heating" and "Cooling", and Figure 21, page 165.

An Example of Savings by Reducing the Amount of Outdoor Air for Ventilation

1. OPERATIONAL CHANGE: ADJUST DAMPERS TO REDUCE OUTDOOR AIR FROM 30 CFM TO 8 CFM PER PERSON DURING OCCUPIED HOURS.

2. ASSUMPTIONS:

   Office building, Miami, Florida

   Floor area: 100,000 Sq. Ft.

   Conditions before operational changes: Occupied 40 hours per week; outdoor ventilation air @ 30 CFM/person x 667 occupants - 20,000 CFM; electric costs = 3.5¢/KWH. Annual energy consumption for chiller = 715,000 KWH/yr. @ 3.5¢/KWH.

3. SAVINGS:

   Energy: 63,000 KWH per year, a savings of 8%.

   Dollars: $2233 per year

4. IMPLEMENTATION COST: none.

MECO 9 <u>USE OUTDOOR AIR FOR FREE COOLING</u>

For the many periods during the year when dry bulb temperature is below the setting for room conditions the use of outdoor air for cooling reduces the hours of operation of the refrigeration system.

Using outdoor air at nighttime to reduce the late afternoon sunloads which are stored in the building mass, and precooling the building, will result in fewer hours of compressor operation on the following day.

Enthalpy control may be even more effective in saving energy in locations where there are fewer than 8,000 wet bulb degree hours.

> On cool days open the damper to circulate 100% outdoor air for sensible cooling. It may be necessary to open the windows slightly to relieve pressure.
>
> If equipped with an enthalpy controller, set it to permit full outdoor air supply when the total heat content of the outdoor air is below room conditions.

See Section 4, "Cooling", page 159.

<u>An Example of Savings by Using Outdoor Air During Occupied Periods in an Economiser Cycle</u>

1. OPERATIONAL CHANGE: OPERATE AN ECONOMISER CYCLE FOR 690 HOURS PER YEAR BY OPENING OUTDOOR AIR DAMPER, CLOSING RETURN AIR DAMPER, AND OPENING A FEW WINDOWS FOR PRESSURE RELIEF.

2. ASSUMPTIONS:

   Office building, Denver, Colorado

   Floor area: 50,000 Sq. Ft.

   Condition before operational changes: occupied 40 hours per week.

   Annual Energy Consumption for Chiller: 245,000 KWH per year @ 3.5¢ per KWH; refrigeration cycle off at night.

3. SAVINGS:

   Energy: 85,000 KWH per year, a savings of 34.7%.

   Dollars: $2975. per year

4. IMPLEMENTATION COST: None.

MECO 10 PERMIT HIGHER INDOOR TEMPERATURES AND RELATIVE HUMIDITY DURING OCCUPIED HOURS.

By allowing higher temperature and humidity conditions in the summer, the cooling load is reduced and chillers or compressors will operate fewer hours and consume less energy per hour of operation. Higher room temperatures will also permit a reduction in supply air quantity with a savings in motor horsepower.

See Section 4 , Figure 20, page 163 for "Suggested Cooling Season Indoor Temperature and Humidity Standards."

An Example of Savings by Raising Indoor Temperature and Humidity Levels and Chilled Water Temperatures

1. OPERATIONAL CHANGE: DURING THE COOLING SEASON, RAISE INDOOR TEMPERATURES FROM 72°F to 78°F AND RELATIVE HUMIDITY FROM 50% to 60%. RAISE CHILLED WATER TEMPERATURES FROM 42°F to 46°F.

2. ASSUMPTION:

   Office building, Miami, Florida

   Floor area: 100,000 Sq. Ft. No of Stories: 10

   Conditions before operational changes: Building occupied 40 hours per week; annual energy consumption for chiller - 715,000 KWH @ 3.5¢ per KWH.

3. SAVINGS:

   Energy: 115,000 KWH per year, a savings of 16%

   Dollars: $4025 per year

4. IMPLEMENTATION COST: None, if done manually.

MECO 11 REDUCE THE SOLAR HEAT GAIN THROUGH WINDOWS

The solar heat gain through windows can be a large percentage of the cooling load in office buildings, schools and in small stores where show windows are in direct sunlight.

The greatest amount of solar radiation in the cooling season strikes the west and east glass, and next the southern facade.

> Reduce the solar heat gain through the windows by adjusting existing awning, blinds, or drapes on each window when they are in direct sunlight.
>
> Add reflective solar film to all windows in direct sunlight.

See Section 4, "Cooling", page 173, Figure 22.

Example of Savings by Reducing Solar Heat Gain

1. OPERATIONAL CHANGE: REFLECTIVE SOLAR FILM* ADDED TO EAST, WEST AND SOUTH WINDOWS TO REDUCE SHADE CO-EFFICIENT FROM .9 to .15. AIR AND CHILLED WATER SYSTEMS OPERATION REDUCED ACCORDINGLY.

2. ASSUMPTIONS:

   Office building, Miami, Florida

   Floor area: 100,000 Sq. Ft. No of stories: 10

   Conditions before operational changes: Cooling system in operation 40 hours per week; window area on west, south and east facade = 10,000 sq. ft. existing windows - clear, single glazed. Annual energy consumption for cooling 1,100,000 KWH @ 3.5¢/KWH.

3. SAVINGS:

   Energy: 170,000 KWH per year, a savings of 15%.

   Dollars: $5,900 per year.

4. IMPLEMENTATION COST: At installation cost of $1.25 per Sq. Ft. = $12,500.

*The film may require replacement after 8 - 10 years.

MECO 12 <u>REDUCE SUPPLY AND RETURN AIR FLOW AND CHILLED WATER QUANTITIES</u>

Reducing the cooling loads and analyzing the operation of the existing air conditioning system make possible many opportunities to reduce fluid flow.

While dampering, in the case of air ducts, and valving, in the case of water piping, will reduce flow rate and energy input to motors, greater savings can be gained by reducing motor speed and/or, for piping systems, changing the impellers. For systems with motors drawing 25 brake horsepower (BHP) or more, the yearly savings can be very significant. CAUTION: Don't neglect the smaller motors and systems; their aggregate energy draw may be very high. Follow references in MECO's 6 and 7 for fan and motor modifications during periods when the cooling system is in operation.

MECO 13 CLEAN AND DESCALE CONDENSER TUBES

The efficiency of chillers and refrigeration condensers decreases markedly as scale builds up in the tubes. Check condenser temperatures on a regular basis and descale tubes at least once per year.

See Section 4 , page 181.

Example of Savings by Condenser Maintenance

1. OPERATIONAL CHANGE: DESCALE CONDENSER TUBES TO REDUCE FOULING FACTOR TO .0005 OR LESS.

2. ASSUMPTIONS:

   Retail Store (department), Dallas, Texas

   Floor area: 100,000 Sq. Ft.

   Conditions before operational changes: Building occupied 72 hours per week; average fouling factor = .001; annual energy consumption for chillers-650,000 KWH/yr. @ 3.0¢/KWH.

3. SAVINGS:

   Energy: 116,000 KWH per year, a savings of 18%.

   Dollars: $3,480 per year.

4. IMPLEMENTATION COST:

   $1200 per year to maintain the condensers and all air conditioning equipment.

MECO 14 OPERATE AT HIGHER CHILLED WATER AND SUCTION TEMPERATURES TO INCREASE THE EFFICIENCY OF THE REFRIGERATION CHILLERS.

There are extensive periods of time (in some cases the entire year), during which the chilled water temperature can be raised by 4° or 6° or more. Accordingly, the refrigeration compressor or chiller can operate at higher suction temperatures. An increase of 1° in the suction temperature of the chiller, or compressor in direct expansion systems, results in a reduction of 1 1/2 to 2% in the power requirement for the refrigeration unit. The savings in operating costs by increasing chilled water or suction temperatures for systems of 15 H.P. and more are significant.

Raise the chilled water temperature from two to eight degrees higher when cooling load permits.

Raise the chilled water temperature in buildings for those portions of the day that cooling loads are likely to be lower (i.e. during slack business hours in retail stores; noon hours when office buildings are partially vacated; morning, pre-occupancy periods after a night shut down.)

See Section 4 , "Cooling" page 178.

An Example of Energy Savings by Raising Chilled Water Temperature

1. OPERATIONAL CHANGE: RAISE CHILLED WATER TEMPERATURE FROM 42° to 48"F. FOR ALL NORMAL OPERATION.

2. ASSUMPTIONS:

   Retail Store (department) Los Angeles, California

   Floor area: 50,000 Sq. Ft.

   Present conditions before operational changes:

   Building occupied 72 hours/wk; cooling system off at night; present energy consumption for refrigeration = 320,000 KWH/yr. @ 3.5¢ KWH.

3. SAVINGS:

   Energy: 32,000 KWH/yr., a savings of 10%

   Dollars: $1120/yr.

4. IMPLEMENTATION COST: None if done manually; nominal cost for controller and sensor for automatic operation.

MECO 15 REDUCE THE CONDENSING TEMPERATURE OF COMMERCIAL REFRIGERATION UNITS TO IMPROVE OPERATING EFFICIENCY

In general, air-cooled condensing units serve a large number of supermarket refrigeration cases. These units are often crowded into storage areas where they are partially blocked, mounted outdoors in direct sunlight, or mounted and neglected on the roof or another remote location.

Refer to Section 4, "Commercial Refrigeration", page 226 for guidelines.

Example

1. OPERATIONAL CHANGE: CONDENSER COILS FOR REFRIGERATION CLEANED TO REDUCE AVERAGE CONDENSING TEMPERATURE FROM 115°F to 95°F.

2. ASSUMPTIONS:

   Supermarket, New York, New York

   Floor area: 25,000 Sq. Ft.

   Conditions before operational change:

   120 H.P. installed capacity; refrigeration units operate an average of 12 hrs./day or 4380 hours/yr. Annual energy consumption for refrigeration = 420,000 KWH/yr. @ 4.5¢/KWH.

3. SAVINGS:

   Energy: 84,000 KWH/yr., a savings of 20%.

   Dollars: $3780/yr.

4. IMPLEMENTATION COST: Negligible

3. LIGHTING

Modifications to the operation of the lighting system and to the system itself provide the greatest opportunity to reduce energy consumption. Simply turning off unnecessary lights, day and night, and making greater use of available daylight for illumination saves energy for both lighting and air conditioning with no added costs. Better cleaning and maintenance practices increase the efficiency of the lighting system and provide the opportunity for lamp replacement (by lamps of lower wattage) or removal, or the switching off of lights, with little or no reduction in illumination levels.

MECO 16 UTILIZE DAYLIGHT TO REDUCE THE LIGHTING LOAD

Windows, properly exploited, can provide a sizeable part of the illumination required in small stores and office buildings during a large portion of the buildings occupied hours.

1. Open drapes and blinds during the day to take advantage of daylight at the perimeters of the building while controlling glare and excessive solar radiation. Drapes should be used to control light greatly in excess of that required. It should be recognized that excess daylight may cause materials to fade and change color.

2. Switch off the lights which are not needed when daylight can supply necessary illumination.

Refer to Section 4, "Lighting" for comprehensive guidelines to maximize the use of daylight for illumination.

Example of Energy Savings by Reducing Lighting Load

1. OPERATIONAL CHANGE: PERIMETER LIGHTS TURNED OFF APPROXIMATELY 50% OF OCCUPIED HOURS.

2. ASSUMPTIONS:

   Office Building, New York, New York

   Floor area: 100,000 Sq. Ft. No of stories: 10

   Glass area: 33% of net wall area

   Available daylight: 50% of occupied hours

   Switching arrangement: Separate switches for perimeter row of lights.

   Electricity used for lighting: 935,000 KWH @ 4.5¢/KWH

3. SAVINGS:

   Energy: 159,000 KWH/yr., a savings of 17%

   Dollars: $7155/yr.

4. IMPLEMENTATION COST: None

Additional savings in energy for cooling and refrigeration equipment will also result from reduced interior heat gain.

MECO 17 TURN OFF LIGHTS WHEN ENTIRE BUILDING OR PORTIONS ARE UNOCCUPIED

A large percentage of energy used for lighting is wasted when all lights are burning and only a samll portion of the building is in use.

Turn off lights at night.

Turn off lights in auditoriums, conference rooms, cafeterias, computer rooms and other areas when not used during the day.

Schedule cleaning hours during daylight. If this is not entirely possible, illuminate only that portion of the building which is being cleaned at any one time.

Refer to Section 4 "Lighting" for guidelines on the use and operation of lighting systems to conserve energy.

Example of Energy Saved by Turning off Lights

1. OPERATIONAL CHANGE: LIGHTING TURNED ON AT 8:00 AM AND OFF AT 5:00 PM FOR 5 WEEK DAYS. MINIMAL NIGHT LIGHTING DURING UNOCCUPIED HOURS.

2. ASSUMPTIONS:

   Office building, New York, New York

   Floor area: 100,000 sq. ft.

   Conditions before operational changes: Building occupied 40 hrs./wk. Lighting turned on at 7:00 A.M. and off at 7:00 P.M. for 5 week days. Connected lighting load of 4-watts per sq. ft., = 400,000 KWH X 4.5¢/KWH.

3. SAVINGS:

   Energy: 300,000 KWH/yr., a savings of 25%

   Dollars: $13,500/yr.

4. IMPLEMENTATION COST: None.

MECO 18 <u>REDUCE ILLUMINATION LEVELS TO REDUCE LIGHTING LOAD</u>

Lighting levels are frequently higher than necessary for a given task, and can be reduced in many areas of a building during the day to suit the task being performed. The level of illumination necessary over filing cabinets, dead corners, storage areas and some clerical areas, need not be as high as those levels for accounting areas, drafting tables or detail work stations occupied for many hours per day. Uniform lighting in large areas can be unnecessary and wasteful, in sparsely occupied spaces. Dfferent tasks done in an area may require different light levels; reduce lighting levels when possible.

1. Maintain existing lighting system to improve the footcandles/watt output.

2. Analyze the tasks to be performed and reduce the levels where the tasks are not so critical by:

   (a) Replacing existing lamps with lower wattage, lower output lamps.

   (b) Removing some lamps and ballasts from fixtures.

See Section 4 "Lighting", Figure 26, page 237 for Recommended Lighting guidelines and energy conservation options. See ECM 2 for additional measures involving switching, and the relocation and replacement of fixtures and ballasts.

<u>Example of Saving Energy by Reducing Lighting Level through Removing Lamps and Ballasts</u>

1. OPERATIONAL CHANGE: REMOVE 2 OF THE 4 LAMPS FROM HALF OF THE OVERHEAD 2' x 4', FLUORESCENT FIXTURES AND DISCONNECT THE ASSOCIATED BALLASTS.

2. ASSUMPTIONS:

   Retail store (department), Los Angeles, California

   Floor area: 100,000 Sq. Ft.

   Conditions before operational change: Lights on for 72 hrs. per week; lighting levels average 80 foot candles. Electric use, 1,400,000 KWH/yr. @ 3.5¢/KWH.

MECO 18 REDUCE ILLUMINATION LEVELS TO REDUCE LIGHTING LOAD (Cont'd)

3. SAVINGS:

   Energy: 375,000 KWH/yr., a savings of 28%

   Dollars: $13,000/yr.

4. IMPLEMENTATION COST: $3600 to remove lamps and disconnect ballasts.

5. NEW LIGHTING LEVELS AVERAGE 65 FOOTCANDLES. NOTE THAT THE LEVEL OF ILLUMINATION DECREASED ONLY 16%.

MECO 19 REDUCE THE LEVEL OF ILLUMINATION IN PARKING LOTS TO REDUCE ELECTRIC LOAD

Parking lots require an average of only one Footcandle of even illumination. Overlighting, inefficient light sources, and unnecessarily prolonged periods of operation account for excessive energy usage.

1. Reduce the level of lighting if over one footcandle, while maintaining reasonable uniformity of illumination.

   (a) Replace lamps with more efficient light sources.

   (b) Reduce wattage of lamps or remove unnecessary ones.

Refer to Section 4, "Lighting", page 236 for more comprehensive guidelines.

1. OPERATIONAL CHANGE: REDUCE THE WATTAGE OF THE LAMPS IN A PARKING LOT TO REDUCE LIGHTING LEVELS TO AN AVERAGE OF 1 FOOTCANDLE.

2. ASSUMPTIONS:

   Retail store (2500 car parking lot), Chicago, Illinois

   Conditions before operational changes: Lights operated 4 hrs./day x 315 days/yr. = 1260 hours/yr. to maintain an average of 2 footcandles.

   Electric usage - 256,000 KWH @ 3.5¢/KWH.

3. SAVINGS;

   Energy: 128,000 KWH/yr., a savings of 50%

   Dollars: $4,480/yr. @ 3.5¢/KWH.

4. IMPLEMENTATION COST: None, when lamps are changed at normal relamping periods.

4. DOMESTIC HOT WATER

There are easily-implemented opportunities to conserve energy used to heat hot water at minimal cost by lowering the temperature of hot water at the faucets and reducing the volume which is used.

In general, office buildings use 2 to 3 gallons ot hot water per capita per day, residences about 20 gallons/capita/day and religious buildings and stores less. Hospitals, laundries, cafeterias and restaurant kitchens use considerably more.

Heat lost from storage tanks and circulating pipes is in proportion to the temperature difference between the water and ambient air. Therefore, reducing the maintained temperature of hot water not only reduces the amount of energy required to heat each gallon of water used but also reduces the heat loss from the tank and piping system.

In buildings which have kitchens requiring very hot water for dishwashing, boost the temperature at the equipment, rather than maintaining a high temperature for the entire building hot water system. See ECM- 2 for details.

Reduce the temperature of hot water at faucets to 90°F.

Reduce the consumption of hot water in all buildings by flow restrictors in the piping, self-closing faucets or flow restrictor taps.

Refer to Section 4, "Domestic Hot Water", page 141, for data on usage in buildings and for conservation guidelines.

MECO 20 <u>REDUCE THE QUANTITY AND TEMPERATURE OF DOMESTIC HOT WATER</u>

<u>Example of Savings by Reducing Temperature and Quantity of Hot Water</u>

1. OPERATIONAL CHANGE: INSTALL 1/2 GPM SPRAY NOZZLES ON LAVATORY FAUCETS AND REDUCE TEMPERATURE FROM 135° TO 90°F.

2. ASSUMPTIONS:

   Office building, New York, New York

   Occupancy: 3500 people

   Hot water usage: 2 GPD/capita - 135°F. delivery temperature

   Total consumption: 7,000 gallons/day

   Oil consumption for hot water: 12,000/gallons/yr. @ 36¢/gal.

3. SAVINGS:

   Energy: 6240 gal./oil/yr., a savings of 52%

   Dollars: $2,250 per year

4. IMPLEMENTATION COST:

   $1750 for spray valves

SECTION 3

USE AND IMPLEMENTATION OF THE MANUAL

USE AND IMPLEMENTATION OF THE MANUAL

A. BACKGROUND

The opportunities to conserve energy are identified in bold type and numbered ECO-I through ECO-40 in Section 4 of this manual. For each sub-system, i.e. Heating, Cooling, Domestic Hot Water, Lighting, Power, HVAC, a brief discussion describes the conservation concept for each ECO and reference is made to the appropriate Figures which are the Charts, Graphs and Tables for use in quantifying the amount of energy which can be saved for each ECO. The options for consideration are summarized in the guidelines following each section.

Each set of guidelines includes a number of options for consideration, and in many cases, a choice must be made between them. In order to choose the appropriate guidelines and use the Graphs and Charts which are applicable, you must first identify the factors which are particular to your building. Instructions for preparing identification profiles are described in "B" below, which also describes the method of determining the amount of energy your building now uses. Use profile Forms, Figures 3,10,11 and 12, pages 55,71,75,85 to assemble the data you need.

Before assembling your identification and energy use profile, go back and reread the Introduction and Scope, and the Summary of Energy Conservation Principles, Section 1. Then review the major energy conservation opportunities (MECO's) which are summarized in Section 2. The case histories, and examples in Section 2. showing savings are presented to give you an idea of the potential economic benefits as well as energy conservation potential which are possible. The energy savings for each example selected are conservative. More dramatic savings are possible.

Before starting to construct your identification profiles, read all of Section 4 to gain a greater understanding of the general conservation opportunities which are available, but don't try to quantify savings for your building before you construct the four profiles, page 71 - 88.*

---

*The implementation costs given in Section are for New York City. Refer to Appendix A to determine costs for other locations.

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We strongly suggest that you obtain and read ECM- 2 after you have constructed your profiles to understand the broadest range of energy conservation opportunities which are available. An understanding of the further energy savings which are possible may influence your course of action. For instance, if after consulting Section 4 in ECM-1, you are contemplating caulking windows to reduce heat loss in the winter you may decide, after reading ECM- 2 that you can benefit from lower life cycle costs by investing in storm windows which will also reduce infiltration and conduction losses without the need for caulking. Storm windows will cost more initially, but will result in lower life cycle costs.

The Index at the end of ECM-1 and ECM-2 should be used to quickly find the information on specific subjects or systems which are of interest to you.

B. ENERGY LOADS

1. Building Load

The magnitude of the "building" load and the amount of energy required to maintain the desired indoor temperature and humidity levels is dependent upon (1) the location of the building and climate, (2) the degree of enviornmental control which is maintained, (3) the number of occupants and period of occupancy, (4) the thermal performance of building structure and (5) the use of the building.

a) Location

The location of the building affects the heating and cooling loads, since the angle and amount of solar radiation which strikes the building exterior surfaces determines the solar heat gain at any period of the year. Solar heat gain may be detrimental in the summer (by increasing the cooling load) and/or beneficial in the winter (by providing heat to the building and reducing the heat load).

The amount of sunshine also determines the amount of available daylight for natural illumination.

The location also determines the climatic conditions to which the building is subjected, and in turn, the peak, and magnitude of the annual heating and cooling loads.

b) Climate

The major climatic conditions which affect the amount of energy used for heating and cooling are: (1) temperature, (2) humidity, (3) wind, (4) the high-low range (diurnal swing) of (1), (2) and (3); (5) the severity of the winter (degree days) and (6) the severity of the summer (cooling wet bulb and dry bulb degree hours)

c) Degree of Environmental Control and Process Loads

The degree and length of time that indoor conditions such as temperature, humidity, amount of ventilation, and quantity and temperature of hot water, influence the size of the "building" load, and the amount of energy required to supply it.

The lighting levels influence the amount of electricity required for illumination when daylight is not available and used.

Energy usage for the operation of elevators, escalators, business machines, commercial refrigeration, cooking equipment, communications and special processes (packaging, etc.) is also dependent upon the period of time they are used. Processes and equipment which emit heat also affect the building's heating and cooling loads.

d) Heat Loss and Heat Gain

The magnitude of the heating and cooling loads due to conduction of heat through the building envelope, and the leakage of outdoor air (infiltration) which must be heated, cooled, and humidified or dehumidified also depends upon the thermal and structural properties of the building as well as on climate, and periods of operation of the heating and cooling equipment to maintain established indoor conditions.

2. Distribution Loads

The energy used in heating, ventilating and air conditioning systems to distribute hot or cold air or water is mainly for motor-driven fans, and hot or chilled water or condenser water motor-driven pumps.

Additional loads are caused by fluid leakage or heat transfer in hot or cold ducts and pipes.

In lighting systems, the fixtures themselves are responsible for reducing the effective lumen output from the lamps, and, along with lamps with low lumen/watt output, power losses from conductors, transformers and switch gear, account for a major amount of the energy used for lighting.

3. Energy-Using Equipment Efficiency

The primary energy conversion units, such as boilers, furnaces, compressors and chillers, which are supplied with energy in the form of fuel or electric power must supply all of the "building" and distribution loads. The amount of energy required to meet the "building" loads and distribution loads is dependent upon the efficiency of the primary energy-conversion equipment.

In order to improve the seasonal efficiency of existing equipment, the characteristics, condition and operating mode of the equipment and systems must first be determined.

C. DEVELOPING THE IDENTIFICATION BUILDING PROFILES - ENERGY CONSUMPTION/PARAMETERS

In order to quantify the total energy savings for your building by using the charts, graphs, and tables in ECM-1 (and ECM-2) which provide unit savings, complete the four-part profile which identifies each of the factors listed below which are particular to your building. Enter the information on the appropriate profile form as follows:

1. Location and climate zone profile - Figure 3, page 55.
2. Building type construction, condition and use profile Figure 10, page 71.
3. Mechanical and electrical systems profile - Figure 11, page .
4. Audit of present energy use - Figure 12, page 85.

Where the information is required for use with manual ECM-2 but not necessary for ECM-1, it is asterisked (*) on each profile form.

STEP 1: PREPARE A BUILDING LOCATION AND CLIMATIC ZONE PROFILE

Identify the climatic conditions to which your building is exposed over extended periods of time with the aid of climatic maps, (Figures 4 - 9) on pages 57-67, and enter each value on the appropriate line, Column A, Figure 3. The geographic locations should be plotted on each of the maps and relevant conditions read from the contour lines. If your building lies between contour lines, the values should be interpolated; if in doubt consult your nearest weather station or an enviornmental engineer through the ACEC Chapter in your State.

LOCATION AND CLIMATIC ZONE PROFILE FORM **fig. 3**

	Column A Value	From
Latitude		Figure 4
Heating Degree Days		Figure 4
Solar Radiation in Langleys		Figure 5
Degree Hours less than 54°F W.B. when D.B. is less that 68°F		Figure 6
Degree Hours greater than 78°F D.B.		Figure 7
Degree hours greater than 66°F W.B.		Figure 8
Degree hours greater than 85°F D.B.		Figure 9

The climatic information shown on the maps Figures 4 - 9 was obtained either from the Climatic Atlas or developed from AFM88/8 (See back of each figure for specific reference)

These maps provide a broad general picture of climatic conditions in any particular location; they cannot however indicate the macro-climate or variation of conditions experienced within local areas. Local knowledge of the climate should be used to modify the general conditions when more precise answers are required. For example, one area may be known to be 10°F colder in winter than the average of surrounding areas and the heating degree days should be modified accordingly.

1. Estimate the Annual Heating Degree Days and Identify Building Location (Figure 4)

Dry bulb degree days influence the annual energy consumption for "building" heating loads. For additional information on degree days in your city, see Reference 11. Degree day information is required for use with Figure 13 (to determine savings due to temperature set-back) and Figure 16.

2. Estimate the Annual Mean Daily Solar Radiation (Figure 5)

Solar radiation, (measured in Langleys or BTU's) influences the annual energy consumption for the "building" cooling load by increasing heat gain by radiation through glazing, and by conduction through opaque roofs and exterior wall surfaces. Solar heat gain reduces the "building" heating load in winter. For additional information on solar radiation effects, refer to Reference 6. Radiation values are useful to determine the benefits of controlling solar radiation to reduce cooling loads, (see Fig. 22).

3. Estimate the Annual Number of Wet Bulb Degree Hours Below 59°F W.B. when the Dry Bulb Degree Hours are Below 68°F. (Figure 6)

This value influences the annual energy consumption for "building" heating load to maintain relative humidity levels in the winter and is needed to determine the energy savings by reducing relative humidity levels using Figure 17.

4. Estimate the Number of Annual Dry Bulb (D.B.) Degree Hours when D.B. Temperatures are Above 78°F. (Figure 7)

This value influences the annual energy consumption for "building" cooling load due to heat gain by conduction through the building envelope, and for "building" cooling load required to lower the dry bulb temperature of outdoor air (for ventilation and infiltration) to room conditions of 78°F. (suggested standards, Figure 20). Use information from Figure 7 to determine the savings due to reduced D.B. degree hours alone by reducing infiltration and ventilation during the cooling season.

5. Estimate the Number of Annual Wet Bulb (W.B.) Degree Hours when the W.B. Temperature is Above 66°F. (Figure 8)

This value influences the annual energy consumption for "building" cooling load to cool and dehumidify outdoor

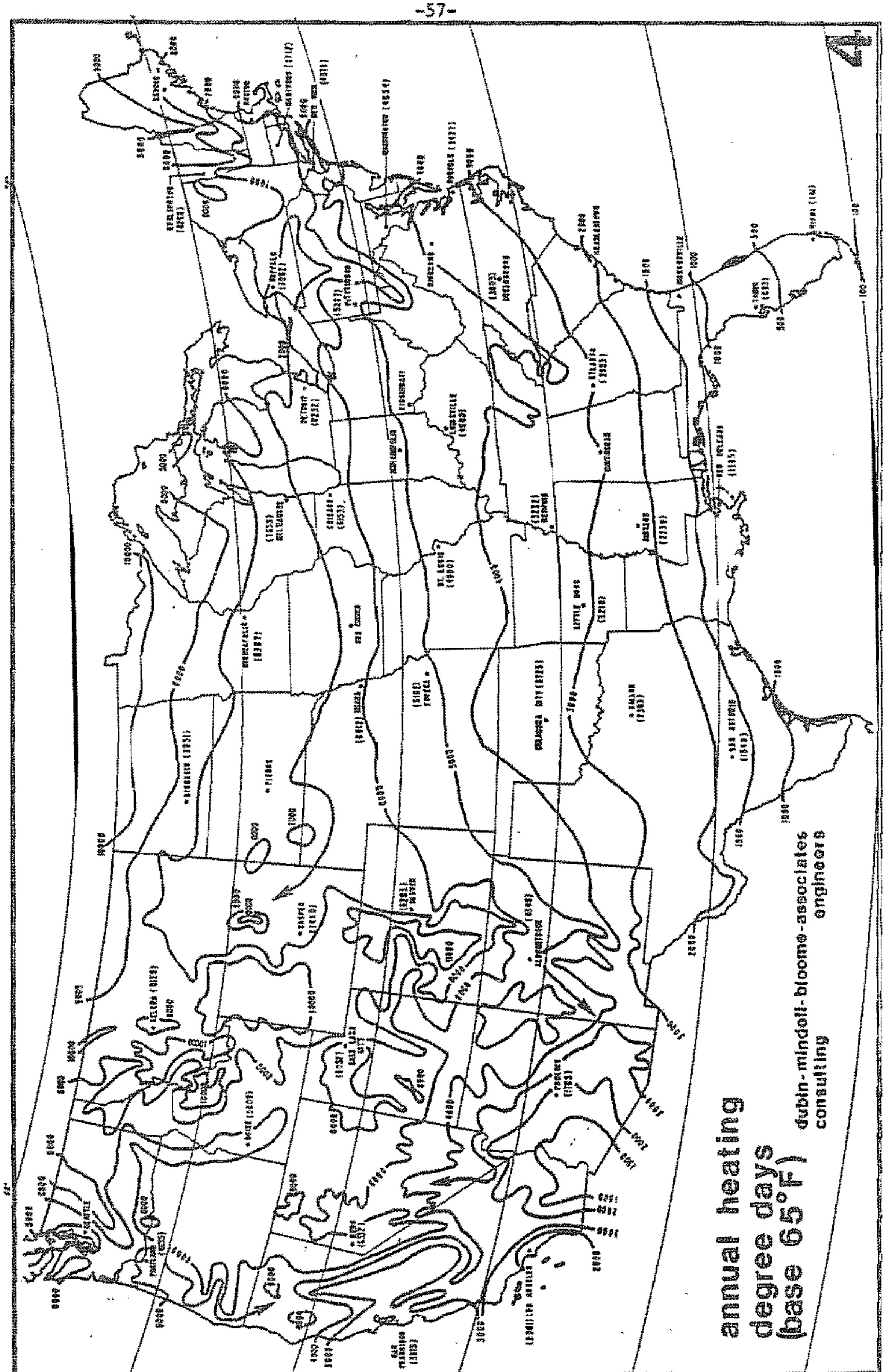

4
annual heating
degree days
(base 65°F)
dubin-mindell-bloome-associates
consulting engineers

Figure #4 Engineering Data

Source: Climatic Atlas of the United States
U.S. Department of Commerce
June, 1968
Page 36

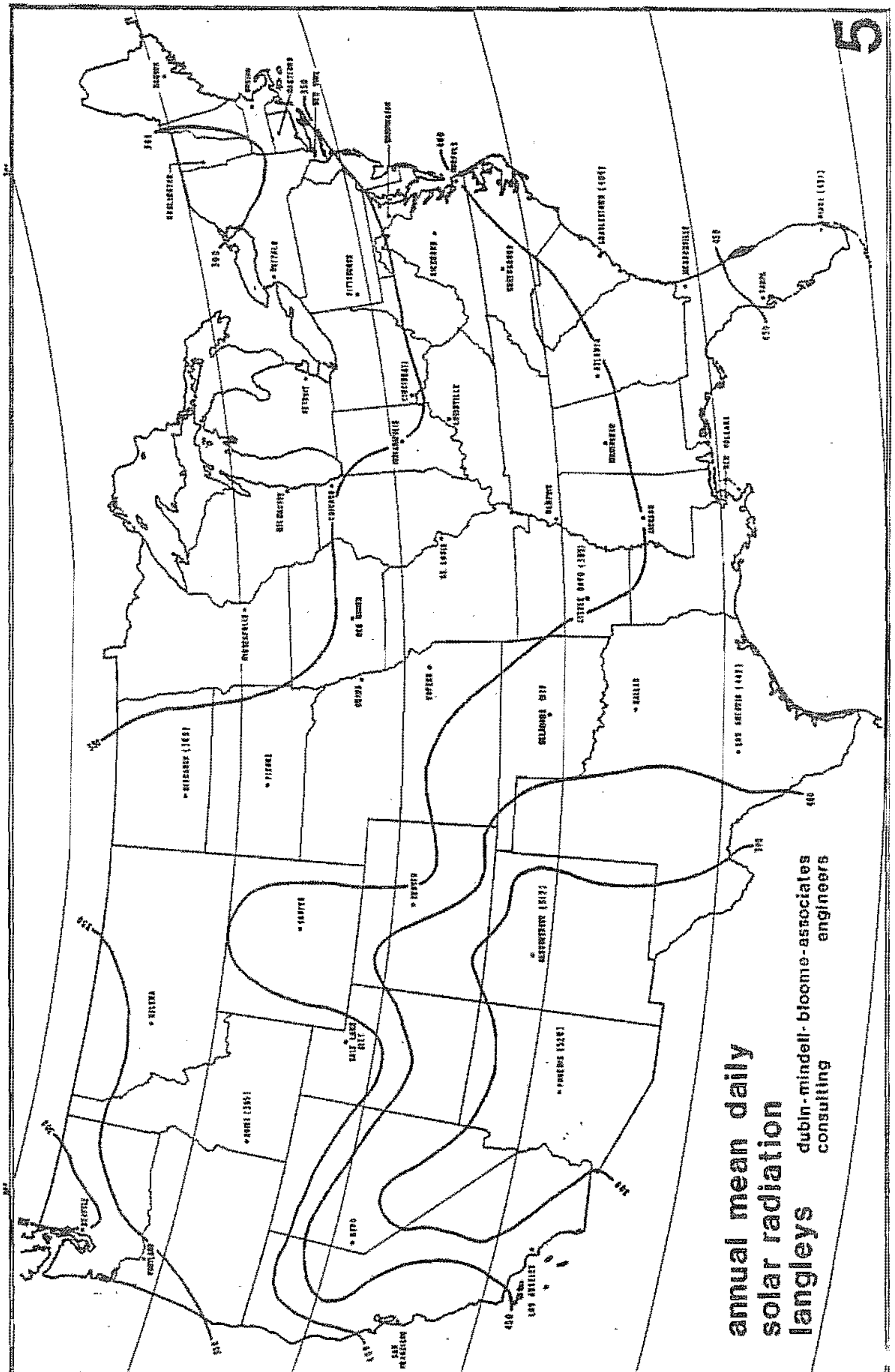
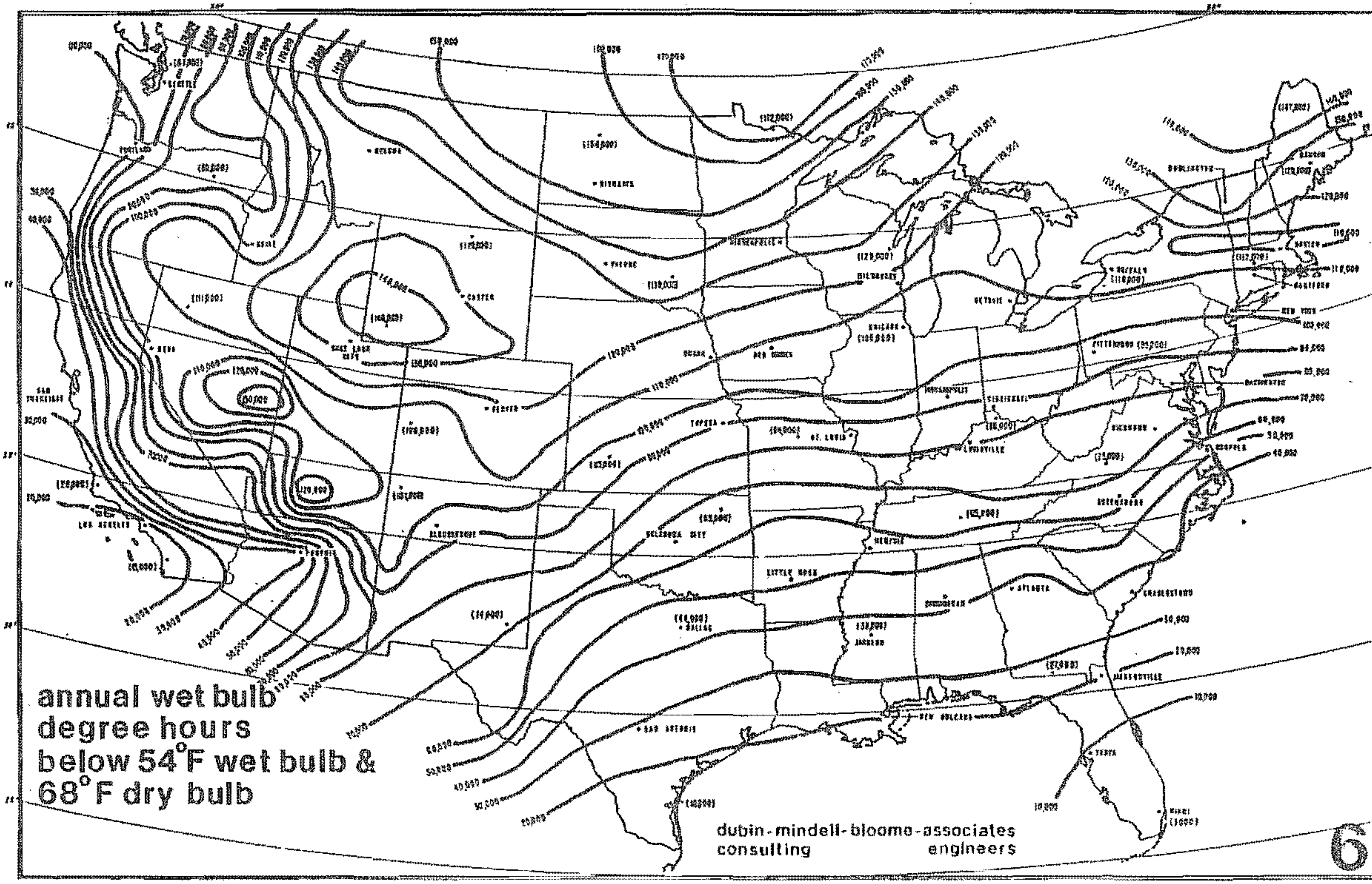

5
annual mean daily
solar radiation
langleys
dubin-mindell-bloome-associates
consulting engineers

Figure #5 Engineering Data

Source: Climatic Atlas of the United States
U.S. Department of Commerce
June, 1968
Page 70



annual wet bulb degree hours below 54°F wet bulb & 68°F dry bulb

Figure #6 Engineering Data

Source: AFM 88-8
U.S. Government Printing Office
15 June 1967

107 Locations in United States

<u>24 hrs/day October - April</u>

DB less than 68°.

WB taken in 5° increments less than 54°F WB.

Base WB taken at 54°F.

WB temperature difference taken from median of 5° range to 54°, i.e.: for 45 to 49 range, WB temperature difference = 54-47 or 7°F. Temperature difference multiplied by number of hours in each WB temperature range, for October thru April and summed for total. Locations with heating seasons significantly longer than October-April should be analyzed individually for maximum accuracy.

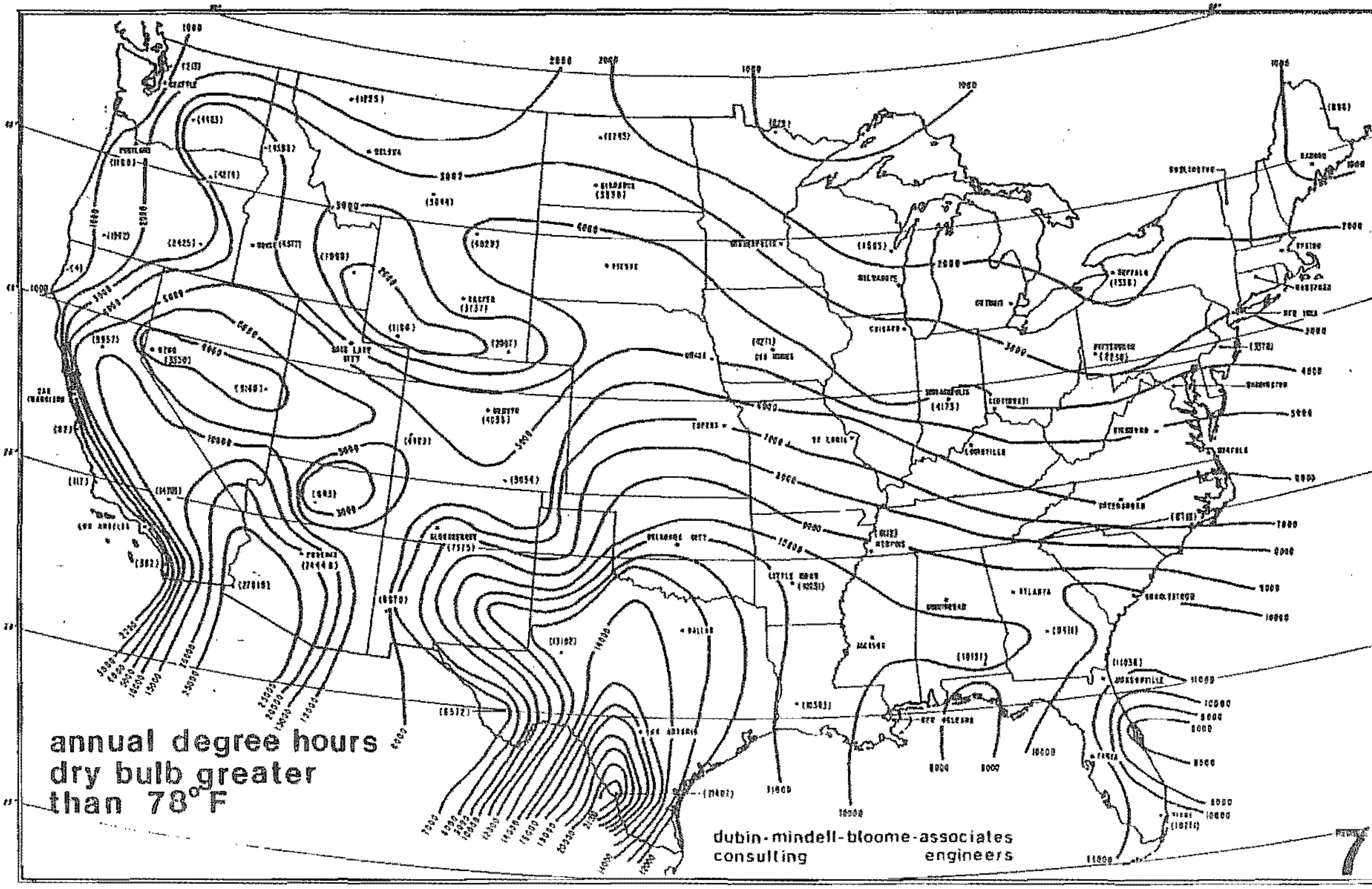

annual degree hours
dry bulb greater
than 78°F
dubin-mindell-bloome-associates
consulting engineers

Figure #7 Engineering Data

Source: AFM 88-8
U.S. Government Printing Office
15 June 1967

107 Locations in U.S.

12 Mos/yr 8 Hrs/Day 0930-1730

DB taken in 5°F increments beginning with 80-84°F.

DB temperature difference taken from median of 5°F range to 78°F, i.e., for 85° to 89°F range, DB Temperature Difference = 87°-78°F = 9°F. Temperature Difference multiplied by No. of hours in each DB Temperature Range and summed for total.

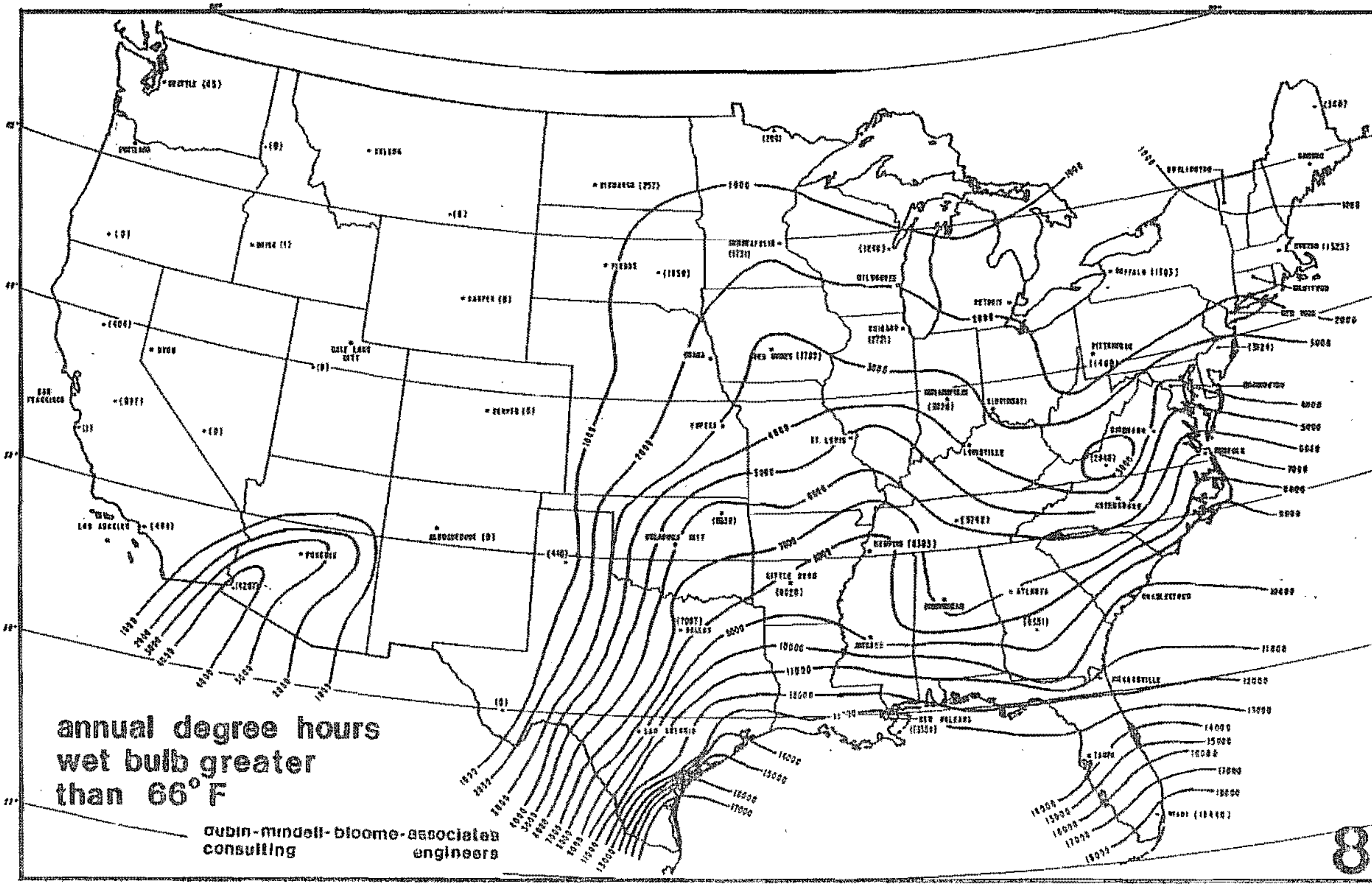

annual degree hours
wet bulb greater
than 66°F
dubin-mindell-bloome-associates
consulting engineers
8

Figure #8 Engineering Data

Source: AFM 88-8
U.S. Government Printing Office
15 June 1967

107 Locations in U.S.

12 Mos/yr 8 hr/day 0930-1730

WB taken in 1°F increments beginning with 67°F

WB temperature difference taken from 66°F

Temperature difference multiplied by No. of hours at each WB temperature and summed for total.

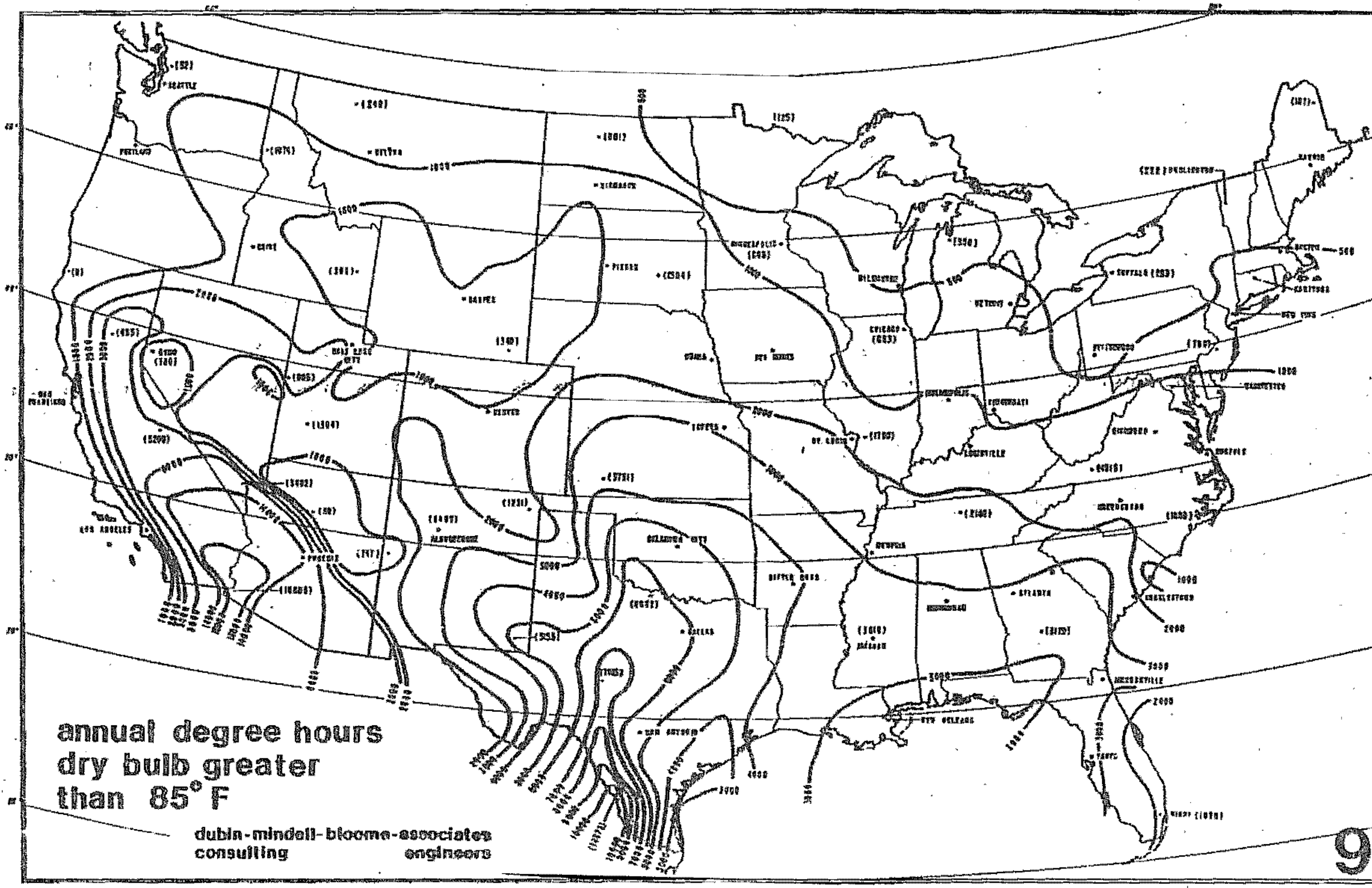

annual degree hours
dry bulb greater
than 85° F
dubin-mindell-bloome-associates
consulting engineers
9

Figure #9 Engineering Data

Source: AFM 88-8
U.S. Government Printing Office
15 June 1967

107 Locations in U.S.

12 Mos/yr 8 Hr/day 0930-1730

DB taken in 5°F increments beginning with 85-89°F

DB temperature difference taken from median of 5°F range to 85°F, i.e., for 90 to 94°F range, DB Temperature Difference = 92-85°F = 7°F

Temperature Difference multiplied by No. of hours in each DB Temperature Range and summed for total.

air to room conditions of 78° D.B. and 55% R.H.(refer to standards, Fig. 20). Use information from Figure 8 to determine total energy savings by reducing outdoor air leakage and ventilation during the cooling season (Figure 21).

6. Estimate the Number of Annual Dry Bulb Degree Hours Above 85°F. (Figure 9)

This value influences the annual energy consumption for "building" cooling load due to outdoor air when enthalpy conditions are low enough to permit full use of outdoor air, but existing cooling coil cannot maintain dry bulb conditions with 100% outdoor air.

STEP 2: PREPARE A BUILDING TYPE, CONSTRUCTION, AND USE PROFILE

Prepare a profile using the form on page 71 (Figure 10) to record the information. Use existing construction or as-built drawings and plans, if available, for building configuration, construction details, and dimensions. Verify the information on the site since changes may have been made to the building after the plans were completed. If plans do not exist, obtain all data by inspection of the building. In particular, note and record the physical condition of the building elements, especially apparent deficiencies, i.e. leaks, missing insulation, leaky windows, etc. Where there are a typical conditions which are not accounted for in Figure 10, i.e. auditoriums, gymnasiums or cafeterias used intermittently in office buildings, or store room areas in supermarkets, it is important to list areas, lighting system details, temperature levels, control systems, and the number of occupants and occupied periods so that these areas can be addressed separately and so that the amount of energy currently used, (and then conserved after implementing the individual guidelines in Section .) can be determined.

In listing the number of occupants for office buildings, record the average number of employees plus the estimated number of visitors; for retail stores, record the number of employees plus the number of customers; and for religious buildings record the number of people present at one time for various periods during the day and the week. Energy can be saved by reducing ventilation rates when occupancy is reduced even for portions of the day, and temperature can be reset during unoccupied periods for sections of the building.

BUILDING TYPE, CONSTRUCTION AND USE PROFILE - fig.10

Configuration and Construction:

Line No. (Circle Appropriate items and fill in blank)

1. Primary Bldg. Use:
2. Length, Feet and Orientation ______Ft. N. W. E. S.
3. Width, Feet and Orientation ______Ft. N. W. E. S.
4. Number of floors: ______

*5. Height from floor to floor ______

*6. Height from floor to ceiling______

7. Floor area, gross sq. ft. : Lines 2 x 3 x 4 = ______sq.ft.
8. Window Glazing: single, double, clear, reflective
9. Window Type: Fixed sash, double hung, casement
10. Window Condition: Loose fitting, medium, tight
11. Windows: Number area, orientation: North - No.______ gross area:______
12. " " " West - No.______ " ______
13. " " " East - No.______ " ______
14. " " " South - No.______ " ______
15. Door types and numbers: 1-single;* 2-vestibule;* 3-revolving

    North - No.______ Type______
16. Door Types: East - No.______ Type______
17. Door Types: West - No.______ Type______
18. Door Types: South - No.______ Type______

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Fig. 10 (Cont'd.)

Line No. (Circle appropriate item and fill in blank)

*19. Gross wall area and orientation: North: Lines 2Nx3Nx4x5=______sq.ft.

*20. Gross wall area and orientation: West : Lines 2Wx3Wx4x5=______sq.ft.

*21. Gross wall area and orientation: East : Lines 2Ex3Ex4x5=______sq.ft.

*22. Gross wall area and orientation: South: Lines 2Sx3Sx4x5=______sq.ft.

*23. Net wall area and orientation: North: Lines 19-11(area)_____sq.ft.

*24. Net wall area and orientation: West : Lines 20-12 " _____sq.ft.

*25. Net wall area and orientation: East : Lines 21-13 " _____sq.ft.

*26. Net wall area and orientation: South: Lines 22-14 " _____sq.ft.

*27. Exterior opaque wall construction: Circle Type:

1-frame; 2-curtain wall; 3-solid masonry; 4-brick & masonry;

5-masonry cavity

*28. Exterior opaque wall insulation: Material:____________

Thickness:________

*29. Roof construction: Circle Types: 1-masonry; 2-wood;

3-metal; 4-flat; 5-sloped; 6-pitched; 7-light; 8-dark

*30. Roof insulation: Type:________Thickness:________

"U"Value:___________

*Information required for ECM-2 only. All other items required for ECM-1 and ECM- 2.

*31. Floor: Circle Type: 1-slab on grade; 2-over heated space;

3-over unheated space; 4-wood; 5-concrete; 6-other

32. 1) Number of working hours/wk. 2) Number of Occupants ____

(a) For offices, employees & visitors; stores, employees & customers; religious buildings, occupants.

33. Number of custodial hours per week__________;

After dark summer________; after dark winter________;

Saturdays________; Sundays___________;

34. Temperature and relative humidity inside conditions:

	Season	Temperature	Relative Humidity
34a.	If Heated-Winter	Occupied Hours_____°F	__________%RH
34b.		Unoccupied Hours_____°F	__________%RH
34c.	If Air Conditioned – Summer	Occupied Hours_____°F	__________%RH
34d.		Unoccupied Hours_____°F	__________%RH

35. Ventilation: Outside air:

35a. During occupied hours on/off Amount in total CFM______

35b. CFM/person: Line 35a ÷ Line 32 (2) = ___________________

35c. During unoccupied hours on/off, Amount in total CFM___

STEP 3: PREPARE AN ELECTRICAL AND MECHANICAL SYSTEMS PROFILE

Prepare a profile of the lighting, power, heating, ventilating, air conditioning, and domestic hot water systems using Fig. 11, page 75 to record the information.

The original building and engineering plans, and as-built plans and specifications should be used with caution since the mechanical and electrical systems in older buildings have frequently undergone changes and/or the plans may

*Information required for ECM- 2 only. All other items required for ECM-1 and ECM-2 .

have been incomplete to begin with.) During your on-site survey, note and record a typical conditions such as lighting fixture patterns, or special requirements for portions of the building which are not accounted for in Figure 11. Small variations from the norm will not materially affect the conservation program.

Except for those buildings which employ full time operating and maintenance personnel, it may be difficult or impossible for the owners or operators of the buildings to complete the building and electrical and mechanical profiles without outside help to determine the type and physical characteristics or operating efficiencies of many of the mechanical and electrical systems. Seek assistance from your heating service oil burner (and/or boiler) maintenance company, which may also assist you in identifying other features and conditions of the heating and ventilating systems.

Companies which specialize in balancing HVAC systems are available for preliminary consulation to determine existing conditions. The local utility company can provide help in identifying electrical equipment and systems and information on motor efficiencies.

Where additional information is needed, your State Chapter of the American Consulting Engineers Council can recommend qualified consulting engineers whose services are available to make the preliminary assessments of your existing systems.

ELECTRICAL AND MECHANICAL SYSTEMS PROFILE **fig. 11**

Line No. (Circle appropriate item and fill in blank)

1. Electric lighting system

Lighting fixtures in primary spaces such as office areas, halls of worship, store sales areas.

(1) Incandescent; (2) Fluorescent: (3) Other note________

(4) # of fluorescent fixtures____;(5) # of lamps per fixture______;(6) Wattage per lamp______;(7) Total wattage of all fluorescent fixtures_______;(8) Total wattage of all incandescent lamps____(9) Total wattage of incandescent and fluorescent lamps_________.

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Fig. 11 (Cont'd)

Line No. (Circle appropriate item and fill in blank)

2. Lighting fixtures in secondary spaces, such as corridors, toilet rooms, storage rooms.

   (1) Incandescent; (2) Fluorescent; (3) Other note______

   (4) # of fluorescent fixtures_____; (5) # of lamps per fixture_______; (6) Wattage per lamp__________;

   (7) Total wattage of all fluorescent fixtures________;

   (8) Total wattage of all incandescent lamps_________;

   (9) Total wattage of incandescent and fluorescent lamps___________.

3. Total installed wattage: Lines 1 (9) + 2 (9)= _________

4. Average installed watts/sq.ft. Lines 3÷7 (Fig.10)_______

*5. Type lighting fixtures: (1) Pendant mounted; (2) Surface mounted; (3) Recessed; (4) Wall mounted; (5) Luminous ceiling; (6) Cove mounted; (7) Exterior lighting on walls; (8) Exterior lighting on standards.

6. Total wattage of exterior lighting for: (1) Security____ (2) Parking lots and drive______.

7. Area of parking lots______length x_______width=_____Sq.ft.

8. Parking lot lighting in watts/sq.ft., Lines 6 (2) ÷7 sq. ft. _______w/sq.ft.

9. Hours/wk. parking lot lighting is in operation___________

*Information required for ECM-2 only. All other items required for ECM-1 and ECM-2.

VERTICAL TRANSPORTATION

10. Escalators: Number________Operation hours/day___________

11. Elevators : Number________*Type: Gear, Gearless, Hydraulic Operation Hours/day________*Total connected H.P.__________.

DOMESTIC HOT WATER SYSTEMS

12. Method of generation and storage: Separate water heater; (1) Oil; (2) Gas; (3) Electric; (4) Coal; (5) Tankless heater on space heating boiler; (6) Tank heater on space heating boiler; (7) Storage tank size if any _____gals.; (8)*Tank insulation thickness________Type________(9) Aquastat setting_________°F.

13. Estimated annual usage:

    (1) Office Bldgs: Fig.10 Line 32(2)x750 _______gal/yr.

    (2) Restaurants: Meals served/yr.x3 gal/meal= _____gal/yr.

    (3) Religious Bldgs: Line 32(2)x50 gal/yr=_________gal/yr.
    (Does not include special cooking facilities)

    (4) Stores: Fig.10 Line 32(2)x number of days=_____gal/yr.

    (5) For residential buildings - 7200 gal/capita/yr.

    (6) For Schools - 50 gal/capita/week

    (7) For Hospitals - varies with type

*Information required for ECM-2 only. All other items required for ECM-1 and ECM-2.

HEATING AND AIR CONDITIONING SYSTEMS

14. Boilers or furnace type for space heating (Circle items)

    (1) Hot water; (2) Low pressure steam; (3) High pressure steam; (4) Fire tube; (5) Water tube; (6) Cast iron; (7) Steel; (8) Gravity hot air; (9) Forced warm air.

15. a) Boiler or furnace rating________ $BTUx10^3$/hr. or ________Boiler H.P.

    b) Present measured peak load combustion efficiency______%.

16. Compressors and chillers:

    (1) Number________

    (2) Rating of each in tons of refrigeration___________

    (3) Total tons of refrigeration (1) x (2) = __________

    (4) If electric drive, total motor horsepower ________H.P.

    *(5) If absorption units, total peak steam consumption_________H.P.

17. If central air conditioning systems, indicate: (1) Cooling tower motor sizes total_______H.P.; (2) Air cooled condenser motor sizes total_________H.P. Condenser pumps No_______ Total_______H.P.

18. If room air conditioners or through-the-wall units: Indicate (1) total number_______(2) Horsepower _______/unit.

    (3) Total connected Horsepower (1) x (2) = ____________.

*Information required for ECM-2 only. All other items required for ECM-1 and ECM-2.

Fig. 11 (Cont'd).

Line No. (Circle appropriate item and fill in blank)

19. If commercial refrigeration, indicate: (1) Number of cold cases or refrigerators_______; (2) Number of condensing units_________ (3) Total connected horsepower of condensing units_________H.P.

HVAC SYSTEMS

Check the systems and fill in appropriate information:

20. All air HVAC systems: Check types-fill in blanks.

(1) Single zone_______a) Number of air handling units____

b) Total Horsepower _______________

c) Total CFM/air handling unit_____

(2) Terminal reheat___a) Number of air handling units____

b) Total Horsepower _______________

c) Static pressure_________________

d) Number of reheat boxes__________

e) Type reheat Coil: 1. hot water 2. electric 3. steam

*f) CFM/air handling unit___________

(3) Variable Volume__a) Number of air handling units_____

b) Total horsepower _______________

c) Dump type system_________________

d) Vaned inlet______________________

e) CFM/air handling unit___________

*Information required for ECM-2 only. All other items required for ECM-1 and ECM-2.

(4) Induction_______ a) Number of air handling units____

b) Total horsepower ______________

c) Static pressure________________

d) Number of terminal units________

*e) CFM/air handling unit__________

(5) Dual duct_______ a) Number of air handling units____

b) Total horsepower ______________

c) Static pressure________________

d) Number of terminal units________

e) CFM/air handling unit__________

(6) Multi-zone units a) Number of air handling units____

b) Total horsepower ______________

c) Static pressure________________

d) Number of terminal units________

e) CFM/air handling unit__________

(7) Forced warm air furnaces No.__________

a) Total horse power of blowers_____

b) CFM/furnace____________________

21. Water-air systems

(1) 2 Pipe fan coil__ a) Number of units______________

b) Total connected horsepower______

(2) 4 Pipe fan coil__ a) Number of units______________

b) Total connected horsepower______

(3) Unitary Heat Pumps______ a) Number of units______________

b) Total connected horsepower______

*Information required for ECM-1 only. All other items required for ECM-1 and ECM-2.

22. Pumps

(1) Chilled water pumps______________

a) Number of units________________

b) Total connected horsepower______

(2) Condenser water pumps____________

a) Number of units ________________

b) Total connected horsepower______

(3) Boiler feed pumps_______________

a) Number of units________________

b) Total connected horsepower______

(4) Hot water pumps for space heating________________

a) Number of units ________________

b) Total connected horsepower______

(5) Recirculating pumps for domestic hot water__________

a) Number of units ________________

b) Total connected horsepower______

23. (1) Outside air fans_______________________________

a) Number of units________________

b) Total connected horsepower______

c) CFM/fan unit___________________

(2) Supply air fans (Check the number and total H.P. for all)

a) Number of backward curved multivane fans___ HP___

b) Number of forward curved multivane fans____ HP___

c) Number of axial fans________________________ HP___

d) Number of propeller fans____________________ HP___

e) CFM/fan unit_____________________________________

23. (3) Exhaust air fans________________________

a) Number of backward curved multivane fans____ HP___

b) Number of forward curved multivane fans____ HP___

c) Number of axial fans________________ HP___

d) Number of propeller fans______________ HP___

e) CFM/fan________________________

24. Check if installed:

(1) Fin tube radiators_____ (5)Supply and return ducts___

(2) Cast iron radiators_____ (6)Outside air dampers______

(3) Radiant heating coils___ (7)Steam piping____________

(4) Hot water piping_______ (8)Exhaust duct work________

STEP 4: PREPARE AN ENERGY CONSUMPTION AUDIT

Prepare a profile of your existing consumption of energy and record the data in the form Figure 12, page 85.

In some buildings (usually only a nominal number of large buildings) there are BTU or energy consumption meters which record quantities of fuel and power used. However, in most cases, these do not exist and the yearly energy used must be ascertained from the fuel and utility bills. To start with, determine the gross number of BTU's which your building uses per year per square foot of gross floor area. This is relatively easy to do and will provide the first bit of information to allow you to compare the energy your building uses with others as a starting point to establish a target, a goal for reduction in energy use. The ultimate savings in energy can be expressed as a percentage of your current consumption. You will be considering energy conservation measures by individual systems and subsystems. It is important to break down the total amount of energy used by the heating system as a whole, and by, or due to each of its sub-components. Energy for cooling, lighting and power must also be broken down into sub-system use.

1. Gather from your monthly utility and fuel suppliers' bills the annual usage of energy in gallons of oil, cubic feet of gas, pounds of propene, tons of coal and kilowatt hours of electricity. Record the gross yearly quantity of

fuel and power in profile Figure 12, Column A, page 85. Convert the units of fuel and electricity to equivalent BTU's by multiplying the quantities of fuel and power by the appropriate conversion factor in Column B. Record the product in Column C.

Conversion factors are based on the number of BTU's in a gallon of oil, cubic foot of gas, ton of coal and kilowatt hours of electricity. Total the gross number of BTU's and enter the result on line 7, of Figure 12. Determine the BTU's in thousands used per year, per square foot of floor space by dividing the gross quantity of BTU's in thousands (line 7, Figure 12) by the gross area in square feet (line 7, Figure 4) Many office buildings use from 80,000 to 500,000 BTU's/sq.ft./yr.

Stores consume energy at a rate within about the same range and religious buildings at wpmewhat less than the lower end of the range. Hospitals generally use more energy/sq.ft. and housing less. Schools use less energy/sq.ft. than office buildings. New office buildings are now being designed and constructed in an energy conservation mode to consume as little as 55,000 BTU's/sq.ft./yr. or less. A realistic energy budget goal for existing buildings may be as low as 75,000 BTU's/sq.ft./yr. for office buildings and stores' 60,000 BTU's/sq.ft./yr. for schools, and 35,000 BTU's/sq.ft./vr for religious buildings. See how close to these figures you can approach or if you can better them. Your existing consumption will give you a starting point. The difference between that figure and the target energy budget, will provide an order of the magnitude of savings to strive for.

Next break down the average annual BTU consumption by system, using Fig. 12, Sections 2,3,4 and 5 to record the data. The duration and severity of winter varies from year to year, and affects the quantity of heat required. To obtain the most accurate results, five or more years of energy consumption should be averaged to determine fuel consumption for a typical year for heating. If records are only available for the previous year's fuel consumption, these can be corrected to a typical year by dividing the actual fuel consumption by heating degree days actually experienced for that year, then multiplying by the average yearly degree days for the building's geographic location, as shown in Figure 4. The heating degree days for the year corresponding to actual fuel consumption can be obtained from the weather bureau, or a local fuel supplier.

EXAMPLE

$$\frac{\text{1973 fuel consumption}}{\text{1973 degree days}} \times \text{average yearly degree days} = \text{average yearly fuel consumption}$$

Fuel bills often do not differentiate between the end use for heating or other purposes, and an adjustment must be made. If oil, gas, or coal is the primary fuel, and is used for both heating and domestic hot water, the usage should be broken down between the two. The space heating load occurs in the winter, but the domestic hot water load is continuous for the whole year at a rate that can be assumed constant. To determine the amount of the monthly fuel bills that can be attributed only to heating, select one average winter month's consumption, subtract one average summer month's consumption and multiply the answer by the total number of heating months. The difference between total fuel used and heating fuel use will be the domestic hot water energy consumption.

If the building is heated by electricity and the total electrical usage of the building is metered and billed in a lump sum, the bill will include energy for heating, lighting, and power. To arrive at the amount of electricity used for heating only, it is necessary to assess the quantity used for lighting and power and subtract this from the total billing. In small buildings, a quick assessment of the electricity usage for lighting can be made by counting the number of lighting fixtures and multiplying the wattage of each lamp and the average number of hours that these are switched on during the heating season. This will give the total number of watt-hours consumption that can be attributed to lighting. Divide watt-hrs. by 1000 to get kilowatt-hrs. Similarly, a survey can be made of all electrical motors that are in use during the heating season and their nominal horsepower rating (multiplied by .800) to determine the approximate amount of electricity in KWH used for each hour of running. (This formula assumes an efficiency of 93% for electric motors). The KWH should then be multiplied by the number of hours of operation during the heating season to determine the total kilowatt hours that can be attributed to power. The sum of the kilowatt hours assessed for lighting and power should then be subtracted from the total power consumed by the building for the heating season, to determine the amount used for heating. In large, complex buildings where simultaneous heating and cooling are likely to occur, you should seek professional help to prepare a more accurate analysis of energy flow, if your maintenance staff is unable to do so. To determine the energy used for lighting and for power for the entire year, the same method of determining energy use in the heating season, described above, can be used for a 12-month period.

To determine the amount of energy used for air conditioning, estimate the energy for fans and pumps as outlined above. For electric driven refrigeration units the KWH can be estimated by deducting the energy used for lighting and other motors from the June, July, August, and September electric utility bills.

ENERGY USE AUDIT

fig.12

1. Gross Annual Fuel and Energy Consumption

Line No.

	A	B Conversion Factor		C Thousands of BTU's/yr.
1. Oil - gallons		x 138 (1) x 146 (2)	= =	
2. Gas - Cubic Feet		x 1.0 (3) x 0.8 (4)	= =	
3. Coal - Short tons		x 26000	=	
4. Steam-Pounds x 10^3		x 900	=	
5. Propane Gas - lbs.		x 21.5	=	
6. Electricity-KW.Hrs.		x 3.413	=	
7. Total BTU's x 10^3/yr.	....			

8. BTU's x 10^3/Yr/Per Square Foot of Floor Area ________

(Line 7 ÷ Figure 4, Line 7)

Use for (1) No.2 Oil; (2) No. 6 Oil; (3) Natural Gas; (4) Mfg. Gas

2. Annual Fuel and Energy Consumption for Heating

Line No.

	A	B Conversion Factor	C Thousands of BTU's/yr.
		x 138 (1)	=
9. Oil - gallons	______	x 146 (2)	= ______
		x 1.0 (3)	= ______
10. Gas - Cubic Feet	______	x 0.8 (4)	= ______
11. Coal - Short tons	______	x 26000	= ______
12. Steam - Pounds x 10^3	______	x 900	= ______
13. Propane Gas - lbs.	______	x 21.5	= ______
14. Electricity-Kw.Hrs.	______	x 3.413	= ______
15. Total BTU's x	....		= ______

16. BTU's x 10^3/Yr Per Square Foot of Floor Area ______
(Line 15 Line 7)

3. Annual and Energy Consumption for Domestic Hot Water

Line No.

	A	B Conversion Factor	C Thousands of BTU's/Yr.
17. Oil - Gallons		x 138 (1)	= ______
	______	x 146 (2)	= ______
18. Gas - Cubic Feet	______	x 1.0 (3)	= ______
		x 0.8 (4)	=

3. Annual Fuel and Energy Consumption for Domestic Hot Water (Cont'd)

Line No.	A	B Conversion Factor	C Thousands of BTU's/Yr.
19. Coal - Short Tons		x 26000 =	
20. Steam-Pounds x 10^3		x 900 =	
21. Propane Gas - lbs.		x 21.5 =	
22. Electricity-Kw.Hrs		x 3.413 =	
23. Total BTU's/Yr. x 10^3..................			
24. BTU's x 10^3Yr/Per Square Foot of Floor Area (Line 23 ÷ Figure 4, Line 7)			

4. Annual Fuel and/or Energy Consumption for Cooling (Compressors and Chillers)

Line No.	A	B Conversion Factor	C Thousands of BTU's/Yr.
a) if absorption cooling			
		x 138 (1) =	
25. Oil - Gallons		x 146 (2) =	
		x 1.0 (3) =	
26. Gas - Cubic Feet		x 0.8 (4) =	
27. Coal - Short Tons		x 26000 =	
28. Steam-Pounds x 10^3		x 900 =	
29. Propane Gas - lbs		x 21.5 =	
30. Total BTU's/yr x 10^3....................			
31. BTU's x 10^3/Yr Per Square Foot of Floor Area (Line 30 ÷ Fig. 4 Line 7)			
b) If Electric Cooling			
32. Electricity-KWH		x 3.413 =	
33. BTU's x 10^3/Yr Per Square Foot of Floor Area (Line 32 ÷ Fig. 4 Line 7)			

5. Estimated Annual Energy Consumption for Interior Lighting:

Line No.	A	B Conversion Factor	C Thousands of BTU's/Yr
34. KWH	______	x 3.413 =	______

Fig. 10 Line 3 x Fig. 10 Line 33 (1)

35. BTU's x 10^3/Yr/Per Square Foot of Floor Area______
(Fig. 10 Line 35 Col. C + Fig. 4 Line 7)

6. Estimated Annual Electrical Energy Consumption for all Motors and Machines If Building and Hot Water Are Not Electrically Heated: (1)

36. Total Kw. Hrs. ______ Less Kw. Hrs. Lighting______ = ______Kw.Hrs.
(Line 22, Col. A)

37. Kw. Hrs./Yr/Sq.ft. Floor area = ____________(1)
(Line 37 Col. C ÷ Fig.4 Line 7)

38. BTU's x 10^3/Yr/Sq.ft. floor area = (Line 37) x3.431______(2)

(1) and (2) If building heat and hot water are electrically heated, deduct the Kw.Hrs./Yr/per sq. ft. and BTU's/Yr/Sq.ft. for heating and hot water. (Lines 37 and 38)

D. PROCEDURES FOR IMPLEMENTING DETAILED CONSERVATION OPPORTUNITIES

Each of the following steps, 5-11, are abstracts of more complete options detailed in Sections 4A-G , and are listed here to denote the general type of action to be taken. The order of steps may be interchanged for many items depending on the conditions in your building and your resources (labor, mostly) to pursue each suggestion.

STEP 5: REDUCE NEGLIGENT WASTE

Using the guidelines of Sections 4A-G for each system as a checklist, identify those items in your building that can be cleaned, repaired, or servided to improve their performance and take the appropriate corrective action. Record the action and date performed in a permanent conservation record book which you should set up for your energy conservation program.

STEP 6: SET UP SYSTEM AND MAINTAIN RECORDS

Using your energy conservation record book, which should include all identification profiles and initial energy audit, maintain a running diary of all actions which you take to implement the ECO's appropriate to your building. Provide space for recording future fuel and energy bills, converted to BTU's, to ascertain the effectiveness of your energy conservation program. You will not be able to measure your accomplishments by comparing the utility bills only, due to rising costs; the numbers in BTU's are needed. (But remember, if you hadn't undertaken this program, the bills would have been even higher.) In your record book, outline the additional measures you plan to take and don't delay implementing them. As you accomplish each change, record the date and check off the item. Record the estimated time and expense for in-house labor or contract labor for each ECO you propose to initiate; after completion of the work, record the actual costs. CAUTION: Do not get bogged down in paper work. If you will be delayed by setting up and maintaining a record system, initiate immediate action for steps 5 and 7.

STEP 7: CHANGE THE ENVIRONMENTAL CONDITIONS

Review the way you operate your building. Close off unused spaces and cut off all services to them. Turn off unnecessary lights. Reduce the indoor temperatures during the heating season by resetting thermostats and adjust thermostats to maintain higher temperatures in the summer (See Section 4 for special instructions for terminal reheat systems and core areas of large buildings.) Turn off the air conditioning system and all auxiliary fans and pumps and condenser or cooling towers at night and on weekends. Reduce the quantity of domestic hot water and reset aquastats to maintain lower temperatures, prepare memos to occupants telling them what you are doing. Tag light switches and other control devices to make it easy to identify them; they will get more attention when highly visible. Operate drapes, venetian blinds, windows to maximize solar heat gain in winter, to make maximum use of daylight all year round, and to minimize solar heat gain in summer.

Select the guidelines form each portion of Section 4 that list the options for changing the enviornmental conditions and inaugurate them without delay.

When you find that dampers or other controls are not installed to permit you to take full advantage of any guideline, consult ECM 2 for further instructions.

STEP 8: REDUCE ENERGY CONSUMPTION FOR LIGHTING

Clean walls and other interior surfaces to increase the effectiveness of the lighting system. Clean the lamps, tubes, louvres and fixtures; next, replace lamps with ones of lower wattage, or with lamps or tubes that provide more lumens per watt. Remove lamps from fixtures where the tasks do not require the current illumination levels. Follow guidelines from Section 4F, "Lighting" for the measures and methods to follow. Where extra switches would permit a savings in energy without sacrificing visual performance consult ECM 2 for specific instructions for adding them.

STEP 9: REDUCE HEAT LOSS AND HEAT GAIN.

Reduce the "building" heating and cooling loads by reducing the air leakage into the building and heat transmission through the windows. Caulking cracks, weatherstripping, and adding storm windows and doors for small buildings in climatic zones of 5000 or more degree days will always result in a short payback period in fuel savings for each dollar invested. (Refer to Section 4 "Heating" and "Cooling") ECM 2 provides more data on window treatment and insulation for walls and roof to reduce heat loss and heat gain for each typical climatic zone.

STEP 10: REDUCE THE DISTRIBUTION LOADS.

In addition to repairing leaks and insulation, and cleaning filters in air systems to reduce losses, the piping, pumping, duct, and fan systems should be analyzed to determine the potential for reducing energy consumption due to these systems. Bear in mind, though, that the equipment may not have been operating even in accordance with present loads, so there may be a opportunity for conservation by adjusting primary equipment for present loads as well as for new load reductions. Before making any adjustments to motor speeds, dampers, and major controls a survey of the systems which they serve, and the actual conditions of operation and load should be made by competent personnel who understand the equipment and systems. Avoid do-it-yourself adjustments to these systems, since it is possible to seriously disrupt operation and jeopardize equipment if improper adjustments are made. For their guidance, we suggest that you provide ECM-1 and ECM-2 to your operation and maintenance personnel and to outside service organizations which you retain for maintenance and repairs. If you seek professional advice, make sure that architects and engineers whom you consult are familiar with these manuals.

STEP 11: IMPROVE THE EFFICIENCY OF THE PRIMARY ENERGY CONVERSION EQUIPMENT

Use qualified service personnel to measure combustion efficiencies, and the performance of compressors, chillers, cooling towers, condenser pumps and motors and to service and adjust them to operate in accordance with the new loads (which will have been reduced by actions taken in previous steps.) Equipment should be adjusted for "seasonal" efficiency, not simply peak efficiencies. Use the appropriate instructions and guidelines in Section 4 of ECM-1.

ECM- 2 should be consulted for specific measures which entail more than a nominal cost to improve operating efficiencies. It provides guidelines for major alteration or replacements. If systems and equipment are obsolete or beyond significant improvement, replace them.

SECTION 4-A

DETAILED ENERGY CONSERVATION OPPORTUNITIES

INDEX

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SECTION 4

HEATING & VENTILATION

INDEX

HEATING AND VENTILATION

A. BACKGROUND

The yearly consumption of energy for heating and ventilating can be reduced in three major categories:

(1) Reduce the "building" heat load
(2) Reduce the distribution system load
(3) Increase the efficiency of the primary energy-conversion equipment.

Categories 1 and 3 are addressed in this section, and category 2 in Section 4D , "Distribution and HVAC Systems".

B. "BUILDING" HEATING LOADS

One of the factors which determine the "building" heat load is the average difference between indoor and outdoor temperatures -- the larger the temperature difference, the greater the load. Reduce the load by maintaining lower indoor temperatures for as long a period as possible during the heating season. Lowering the temperature to 68°F. or less in the major areas of the building when it is occupied, and maintaining even lower temperatures in less critical areas will conserve energy. The amount of heat produced internally by lights, people and business machines (internal heat gains) and the amount of sunlight impinging upon the structure and transmitted through window panes and doors also reduces "building" heating load.

Realize greater savings by reducing the indoor temperature at night and during weekends. Outdoor temperatures are generally colder at night, and neither solar heat gain nor internal heat gains help at night to offset heat loss.

The amount of outdoor air which is introduced into the building for ventilation or which infiltrates through the building envelope also contributes to the heating load. This air must be heated and humidified to meet indoor conditions. Its ultimate effect on the load depends, as with other heating loads, upon the difference in indoor and outdoor temperatures and the quantity of outdoor air itself. In cold climates, shutting off ventilation air at night — when no ventilation is required for physiological reasons — may result in the single largest savings of energy.

"Building" heating load also depends upon the amount of moisture maintained in the building. The measure of the moisture content of the air is relative humidity (R.H.). When cold outdoor air enters the building -- as ventilation or infiltration -- the relative humidity of the interior of the building drops and additional moisture, in vaporized form, must be added. Vaporization requires energy in the form of heat. The greater the volume of outdoor air, the greater is the heat demand to supply humidification. Lowering the level of humidification conserves energy.

A building is more comfortable at lower temperatures if the relative humidity is maintained at a level within a range of from 20 to 40%. In a "tight" building with little air leakage and a small amount of ventilation, the energy saved by lowering the temperature will exceed the energy required to maintain humidity levels higher than 20%. Without using a computer for a seasonal analysis, the calculation to determine this trade-off is complicated. ECM II describes a method for making such an analysis. Since there is little medical knowledge available to support the contention that relative humidities higher than 20% are more beneficial to health, the recommendation here is to maintain a maximum of 20% R.H. during the daytime in occupied areas of the building and to add no humidification at night.

Finally, the building envelope -- the roof, exterior opaque walls, windows and doors, all of which are subjected to the outdoor climate -- influences the size of the "building" heating load. The effect of infiltration through the envelope is discussed above. In addition, heat is transmitted through the building envelope by conduction in accordance with the temperature difference between indoors and outdoors and the resistance to heat transfer offered by each of the building components.

The rate of heat transfer through the envelope is expressed as a "U" value -- BTU's/hour/sq. ft. of surface per degree of temperature difference between indoors and outdoors. The thin layer of air surrounding the exterior surface of the envelope adds to the insulating value of the wall or roof material. A lower U value means greater resistance to the transmission of heat and saves energy by reducing heat loss from the building.

Single panes of glass in still air (less than 15 m.p.h.) have a U value of 1.13. Double glazing reduces the U value to about .55. The U values of walls and roofs vary from .4 down to .06 depending upon the structural materials and the thickness of any insulation which has been added. Effective measures to reduce the U value and heating load include adding a storm sash to existing windows, replacing the windows with double glazing (or triple glazing in severe climates), and adding insulation to the interior or exterior surfaces of roofs and exterior walls.

Wind destroys the air film around exterior surfaces and causes the U value of the surfaces to increase. Heat loss, especially through window panes and uninsulated walls, increases accordingly. Use shutters, screens, trees, or other shielding devices to reduce wind velocity on the windows to limit heat losses.

C. DISTRIBUTION SYSTEM LOADS

A distribution system is necessary to supply the "building" heating load. It may carry hot water or steam directly from a boiler to radiators or to fan coil units in the spaces to be heated, or to air handling units which transfer the heat from the steam or hot water piping by means of coils located in the unit. Air warmed by air handling units is forced through ducts to registers or diffusers in the conditioned spaces. Return air, drawn through ducts back to the air handling units, is cleansed, along with fresh air also drawn into the unit, by air filters. The unit, when fitted with cooling coils, employs the same blower and duct system for air conditioning. Gravity hot air furnaces deliver hot air, without a blower, directly to the space through a short duct connection. Forced warm air furnaces are equipped with a blower which delivers warm air to the spaces and return air (through ducts similar to those of the air handling units) to the furnace.

The distribution loads, often called "parasitic" loads since they do not contribute directly to the comfort and requirements of the building occupants, include heat losses from piping and duct work, and electric power to drive fans or pumps against the resistance of the duct or piping system. Air, water or steam leaks from these systems, torn and missing insulation, and broken or ill-fitting windows are flagrant examples of negligent waste — they increase the load without performing useful work. Distribution loads are discussed extensively in Section 4D , "Distribution and HVAC Systems".

D. PRIMARY ENERGY-CONVERSION EQUIPMENT

Ultimately, energy, in the form of oil, coal, or gas is consumed by primary equipment and converted, by way of combustion, into heat in a boiler or furnace. The potential energy in the fuel is not fully realized, because it is difficult to achieve and sustain the correct mix, for combustion of air and fuel. Additional losses, thru the breeching or smoke pipe up the chimney, and heat radiation from the boiler surfaces or furnace jacket further reduce the useful heat output of the unit.

Although the efficiency of a burner-furnace unit at any instant may fall just short of 90% for those fueled by oil and gas (and somewhat lower for those fueled by coal), the seasonal efficiency is generally lower by 10% to 30%. as a result of stack losses during and between on-off firing periods. The amount of heat lost is a function of the amount of excess air required for complete combustion, the amount of draft at maximum and part loads, the amount of air leakage into the combustion chamber, the ability of the burner to modulate in accordance with varying "building" loads, the quality of the fuel, and the amount of soot and scale accumulation (reducing heat transfer) on the combustion surfaces.

Proper adjustment of burners, and maintenance of boilers and furnaces improve efficiency -- and reduce fuel consumption accordingly. Many units originally designed for coal, however, have been fitted with gas or oil burners and cannot be made to operate as efficiently as better quality units designed specifically for oil or gas.

After reducing the "building" distribution load, further improve the efficiency of the burner-boiler or furnace units by adjusting the firing rate to accommodate the new loads. Lower the temperatures of the water or air delivered from the unit. Radiation and convection losses from the unit will be reduced with lowered temperature and steam pressures. If, however, it becomes necessary to circulate a greater quantity of air or water to meet room loads, distribution loads may actually increase. To analyze this trade-off thoroughly, seek professional advice. In general, operate the primary equipment at lower temperatures just sufficient to meet room loads.

ECM 2 describes methods of recovering waste heat from boilers, furnaces, and exhaust air to conserve energy.

E. ENERGY CONSERVATION OPTIONS

ECO 1 SET BACK INDOOR TEMPERATURES DURING UNOCCUPIED PERIODS

Energy expended to heat buildings to comfort conditions when they are unoccupied (which, actually, is most of the time) is wasted. Save energy by setting back the temperature level at these times. The savings which can result vary with the length of time and the number of degrees that temperatures are set back. The percentage savings will be greater in warmer climates, but the gross energy saved will be greater in cold climates.

In areas where it is not necessary to maintain high temperatures during occupied periods, i.e. corridors and lobbies, maintain even lower temperatures than for the other spaces. See Figure 13, column B, for suggested winter night setback temperatures. Implement setback by resetting thermostats manually (if automatic setback control has not been installed), or adjusting controls to suggested temperatures (if clock, day-nite, or other automatic reset controls are available). Climate, type of system, and building construction will determine the length of the startup period required to attain daytime temperature levels. Experiment to decide upon the optimal setback temperature and startup time for any particular building. If, in extremely cold weather, experience indicates that the heating system does not raise the temperature sufficiently by the time the building opens for the day, set temperatures back to a level higher than those recommended here for those periods of time only.

fig.13

SUGGESTED HEATING SEASON INDOOR TEMPERATURES

	A Dry Bulb °F. occupied hours maximum	B Dry Bulb °F. unoccupied hours (set-back)
1. OFFICE BUILDINGS, RESIDENCIES, SCHOOLS		
Offices, school rooms, residential spaces	68°	55°
Corridors	62°	52°
Dead Storage Closets	50°	50°
Cafeterias	68°	50°
Mechanical Equipment Rooms	55°	50°
Occupied Storage Areas, Gymnasiums	55°	50°
Auditoriums	68°	50°
Computer Rooms	65°	As required
Lobbies	65°	50°
Doctor Offices	68°	58°
Toilet Rooms	65°	55°
Garages	Do not heat	Do not heat
2. RETAIL STORES		
Department Stores	65°	55°
Supermarkets	60°	50°
Drug Stores	65°	55°
Meat Markets	60°	50°

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FIGURE 13, CONTINUED

SUGGESTED HEATING SEASON INDOOR TEMPERATURES

	A Dry Bulb °F. occupied hours maximum	B Dry Bulb °F unoccupied hours (set-back)	
2. RETAIL STORES (Cont'd)			
Apparel (except dressing rooms)	65°	55°	
Jewelry, hardware, etc.	65°	55°	
Warehouses	55°	50°	
Docks and platforms	Do not heat	Do not heat	
3. RELIGIOUS BUILDINGS*			
		24Hrs. or less	Greater than 24 Hrs.**
Meeting Rooms	68°	55°	50°
Halls of Worship	65°	55°	50°
All other spaces	As noted for office buildings	50°	40°

Use Figure 14 to determine the actual savings in fuel for an average winter for any particular building. From Figure 3, the climate profile, select the degree days for the location and from Figure 12, line 16, find the number of BTU's per square foot per year now consumed for heating.

Enter the graph at the appropriate present heating energy consumption and degree day axes, intersect with the proper setback line, and follow the example line to determine the savings in BTU's per square foot per year. Multiply this value by the gross square foot floor area to give the total yearly savings in BTU's that can be expected for the entire building.

*and other spaces used for only a few hours per week.
**when outdoor temperatures are above 40°F.

heating

energy saved by night setback

fig. 14

dubin-mindell-bloome-associates
consulting engineers

read both axes in same order of magnitude in multiples of 10, 100, or 1000

saving btu x 10^3 per sq. ft. per year

present heating energy consumption btu per sq. ft. per year times selected order of magnitude

degree days

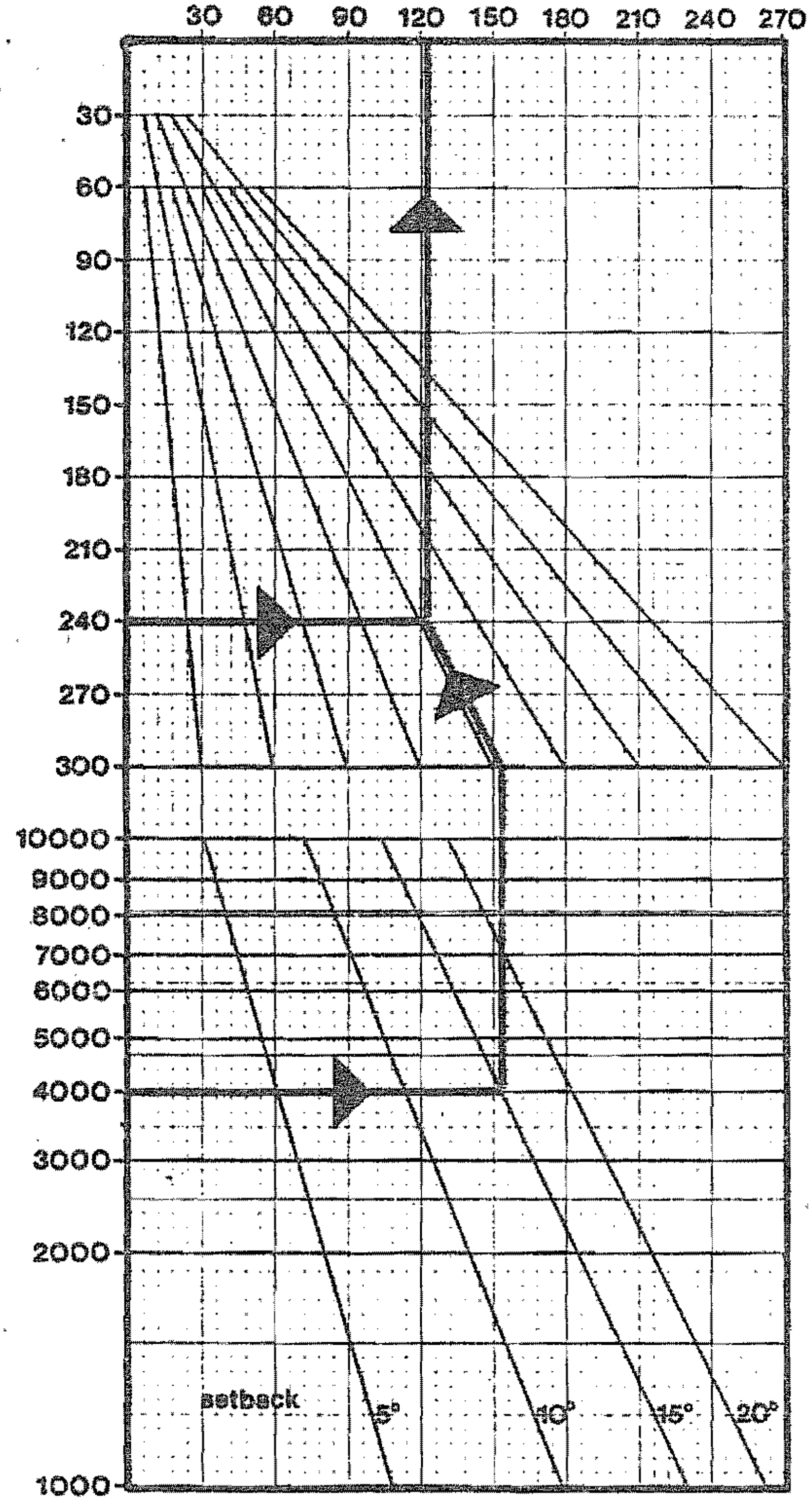

FIGURE #14 Engineering Data

References: AFM 88-8
U.S. Government Printing Office
15 June 1967

Climatic Atlas of the United States
U.S. Dept. of Commerce
June 1968

Five locations with heating degree day totals ranging from 1400-8400 were analyzed regarding time temperature distribution below 68°F DB. The percentage temperature distribution for each of the 5°F ranges which includes the setback from 68°F shown in the lower half of the Figure related to the total number of degree hours below 68°F was determined for 24 hr/day, 365 days/yr. This percentage was then plotted against annual degree days and expanded to cover the entire range of degree days and is shown as the lower half of the Figure.

The upper half of the Figure represents the range of heating energy consumed/sq.ft. for various buildings over the range of 1000 to 10,000 degree days. The extreme right hand line in the upper half represents 90% of the present consumption when projected vertically. Analysis of energy usage for heating by various buildings in several locations showed that it can be safely assumed that approximately 10% of the total heating energy consumption is during occupied hours. Therefore, savings by night setback are applicable to only 90% of the total heating energy consumption. The remainder of the upper half of the Figure simply proportions the energy saved based on the point of entry from the lower section.

Convert this figure to a quantity of fuel by dividing by an appropriate conversion factor. To convert to gallons of #2 oil, divide by 138,000 (the number of BTU's in a gallon); for #6 oil, by 146,000 (BTU's per gallon); for natural gas, by 1,000 (BTU's per cubic foot); for manufactured gas, by 800 (BTU's per cubic foot); and for tons of coal, by $26X10^6$ (BTU's per ton). Multiply this quantity by the unit cost for any type of energy used to calculate cost savings.

Example:

Find the yearly energy saved by lowering the temperature 10°F. during unoccupied hours for the following building:

Type	Office, 40 hrs. occupancy/wk.
Location	Minneapolis, Minn.
Floor Area	100,000 sq.ft.
Fuel	Light Oil (138,000 BTU/gal.)
Present Heating Consumption	76,000 BTU/sq.ft.-yr.
Heating Degree Days from Climatic Zone Profile	8,400

Enter Figure 14 at 8,400 degree days and 76,000 BTU/sq.ft.-year present consumption. Intersect with the 10° set-back line, and follow the example line to determine a savings of 21×10^3 BTU/sq.ft.-year.

Savings: Convert savings in BTU's to gallons at 65% seasonal efficiency

$$\frac{21{,}000 \times 100{,}000 \text{ sq.ft.}}{138{,}000 \times 0.65} = 23{,}411 \text{ gallon}$$

Assuming an average fuel cost of $.36 per gallon, then the savings in dollars per year is 0.36 x 23,411 or $8,428.

Results: Energy Saved 23,411 Gallons per year
Dollars Saved $8428.

ECO 2 REDUCE INDOOR TEMPERATURES DURING OCCUPIED PERIODS

See Figure 13, column A, for recommended heating season indoor temperatures. Maintaining lower indoor temperatures during occupied periods conserves energy, although savings are not as great as those for unoccupied hours. Reduce even lower the temperatures in less critical areas, such as corridors and lobbies, to realize significant savings. The amount of energy conserved will be greatest in buildings which normally have longer periods of occupancy (stores as opposed to schools), and in buildings or sections of buildings with the least internal heat gain and solar radiation to help with the heating load.

ECO 3 AVOID RADIATION EFFECTS TO COLD SURFACES

In cold climates the temperature of an interior surface of an exterior wall or window is considerably lower than room temperature, and people located near to the surface radiate heat to it. Even if the room temperature is 70° or 75°F., these occupants will feel cold, particularly if they are located near windows where the radiation effect is most severe. Often, in order to keep warm, they request that room thermostats be set higher. Overheating of the interior of these particular rooms results and heat loss and energy consumption increase accordingly. A few simple remedies will both save energy and enhance the comfort of the occupants.

ECO 4 REDUCE RELATIVE HUMIDITY LEVELS

Humidification systems vaporize water into the dry ventilating air to increase it's moisture content and achieve the desired R.H. within the building. This humidification process requires a heat input of approximately 1,000 BTU's to vaporize each pound of water. The amount of moisture (water vapor) required to maintain any desired level of relative humidity is proportional to the amount of outdoor air which enters the building and it's dryness and the natural moisture input by the building occupants.

Humidification systems while not universally used are often installed to maintain the comfort and health of occupants, and to preserve materials, and prevent drying and cracking of wood, furniture and building contents. Maintain humidification at the level required for occupants where preservation of materials is not a factor. Do not humidify during unoccupied periods. Winter relative humidity in cold climates drops to 5 or 10% in buildings without humidifiers. In the absence of sufficient evidence to support the contention that higher levels are more comfortable or promote health, it is suggested that 20% relative humidity be maintained in all spaces occupied more than 4 hours per day. Shut off the humidifiers completely in all areas at night and during other unoccupied periods. If complaints of dryness and discomfort result, raise the humidity levels in 5% increments until the appropriate level for each area of the building is determined.

heating fig. 15

yearly energy used per 1000 cfm to maintain various humidity conditions

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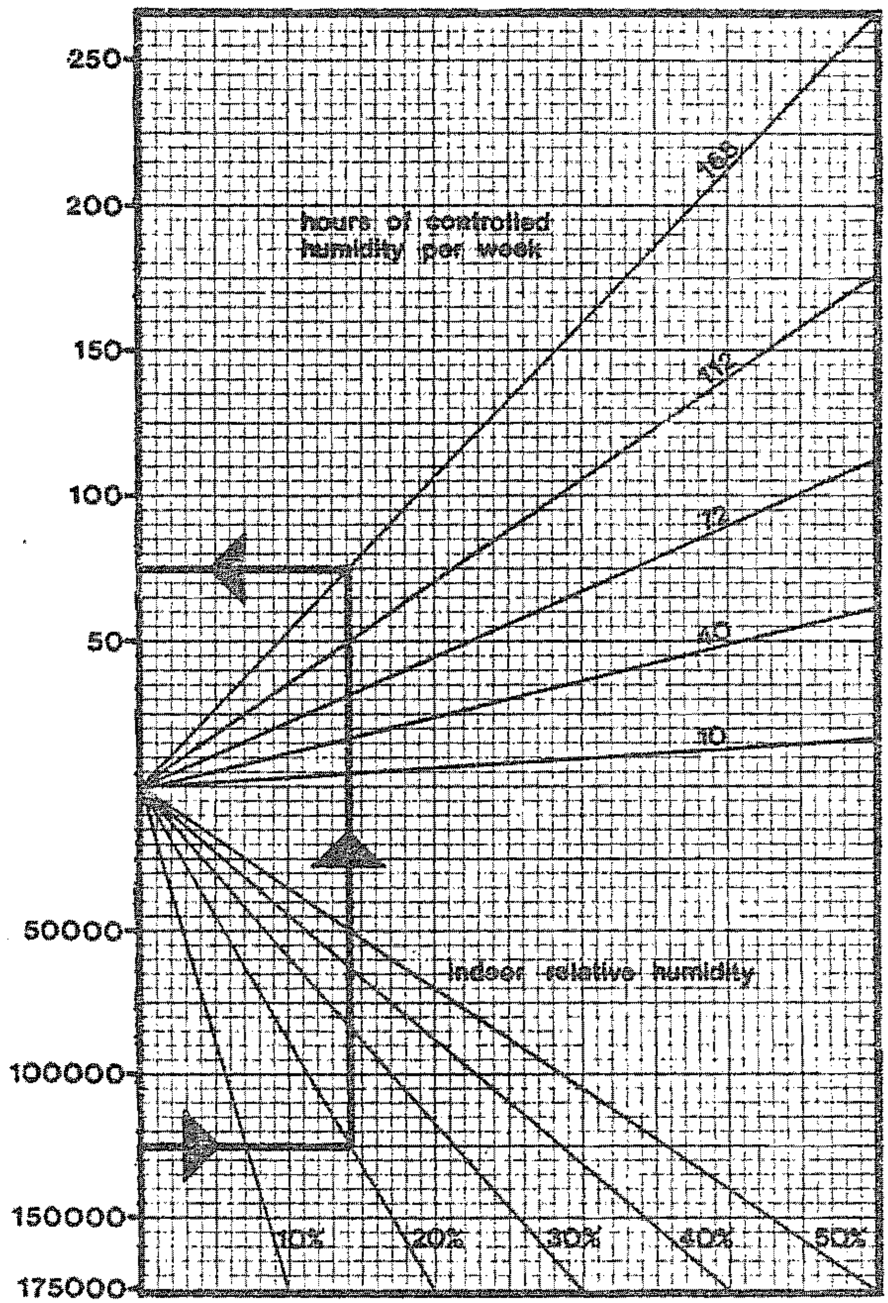

energy used-btu x 10^6 per year per 1000 cfm

annual wet bulb degree hours below 54°F WB & 68°F DB

FIGURE #15 Engineering Data

Data from Figure #6.

WB degree hours based on 24 hours/day, October - April.

Base indoor condition for figure is DB=68°F, WB=54°F, RH=40%.

Energy used is a function of the WB degree hours below the base conditions, the RH maintained and the number of hours of controlled humidity. The figure expresses the energy used per 1000 cfm of air conditioned or humidified.

An analysis of the total heat content of air in the range under consideration indicates an average total heat variation of 0.522 BTU/lb. for each degree WB change. Utilizing the specific heat of air, this can be further broken down to 0.24 BTU/lb. sensible heat and 0.282 BTU/lb. latent heat. One thousand cfm is equal to 4286 lb./hr. and since we are concerned with latent heat only, each degree F WB hour is equal to 4286 x 0.282 or 1208 BTU. Further investigation of the relationship between WB temperature, DB temperature, and total heat shows that latent heat varies directly with RH at constant DB temperature. The lower section of the figure shows this proportional relationship around the base of 40% RH. The upper section proportions the hours of system operation with 168 hr./wk. being 100%.

If higher relative humidities are maintained to reduce static electricity and eliminate shocks, (30% RH will usually achieve this) raise the humidity levels only for those periods when the shocks are a serious problem. Refer to Figure 15 and the following example to determine the energy required for humidification and the potential savings through reduced R.H. levels.

Example:

Find the yearly energy saved by lowering winter relative humidity from 50% to 30%.

Type	Retail Department Store, 72 hrs. occupancy/week
Location	Chicago, Illinois
Fuel	Light Oil (138,000 BTU/gal.)
Outdoor Air Rate	5,000 cfm
Annual Wet Bulb Degree Hours Below 54°F. WB and 68°F.	106,000

Enter Figure 15 at 106,000 degree hours, Follow the example line intersecting with 50% R.H. and 72-hour lines and read yearly energy used of 68×10^6 BTU-yr./1000 CFM.

Re-enter Figure 15 intersecting with the 30% R.H. line and read yearly energy used of 40×10^6 BTU-year/1000 CFM.

Savings: The energy saved equals 68 - 40 or 28×10^6 BTU-Year/1000 CFM and for 5000 CFM, the total is 5 times 28×10^6 or 140×10^6 BTU/year.

Fuel Saved at a seasonal efficiency of 60% =

$$\frac{140 \times 10^6}{138{,}000 \times 0.6} = 1690 \text{ Gallons}$$

At \$.36 per gallon, the savings is 0.36 x 1690 or per year.

Results: Energy Saved 1690 gallons per year
Dollars Saved \$608 per year

Note: For any building, the CFM is a combination of ventilation rate and infiltration converted to CFM. A building with 100,000 sq.ft. of floor area could have as much as 15,000 CFM or more of infiltration.

To calculate the BTU's per square foot floor area that are used for humidification at any desired level, multiply the energy per 1,000 CFM times the total CFM of outdoor air divided by 1,000 and divide the answer by the gross number of square feet of building area. (Figure 10, line 7)

ECO 5 SHUT DOWN VENTILATION SYSTEM DURING UNOCCUPIED HOURS

Ventilation is responsible for a large percentage of the "building" heating load. Cold outdoor air, introduced for ventilation, must be heated to the point that it meets the indoor temperature. The load which this imposes on the heating system is directly proportional to the indoor temperature and the quantity of air introduced for ventilation; the yearly energy used to heat this air is a function of heating degree days.

Many buildings are ventilated at a rate far in excess of that necessary to maintain comfort, dilute odors, or meet code requirements and/or they are operating ventilation systems 24 hours per day even when the building is unoccupied or lightly occupied. These buildings contribute to a gross waste of heating energy.

Use Figure 17 to calculate the amount of energy required to heat outdoor air for any selected period of time, and also to determine the yearly savings in energy per 1000 CFM by shutting off the outdoor air during unoccupied periods.

Ventilation may be provided through a fresh air intake duct to an air handling unit; through outside air intakes of fan coil, window, or through-the-wall units; through intake ducts to rooftop or package heating and cooling units; or, by a separate outdoor air fan. Examine the building systems carefully to determine how ventilation is being supplied, and what control or damper devices are available to reduce and shut off the supply of outdoor air.

A method for reducing outdoor air quantities appears in the example for ECO 6. Use it with Figure 17 to determine the savings for complete shut down of ventilation air. The savings which result from shutting off or reducing ventilation air during the cooling season are described in Section 4 , "Cooling."

ECO 6 REDUCE VENTILATION RATES DURING OCCUPIED PERIODS

The building owner or operator can perform most of the procedures for shutting off ventilation at night or on weekends, but professional advice and help may be necessary to reduce the ventilation rate in all or portions of the building during occupied periods.

First establish the ventilation rate by measuring the volume or air at the outdoor air intakes of the ventilation system. Then determine the local code requirements and compare them with the measured ventilation rate to find the magnitude of possible savings. If the code requirements exceed "Recommended Ventilation Standards", Figure 16, apply for a code variance. Although code figures are often used as a design criteria, with dampers and ducts installed accordingly, they do not necessarily reflect actual building requirements for the number of people occupying spaces for specific periods of time; they often exceed real requirements.

If ventilation is supplied to a building to provide makeup air for toilet, kitchens and other exhuast air quantities, analyze the exhuast systems and operate them only as needed. Savings of fan horsepower for exhaust fans and supply fans and heating energy to temper the supply air will result. Cooling loads will be similarly reduced in the summer.

If supply fans also handle outdoor air for ventilation, increased return air quantities may compensate for the reduction in ventilation air quantities and preclude fan horsepower savings. Reductions in the "building" heating load, however, will result in significant savings.

When two or more spaces with different requirements are served by one system, it is not always possible to control the separate ventilation rates. Not all of the spaces, however, need be supplied at the rate required for the most critical area. Refer to Figure 16 and calculate the maximum amount of outdoor air by the sum of the individual requirements. This procedure, generally, will provide satisfactory conditions for all spaces.

Where separate ventilation systems are installed, group occupants by type of activity, when possible, to reduce the total ventilation rate and conserve energy.

Outdoor air for economiser cooling is discussed separately under Section 4 , "Cooling". Air used for that purpose is not strictly speaking "ventilation".

Use the method outlined in the following example to determine the savings due to reduced ventilation rates during occupied periods.

Example:

From the Identification Profile:

Building Type	Offices
Building Floor Area	100,000 Sq. Ft.
Building Location	Minneapolis, Minnesota
Heating Degree Days	8400
Occupancy	667 people
Indoor Temperature	68°F.
Occupied time	40 hours/week

Present measured ventilation rate - 20,000 CFM

This represents $\frac{20,000}{667}$ = 30 CFM/person

Reduce the rate of ventilation to an average of 8 CFM/person to serve a mixed smoker/non-smoker population. New ventilation rate = 667 x 8 ≈ 5300 CFM
Ventilation reduction = 20,000 - 5300 = 14,700 CFM

Determine from Figure 17 that in an area of 8400 degree days, each 1000 CFM for 40 hours/week requires 50×10^6 BTU/year energy for heating. Therefore, heating energy saved by reducing ventilation = $14.7 \times 50 \times 10^6 = 735 \times 10^6$ BTU/year.

Fuel saved if the oil-fired system has an efficiency of 60%, and if using #2 oil at 138,000 BTU/gallon =

$$\frac{735 \times 10^6}{138,000 \times 0.6} = 8877 \text{ gallons/year}$$

@ $.36/gallon $3195/Year

VENTILATION RECOMMENDATIONS

1. Office Buildings

Work Space	5 CFM/person
Heavy Smoking Areas	15 CFM/person
Lounges	5 CFM/person
Cafeteria	5 CFM/person
Conference Rooms	15 CFM/person
Doctor Offices	5 CFM/person
Toilet Rooms	10 air changes/hour
Lobbies	0
Unoccupied Spaces	0

2. Retail Stores

Trade Areas	6 CFM/customer
Street level with heavy use (less than 5,000 sq.ft. with single or double outside door)	0
Unoccupied Spaces	0

3. Religious Buildings

Halls of Worship	5 CFM/person
Meeting Rooms	10 CFM/person
Unoccupied Spaces	0

ECO 7 REDUCE RATE OF INFILTRATION

Outdoor air infiltrates a building through cracks and openings around windows and doors, through construction joints between individual panels in a panel wall construction, and through porous building materials of the exterior walls, roofs, and floors (over unheated spaces).

Infiltration increases with wind velocity and penetrates the windward side of the building -- usually the north or western exposures in cold climates. However, in high winds, a negative pressure is often created on the lee side, which if the north and western exposures are windowless and/or tight, may induce air into the building through openings in other exposures and through open doors and passageways.

In tall buildings stack action due to the difference between indoor and outdoor temperatures induces air leakage through cracks and openings. Stack effect is always a potential problem for vertical spaces -- service shafts, elevator shafts, and staircases. The density difference between warm air in the shaft and the cold outdoor air induces air to leak into the bottom of the shaft and out of the top.

Infiltration is also induced into the building to replace exhaust air unless mechanical inlet ventilation balances the exhaust. Follow the suggestions for reducing exhaust air quantities and periods of operation, described in ECO 6 to reduce infiltration rates from this cause.

Infiltration, which often accounts for a major portion of heating load, cannot, like ventilation systems, be turned off at night or during weekends (although it may be decreased if exhaust fans are shut down). It can, however, be reduced at all times. Particularly effective measures include caulking cracks around window and door frames and weatherstripping windows and doors. Weatherstripping doors costs about $50 per door or $75 per double door. To weatherstrip metal frame doors with aluminum and rubber costs about twice as much. Weatherstripping costs for windows depend upon type and number, and range between $25 to $50 per window. To rake out old caulking and recaulk around window edges costs about $15 per window (or about $25 per 30 square feet window). Figure 18 reveals infiltration rates for various types of windows. In most climates the average

heating

yearly energy used
per 1000 cfm
outdoor air

fig.17

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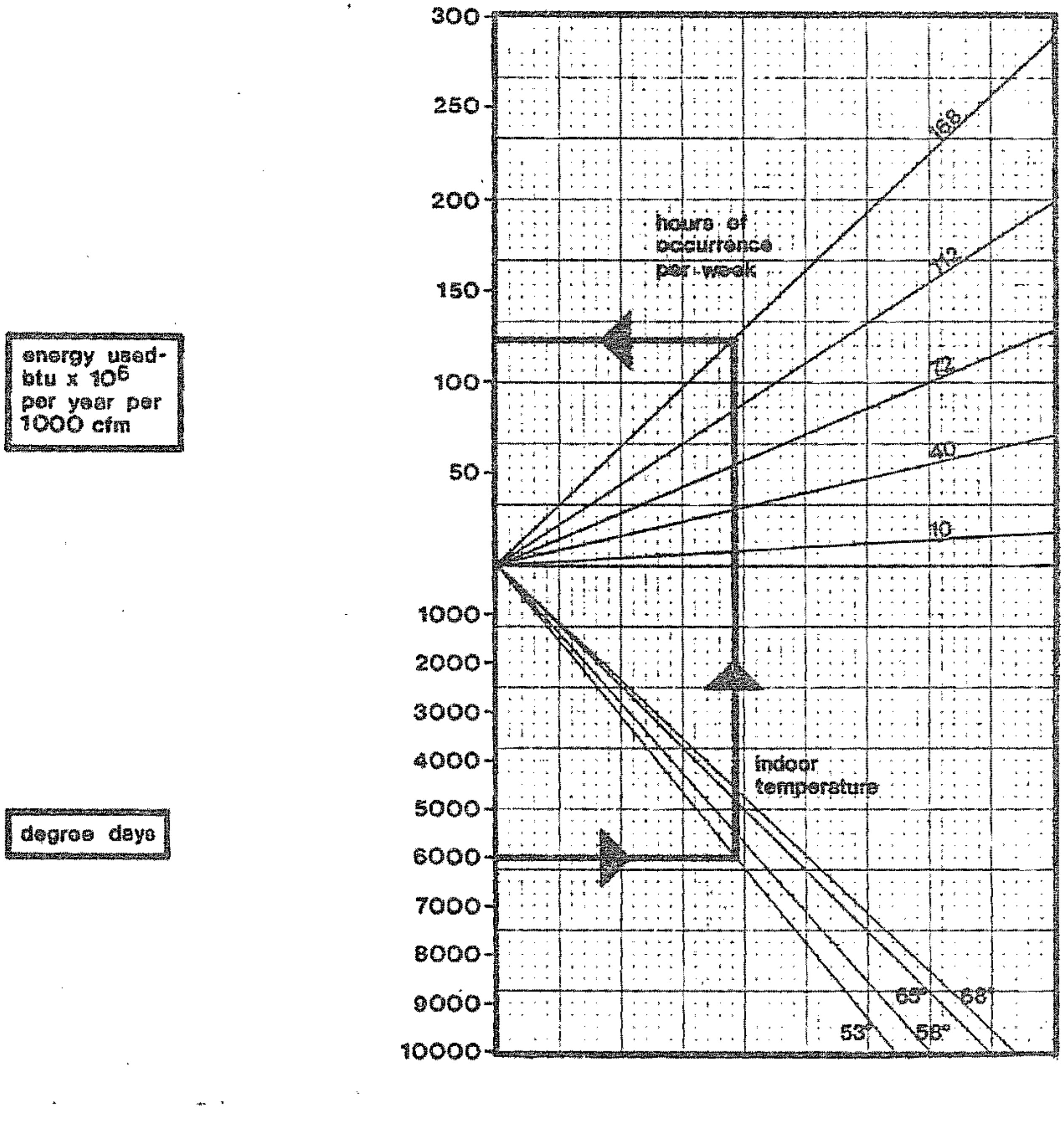

FIGURE # 17 Engineering Data

Date from Figure 4

Energy used is a function of the number of degree days, indoor temperature and the number of hours that temperature is maintained and is expressed as the energy used per 1000 cfm of air conditoned.

The energy used per year was determined as follows:

BTU/yr. = (1000 cfm) (Degree Days/yr.) (24 hr./day 1.08)*

Since degree days are base 65°F, the other temperatures in the lower section of the figure are directly proportional to the 65°F line. The upper section proportions the hours of system operation with 168 hr./week being 100%.

*1.08 is a factor which incorporates specific heat, specific volume, and time.

infiltration

rate of infiltration thru window frames

fig. 18

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key to window infiltration chart
(leakage between sash & frame)

type	material	weatherstripped?	fit
① all hinged	wood metal	yes yes	avg. avg.
② all hinged dbl. hung	wood metal steel	no no no	avg. avg. avg.
③ all dbl. hung	wood steel	yes yes	loose avg.
④ casement	steel	no	avg.
⑤ all hinged	wood	no	loose

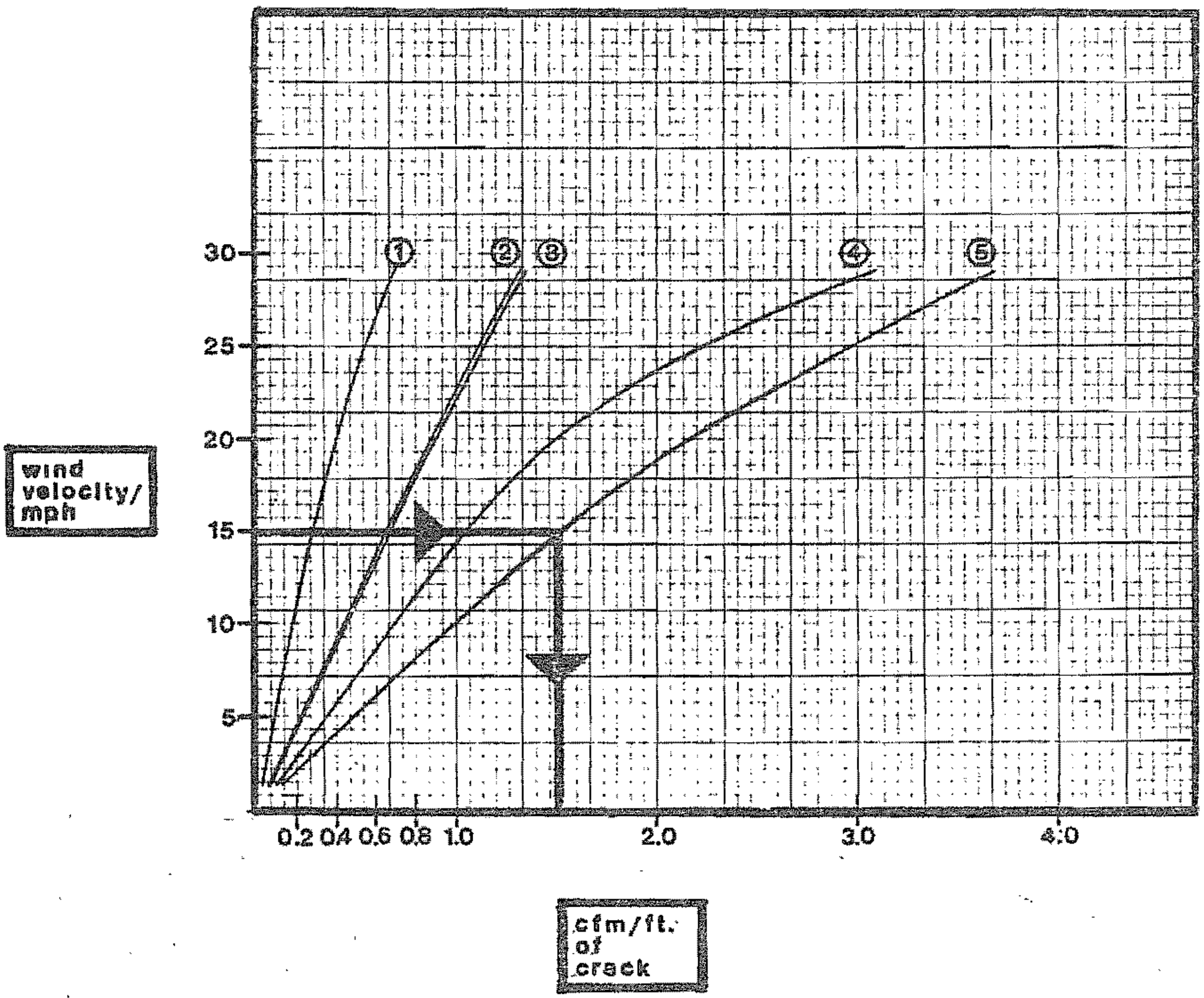

FIGURE #18 Engineering Data

Source of Data: ASHRAE Handbook of Fundamentals, 1972, Pgs. 333, 337,338 wind velocity in the winter is 10 to 15 miles per hour. In some locations it is considerably higher. Check your local weather bureau for relevant information, or draw on individual experience. Wind patterns and velocity vary widely, even on the same street in a city.

The installation of revolving doors and vestibules is an effective measure against air leakage through entrances. Refer to ECM 2 for information on potential energy savings with revolving doors and vestibules as well as additional measures to reduce the effects of stack action.

For porous block walls having leaky mortar joints, point up from the exterior, or paint the wall with epoxy to seal it against air leakage and moisture. A 4 mm coat of epoxy resin costs about 35¢ per square foot for material and labor.*

Use Figure 17, to determine the energy required to heat infiltration air.

To estimate the amount of infiltration occurring in a building because of window leakage, determine, first, the total amount of crack area. Use the following procedure:

Example:

From the Identification Profile:

Building Type	Offices
Building Size	100' x 50' 4 floors
Building Location	Topeka, Kansas
Heating Degree Days	5,000
Indoor Temperature	68°F.
Wind Speed	15 mph
Wind Direction	NW
North Windows	Dimensions: 5'x3'; total no. 28
West Windows	Dimensions: 5'x3'; total no. 56

Window type: loose fitting, double hung wood sash

Determine the crack length/window
Each window perimeter = 5+5+3+3+3 (including the 3'
= 19 ft. horizontal crack between the upper and lower sash)

*The cost of epoxy resin may escalate at a rate higher than that for most costs in this manual.

Total crack length for north and west windows =
19 x 84 windows = 1596 ft.
Determine from Figure 18 the rate of infiltration per
foot of crack = 1.5 CFM
Total infiltration due to window cracks = 159x1.5 = 2394 CFM
Determine from Figure 18 the rate of infiltration per
foot of crack if windows are weatherstripped = 0.25 CFM/ft.
Therefore, total infiltration = 1596 x 0.25 = 399 CFM
Reduction in infiltration = 2394 - 399 - 1995 CFM

Determine seasonal savings in energy for heating.
From Figure 17, each 1000 CFM required 130 x 10^6 BTU/year
Therefore, reducing infiltration by 1995 CFM would
result in a savings 130 x 10^6 x 1.995 = 259.1 x 10^6 BTU/year.

Savings due to weatherstrip = 228.1 x 10^6 BTU/year
Fuel saved, if the heating system uses #2 oil (138,000
BTU's/gallon) and has a seasonal efficiency of 60% =

$$\frac{259 \times 10^6}{138{,}000 \times 0.6} = 3128 \text{ gallons}$$

@ $.36/gallon $1126/year

The cost of weatherstripping 84 windows of 15 sq.ft. each in New York City is $25/window. Adjustment for Topeka (use Denver from Appendix A) = 0.81 x $25 = $20.25 each window.

Therefore, total cost for 84 windows = 84 x 20.25 = $1701

In summary,

$1701 spent on weatherstripping windows will realize a savings in fuel cost of $1126 per year. Capital pay-back will be about 1 1/2 years making the investment worthwhile. If fuel costs continue to escalate, the pay-back period will be even shorter. Because weatherstripping the windows results in additional savings during the cooling season (even though wind velocities and infiltration rates are less), the total yearly savings in energy will be greater than that shown.

ECO 8 INCREASE THE SOLAR HEAT GAIN INTO THE BUILDING

Although solar heat gain adds to the cooling load, it can be very helpful in reducing the heating load. Solar radiation impinging upon an opaque building envelope raises the surface temperature and reduces conduction losses. In an existing building it is difficult to increase this effect. However, if the walls are not heavy construction and are not well-insulated, consider refinishing the exterior south wall in particular, and the east and west walls next, in that order, to increase solar radiation effects. See ECM 2 for details.

Other measures to permit available sunshine to enter the building through windows and glass doors can be implemented readily and the energy conservation benefits, especially in the northern latitudes, are considerable. The amount of sunlight that penetrates the windows depends upon the number of panes of glass, the area of the windows, the orientation of the windows, the type and cleanliness of the glass, the type of solar control device, the latitude where the building is located, and the percentage of sunshine at the location. Charts which address all the variables and permit calculations for exact benefits of increasing the solar heat gain in the winter are impossible within the scope of this manual. A general rule is possible, however. In Minneapolis, there is approximately 25% more sunshine on the south glass and 15% more on the east and west glass than there is on the north face; in Florida, the amount of sunshine striking all facades is nearly equal. Between these two locations, due to sun angles at different latitudes, the percentages of sunlight change linearly with latitude.

The heat contributed by solar radiation through windows can save about 3/4 of a gallon of oil per square foot of south facing glass in Minnesota, and about 1/4 of a gallon of oil per year for east or west facing glass in Miami.

About 10% less sunlight penetrates double glazing than single glazing. However, double glazing reduces the heat load due to conduction, and the benefits from this more than offset the loss of solar radiation.

ECO 9 REDUCE HEAT TRANSMISSION DUE TO CONDUCTIVE LOSSES THROUGH THE BUILDING ENVELOPE

Heat loss through the envelope depends upon the temperature difference between indoors and out; the mode of operation of the heating system; and the mass, color, and insulating value of the exterior walls, roof, windows and floor (over unheated spaces). Wind impingement on the exterior surfaces increases heat loss by transmission. Solar radiation compensates for it by raising the temperature of the exterior surfaces. A single layer of glass transmits 1.1 BTU/square foot of surface per degree of temperature difference (td); double glass transmits about .55 BTU, an uninsulated frame wall about .3 BTU, a 12" masonry and 4" brick wall about .25 BTU's and insulated walls of various types and thicknesses down to .027 BTU's per square foot per degree td.

Insulation and double glazing are discussed in ECM 2. For buildings in climates of 4500 degree days or more, adding a storm sash to windows and adding 6" of fiberglass insulation (to the underside of the roof, or over the ceiling of uninsulated buildings) will have a payback period less than 8 years with oil prices at 36¢ per gallon. Contact at least 2 local contractors for prices before awarding a contract. ECM 2 contains data on the relative effectiveness of double glazing and insulation in various climatic zones in the United States, as well as cost data for various measures to reduce heat loss.

The installation of storm windows reduces infiltration rates as well. Therefore, adding storm windows, may preclude weatherstripping and caulking loose fitting windows. (Removing a single pane of glass and replacing it with a pane of double glazing reduces conduction losses but not infiltration).

For small buildings with few windows, a temporary storm sash, non-operable, can be erectdd quickly with clear heavy duty plastic sheet nailed in place and caulked for tightness at about $4 or $5 per window.

ECO 10 IMPROVE THE BURNER-BOILER/FURNACE SEASONAL EFFICIENCY

Although there are many types and sizes of boilers, furnaces and burners in use today, all have certain common characteristics, and similar techniques can be used to improve their efficiency and conserve energy.

In theory, combustion of oil, gas, or coal requires a given fuel/oxygen ratio for complete burning and maximum efficiency. In practice, air (mixture of oxygen and nitrogen) is used to provide the necessary oxygen for burning and must be supplied in excess of the theoretical requirements to insure complete combustion. The quantity of air that just gives complete combustion is the optimum amount. Any reduction in the optimum air quantity prevents complete combustion and wastes energy -- the maximum heat value of the fuel cannot be released. Any increase over the optimum air quantity for combustion will reduce not the efficiency of combustion itself, but rather the rate of heat transfer to the boiler or furnace; an increase in the stack temperatures (heat lost out the chimney) will also occur. It is important, therefore, that air into the combustion chamber be controlled to achieve the most favorable fuel/air ratio for any given burning rate. Take measures to prevent any other uncontrolled source of air entry through leaks into the combustion chamber.

Clean and adjust burners each year and monitor them periodically during the year to assure optimal combustion efficiency (adjust them at these times as necessary). In large installations make combustion control and monitoring a daily procedure. Use orsat apparatus to check the CO_2 content of the flue gas, and thermometers to check stack temperatures. Taken together, the amount of CO_2 and the stack temperature constitute a measure of the combustion efficiency.

After reducing the "building" and distribution heating load, clean and correct dirty oil nozzles, oversized or undersized nozzles, fouled gas parts, and improperly sized combustion chambers. Reduce nozzle sizes and modify combustion chambers for proper combustion.

The condition of the heat transfer surface directly affects heat transfer from the combustion chamber and/or hot gases. Keep the fire-side of the heat transfer surface clean and free from soot or other deposits and the air and water-side clean and free of scale deposits. Remove deposits by scraping where they are accessible, by chemical treatment, or by a combination. In the case of steam boilers, once the water-side of the boiler is clean, institute correct water treatment and blow down to maintain optimum heat transfer conditions.

Boilers and furnaces may achieve relatively high instantaneous full-load efficiencies (80 - 87%), but because they are operated most of the time at part load, they have lower seasonal efficiencies. Generally, measures which increase the full-load instantaneous will also increase the seasonal efficiency. However, when the peak loads are of very short duration, it may be advantageous to tune the boiler for maximum efficiency at part-load conditions in order to gain greater seasonal efficiency.

Flue gas temperatures from boilers range typically from 250°F. for gas-fired low temperature boilers up to 600°F or more for oil and coal-fired high temperature boilers. Furnaces operate in the same range. Hot flue gas contains useful heat which can be reclaimed for space or air heating, or to preheat feed water, by the installation of heat transfer coils or heat pipes in the breeching. (This measure requires capital expenditure and is dealt with in ECM 2).

GUIDELINES TO REDUCE ENERGY USED IN HEATING

SETBACK TEMPERATURES DURING UNOCCUPIED PERIODS

-Shut off radiators or registers in vestibules and lobbies.

-Reduce the hours of occupancy to the greatest extent possible during periods of severely cold weather.

-Adjust automatic timers or add time clocks to automatically set-back temperature for night and weekend operation.

-When buildings are used after hours for meetings, conferences, cleaning or scattered activities, for instance, reduce the number of spaces occupied and, to the extent possible, consolidate them in the same section of the building. Reduce the temperature and turn off humidifiers in all other parts of the building.

-When there is no danger of freezing, turn off radiators or supply registers in areas that do not have a separate thermostat. Open them when building is occupied.

-Check relevant codes requiring protection for plumbing, fire sprinkler systems, and standpipes before implementing extreme temperature reduction. Public utilities may set temperature requirements for their equipment rooms.

SET BACK TEMPERATURES DURING OCCUPIED HOURS

-Stores are commonly overheated and uncomfortable for transient patrons who are wearing outdoor clothing. To conserve energy, reduce store temperatures to a level that is comfortable for heavily dressed patrons and encourage staff to dress more warmly or provide local heaters.

-In all buildings encourage occupants to wear heavier clothing so that they are comfortable at lower indoor temperatures.

-Some buildings contain large heated areas such as storage spaces that are only occupied by one or two people. In such areas, reduce the temperature to a low level just sufficient to prevent damage to other systems (freezing sprinklers, etc.) and provide local radiant heaters for one or two occupants.

-Corridors and stairwells are unoccupied areas, used only by people who are physically active in moving from one heated space to another. Providing that the temperature does not fall below 55°F., turn off heating in these areas. Keep closed all doors between unheated corridors and heated spaces.

-Some areas of the building require no heating -- spaces which are heated by adjacent areas or which receive solar heat through windows. If thermostats are unavailahle in these areas, shut off radiators, registers, fan coil units. or any other terminal heating devices until the temperature levels suggested in Figure 13 can be maintained.

-Refer to applicable codes. Minimum temperature requirements are specified in OSHA and other occupational regulations to assure employee working conditions.

AVOID RADIATION EFFECTS OF COLD SURFACES

-When the winter sun is not shining on the windows, draw drapes or close venetian blinds to reduce radiation of heat from occupants to cold surfaces. (The cost of adding venetian blinds ranges from $1.00 to $1.60 per square foot.)

-Encourage those working near the exterior walls and windows to wear heavier clothing in winter.

-Close windows tightly in the winter.

-Reduce drafts and increase comfort by caulking and weatherstripping windows to reduce heat loss and to reduce the need to overheat the entire space in order to achieve comfort near the exterior walls. (See ECO-7, page 116).

-Have occupants sit together in interior spaces away from cold walls in sparsely occupied spaces.

-Rearrange desks and task surfaces away from cold exterior surfaces.

-Other methods to reduce transmission to cold exterior surfaces are described under ECO-8 page 122.

REDUCE WINTER HUMIDIFICATION

-Turn off all humidifiers at night and during unoccupied cycles.

-Reduce the amount of infiltration and outdoor air ventilation.

-Reduce or eliminate any introduction of moisture for humidification in corridors, store-rooms, equipment rooms, lounges, lobbies, laundries,supermarkets, stores with high density occupancy, religious buildings, cafeterias, kitchens, etc.

-Use waste steam condensate for winter humidification. Refer to ECM 2 for details.

-Whenever condensation is running freely on the inside of window surfaces, shut off humidifier. Excess moisture will damage structure.

-When humidifier is maintained to eliminate static electricity, shut off humidifier when shocks are not a problem.

-If humidifiers are located in the return air or outdoor air mixing box in the air handling section of the system, relocate them to the hot duct section.

-In pan type humidifiers adjust float or control to eliminate overflow onto hot furnace sections.

-Whenever moisture is condensing on duct work or humidifier casing section, insulate the casing or duct work and/or reduce flow rate.

SHUT OFF VENTILATION AIR DURING UNOCCUPIED PERIODS

-If there are one or more separate fresh air supply fans, deenergize them; use an automatic timer if one is available; or switch off manually. Where an automatic damper closes when the fan shuts down, check it to make sure it closes tightly. Repair it with felt edges if it by-passes air.

-If air handling units which supply warm (or cold) air to spaces are equipped with fresh air inlet duct and damper, close damper as described above. If no damper exists, install a felt-lined damper with remote or local control device and timer control.

-If windows are used to provide ventilation, close them at night.

-If exhaust fan hoods serving kitchens, bakeries, cafeterias, and snack bars are interlocked with outside air fans or dampers, to sure to shut down exhaust system when not needed.

-Close outdoor air dampers for first hours of occupancy when outdoor air has to be heated or cooled.

-Provide ventilation in accordance with occupancy and not on a continuous basis. In many buildings heavy occupancy can be monitored or occurs at regular intervals, so that ventilation can be shut off for certain periods during the day. In a department store designed for peak loads of 1,000 customers, ventilation can usually be shut off for those slack sales periods when only 10% or 20% of the peak occupancy occurs.

-If during the heating season outdoor air temperature in the morning is above desired room conditions, use it for heating by opening damper.

-Generally the amount of outdoor air quantities for window units, through-the-wall units, and fan coil units is fixed. When these units are used to maintain nighttime or unoccupied cycle room temperatures, the outdoor air intakes are generally open. If dampers are available, close them when outdoor air is not needed. Where infiltration is sufficient for daytime ventilation requirements, block off the outdoor air damper completely for some or all of the units.

REDUCE VENTILATION RATES DURING OCCUPIED PERIODS

-Close outdoor air damper, if provided, until desired volume reduction is achieved.

-If damper is not provided, either fit one or blank off part of the outdoor air intake.

-Take particular care in setting outdoor air quantities where window air conditioners, through-the-wall units, and fan coil units and unit ventilators with fresh air intakes are used. Generally, the amount of outdoor air is fixed but can be reset.

-Use an anemometer at the outdoor inlet or louver to measure the amount of outdoor air introduced into the ventilation system. The outdoor air damper setting often differs from the damper indicator setting. Also, a hinged volume damper blade does not proportion air directly with its opening. A blade with 10% opening permits much more than 10% flow.

-Cut off direct outdoor air supply to toilet rooms and other "contaminated" or potentially odorous areas. Permit air from "clean" areas to migrate to the "dirty" areas through door grilles or under-cut doors. This is effective if toilet areas have a mechanical exhaust system, or even if ventilated by open windows (especially those on the lee side of the building).

-Use odor absorbing materials in special areas rather than providing outdoor air for dilution.

-Supply ventilation air to parking garages according to levels indicated by a CO_2 monitoring system.

-Provide baffles so that the wind does not blow directly into an outdoor air intake.

-Operate exhaust systems intermittently throughout the day. Turn them off when possible at times when they are not needed. Operate them at other times such as noon, coffee breaks, heavy cooking times.

-Shut off exhaust hoods in kitchens, snack bars and cafeterias when cooking or baking operations are completed.

REDUCE VENTILATION RATES DURING OCCUPIED PERIODS (Cont'd)

-Many hoods exhuast much more air than necessary. Reduce the quantity of exhaust air from hoods in kitchens and similar operations by closing off a portion of the hood, changing hood type from canopy to high velocity and slowing down exhaust fans to the point just necessary to satisfy exhaust requirements.

-If outdoor temperature is below 45°F., don't operate the ventilation system any longer than needed. Noticeable odors are good indicators of the need to operate the fans or open outdoor dampers. Flushing out the building until odors disappear will usually be satisfactory.

-Concentrate smoking areas together so that one ventilation system can serve them. Adjust outdoor air to serve those areas and reduce all other outdoor air to systems.

-Use window ventilation where possible. This will reduce the power required for mechanical exhaust systems and also the air intake which normally balances the exhaust. Shut off supply air system when window ventilation, alone, is adequate.

-In high ceilinged buildings (religious buildings, auditoriums, etc.) used for short periods of intermittent operation, outdoor air is frequently unnecessary. For longer periods of light occupancy, outdoor air is still unnecessary. A warehouse for example, may have less than one person per 1,000 cu.ft. for less than four hours and no need for outside air ventilation.

-Check codes, where applicable, for specification of minimum exhaust CFM and for rules on recirculation or filtering of air.

IMPROVE BURNER-BOILER EFFICIENCY

The following suggestions are recommended operating and maintenance items to increase boiler, furnace, and heating system efficiency for hot water systems, high pressure steam systems (about 15 psi), low pressure steam systems (less than 15 psi), forced warm air systems, and gravity hot air systems. Review the list and select those items which are applicable to any particular system.

None of these measures can be quantified, in this manual, to show energy savings -- any increase in efficiency depends on the equipment status before and after the maintenance item has been carried out. However, each item will result in greater efficiency and consequent energy savings. Many building owners report fuel savings of 20 to 30%.

-Clean and scrape fire-sides to remove soot and scale.

-Clean water-sides, remove built-up scale.

-Scrape scale from steam drum

-Clean air-sides, remove soot, and scrape scale in forced warm air and hot air furnaces.

-Maintain water level or pressure to radiators or coils on the highest level of the building.

-Insulate units which are in unheated spaces, on roofs, or in air-conditioned spaces. Repair insulation where it is in need. (If the boiler or furnace casing is 10-15% warmer than room temperature, radiation loss could be 10% or more of the capacity of the unit.)

-Check for and seal air leaks between sections of cast iron boilers to improve combustion efficiency.

-If the combustion efficiency is at a maximum but stack temperatures are still too high (over 450°F.), install baffles or turbulators to improve heat transfer. Consult your boiler manufacturer.

-Seal all air leaks into combustion chamber, especially around doors, frames, and inspection ports.

-Maintain the lowest possible steam pressure suitable for supplying radiation or coils.

-Vary the steam pressure in accordance with the space heating or process demands. Steam pressures can be reduced most of the year. Standby losses are reduced

IMPROVE BURNER-BOILER EFFICIENCY (Cont'd)

as pressures are reduced.

-Maintain the lowest possible hot water temperature which will meet space or domestic hot water needs.

-In the absence of indoor-outdoor modulating controls, raise or lower operating temperature (for hot water systems) to conform to indoor-outdoor conditions. For example, operate a boiler at 120°F. with outdoor temperature at 60°, and raise the level to 160° when it is 20° outdoors.

-Clean filters regularly in gravity and forced warm air units to reduce the operating time of the furnace.

-Reduce firing rate and/or enlarge return air opening if hot air temperature of a gravity furnace is over 150°F. at full load. (Refer to ECM 2. for adding a blower).

-Shut down hot air furnaces completely when building is not occupied and there is no danger of freezing.

-Set operating aquastats on steam and hot water boilers to 100°F. during shut-down periods.

-Schedule boiler blowdown on an as-needed basis rather than on a fixed timetable. Smaller and more frequent blowdown quantities are preferable to larger quantities and less frequent blowdown.

Note: Be sure that boiler blowdown procedures adhere to specifications outlined by the manufacturer, the National Board of Boiler and Pressure Vessel Inspectors (of Columbus, Ohio), and local codes. With few exceptions it is illegal, and in all cases undesirable, to discharge boiler blowdown directly to a sanitary sewer.

-Use warm exhaust air from adjacent areas, or from the ceiling of the boiler rooms, to preheat combustion air.

-Use chemical fuel additives to reduce the flashpoint temperature of fuel oil, especially #4 and #6 oils. Proper chemical treatment will reduce soot deposit on #2 oil systems also.

-Interlock combustion air intake with burner operations; maintain prepurge and postpurge as required for some burners.

IMPROVE BURNER-BOILER EFFICIENCY (Cont'd)

-Seal all air leaks into natural draft chimneys, especially where flue pipe enters the wall.

-Repair or rebuild oil burner combustion chambers to the correct size for providing optimum efficiency at 90% of the full load firing rate. Construct chambers with bricks of the refactory type, not common bricks. Incorrect matching of burner and combustion chamber and broken brickwork can result in losses of from 10 to 20%.

-Turn off gas pilots for furnaces, boilers, and space heaters during the non-heating months and during long unoccupied periods.

-Provide an automatic draft damper control to reduce the heat loss through the breeching (smoke pipe) when the gas or oil burner is not in operation. Adjust draft-control with combustion testing equipment to match the firing race.

-Adjust oil burner efficiencies to achieve proper stack temperature, CO_2 and excess air settings. Adjust setting to provide a maximum of 400° - 500° of stack temperature and a minimum of 10% CO_2 at full load conditions. Excess air through a boiler can waste 10 to 30% of the fuel. Accurate testing is essential for the correct burner adjustment to attain maximum efficiency. Use appropriate instruments and institute combustion testing as part of a planned general maintenance program. (A simple combustion testing kit can be purchased for approximately $100).

-Adjusting the firing rate of gas or oil burners at too high a rate will cause short cycling and excessive fuel consumption. Too low a rate will require constant operation and inadequate heat will be delivered to the spaces. If the boiler is oversized, adjust the firing rate to the building load, not the boiler.

-If there is more than one boiler, operate one only up to its maximum load before bringing other boilers on the line. It is inefficient to operate two or more boilers at very low capacity to carry part loads.

-Details or reclaim heat systems and other measures which require capital investment but can show a quick payback period are described in ECM 2 .

REDUCE INFILTRATION

-Operate the exhaust systems as outlined in the guidelines for ECO 5 and 6.

-Inspect the building exterior and interior surfaces and caulk all cracks that allow outdoor air to penetrate the building skin.

-Caulk around all pipes, louvers, or other openings which penetrate the building skin.

-Repair broken or cracked windows. Reglaze with standard or tempered glass of proper thickness, as per building code requirements, or with wire glass if fire rating is required.

-As a temporary measure cover windows with 4 mil plastic sheets and extend the covering over the frame. Hold plastic sheet in place with continuous nailing strip.

-Weatherstrip exterior doors and windows in climates with more than 2000 degree days.

-Cover porous exterior wall and roof materials with epoxy resin.

-Cover window air conditioners with plastic covers in the winter (when not used for heating).

-Install automatic closers on exterior doors.(Cost ranges from $60 to $90 per door depending on whether closers are installed by maintenance staff or outside labor)

To reduce infiltration due to stack effect:

-Reduce temperature in stairwells. (Protect piping from freezing)

-Seal elevator shafts top and bottom and insure that machine room penthouse door is weatherstripped and closed.

-Seal vertical service shafts at top and bottom and, in tall buildings, at every sixth floor.

-Weatherstrip and close doors in basement and roof equipment rooms where these are connected by a vertical shaft which serves the building.

-Check building code for venting requirements and check fire resistance ratings of materials used. Skylights or smoke relief vents may be required.

INCREASE BENEFICIAL SOLAR HEAT GAIN INTO THE BUILDING

-Clean windows to permit maximum sunlight transmission.

-Operate drapes and blinds to permit sunlight (when available) to enter windows during the winter; move desks or work stations out of the direct path of sunlight to avoid occupant discomfort.

-A percentage of direct solar radiation is stored in the structure and furnishings where it will help to offset the heat load at night. Permit the space temperature to rise so that excess heat can be stored in the structure and be available for heating at night or cloudy periods. Even on cloudy days diffuse radiation is considerable; allow it to be transmitted into the occupied spaces.

Note: treat skylights and display windows in the same manner as windows.

-If windows are not fitted with blinds, drapes, or shutters, consider installing them to control the rate of heat flow into and out of the building.

-During heavily clouded weather, and at night, reduce the heat loss through the window by drawing shades and drapes or closing shutters where fitted.

-If direct sunlight or excessive window brightness causes glare, add a light transluscent drape which cuts glare but permits solar heat to enter.

-Readjust blinds during the day if, during particular times of the year, overheating occurs.

-Before installing shades or blinds, check fire code for prohibitions against certain types of materials.

-Where possible, treat the site to increase useful solar heat gain in the winter.

-Trim all foliage shading the southern, eastern or western face of the building in winter. Reduce any evergreen foliage grossly blocking the winter sun.

-Where possible, remove shading devices and any other objects casting shadows on the building surfaces during winter.

SECTION 4-B

DOMESTIC HOT WATER

INDEX

DOMESTIC HOT WATER

A. BACKGROUND

The amount of energy consumed in heating hot water is about 4% of the annual energy used in most large commercial buildings. In smaller commercial buildings, the percentage is smaller. However, in facilities which include restaurants, cafeterias and especially laudromats, the percentage of energy for hot water compared to other systems will be greater.

If domestic hot water is heated by the same boiler which heats the building, and if the load is only 10 or 20% of the total boiler load in those months when the building is heated, the energy used in the fall and in summer months for domestic hot water may be considerably higher than in the winter as the boiler will be operating at low part load efficiency. To determine the amount of energy used for domestic hot water follow the method described in Section 3 , Figure 12.

The opportunities to conserve energy for heating domestic hot water can be summarized as follows:

Reduce the load

- -decrease the quantity of domestic hot water used
- -lower the temperature of the domestic hot water

Reduce the system losses

- -repair leaks and insulate piping and tanks
- -reduce recirculating pump operating time

Increase the efficiency of the domestic hot water generator

B. EXISTING CONDITIONS

1. Average Usage

TABLE 1

Office Buildings

(Without kitchen or cafeteria services) . . .	2 to 3 gallons per capita per day for hand washing and minor cleaning (based on an average permanent occupancy which includes daily visitors)

Department Stores

(Without kitchen and cafeteria services) . . .	1 gallon per customer per day

Kitchen and Cafeterias for hand washing

Dishwashing, rinsing and hand washing	3.0 gallons per meal plus 3 gallons/employee/day

Schools

Boarding	25 gallons per capita per day
Day	3 gallons per capita per day (Does not include cafeteria or athletic facilities)

Apartments

High rental	30 gallons per capita per day
Low rental	20 gallons per capita per day

Hospitals

Medical	30 gallons per capita per day
Surgical	50 gallons per capita per day
Maternity	50 gallons per capita per day
Mental	25 gallons per capita per day
Hotels	30 gallons per capita per day

2. Average Temperatures

The usual temperature at which hot water is supplied - from 120°F. to 150°F. - is too hot to use directly and must be mixed with cold water at the tap. For dishwashing and sterilization the delivery temperature is generally 160°F. or higher. Often hot water supplied to all faucets is at temperature required for the kitchen. Frequently, the hot water, generated and stored in tanks at 150° to 160°F., loses heat by conduction and radiation from the tank and piping, even before the delivery at wasteful temperatures.

When hot water is supplied by a tankless heater, it is within 5° or 6°F. of the boiler water temperature maintained to heat the building. A mixing valve is often used to control the delivery temperature, but frequently the temperature at which it is set is excessive. If the tankless heater, or tank heater, is installed inside the boiler, the losses from the domestic heater may be considerable.

3. Methods of Generation and Storage

   a) By a tankless heater from a hot water boiler used to heat the building, or by a below-the-water line tankless heater on a steam heating boiler.

   b) By a tank heater and storage tank combination which is either a hot water or steam-heating boiler. The tank heater may be integral with the storage tank, or separately mounted and connected to the boiler and tank by piping.

   c) By a separate oil, gas, coal or electric domestic hot water heater with integral storage tank.

   d) By separate electric booster heaters without storage tanks.

4. Distribution

   Hot water is distributed either by gravity circulation or by a recirculating hot water pump through separate piping to the fixtures. The recirculating hot water pump delivers hot water instantly at the faucets and reduces the total quantity of water used by saving the cold water which is usually drawn upon first opening the faucet. However, because the pump requires electrical power for operation, and because its piping system must always be filled with hot water and experience heat loss, the use of the recirculating pump could be energy-wasteful in systems where all faucets are close to the tank.

C. ENERGY CONSERVATION OPPORTUNITIES

ECO 11 REDUCE THE TEMPERATURE OF DOMESTIC HOT WATER SUPPLIED TO TAPS

Lowering the temperature of the hot water reduces both the "building" domestic hot water load, as well as the distribution load. The building load for hot water heating is expressed by the following formula:

> Yearly BTU's = Q x Td_B, where Q = Quantity of domestic hot water used per year in pounds, and Td_B = Magnitude of the difference, in °F., between the temperature of cold water entering the heater, and the temperature of the hot water at the faucets.

The parasitic load is determined similarly, except:

> Yearly BTU's = Q x Td_p, where td_p= Magnitude of the difference, in °F., between the generation temperature and the temperature of the water at the taps.

Total load, then, is calculated as follows:

$$\text{Yearly BTU's} = (QxTd_B) + (QxTd_p).$$

Or, because:

$$Td = Td_B + Td_p$$

(that is, the difference between the temperature of the water as it enters the heater and the generation temperature), it is calculated more simply as follows:

$$\text{Yearly BTU's} = QxTd$$

Figure 19 indicates energy used for domestic hot water at various generation temperatures and usage rates. An incoming water temperature of 50°F. and 251 days of occupancy per year are assumed.

hot water

savings for reduction of faucet flow rate and water temperature

fig. 19

dubin-mindell-bloome-associates consulting engineers

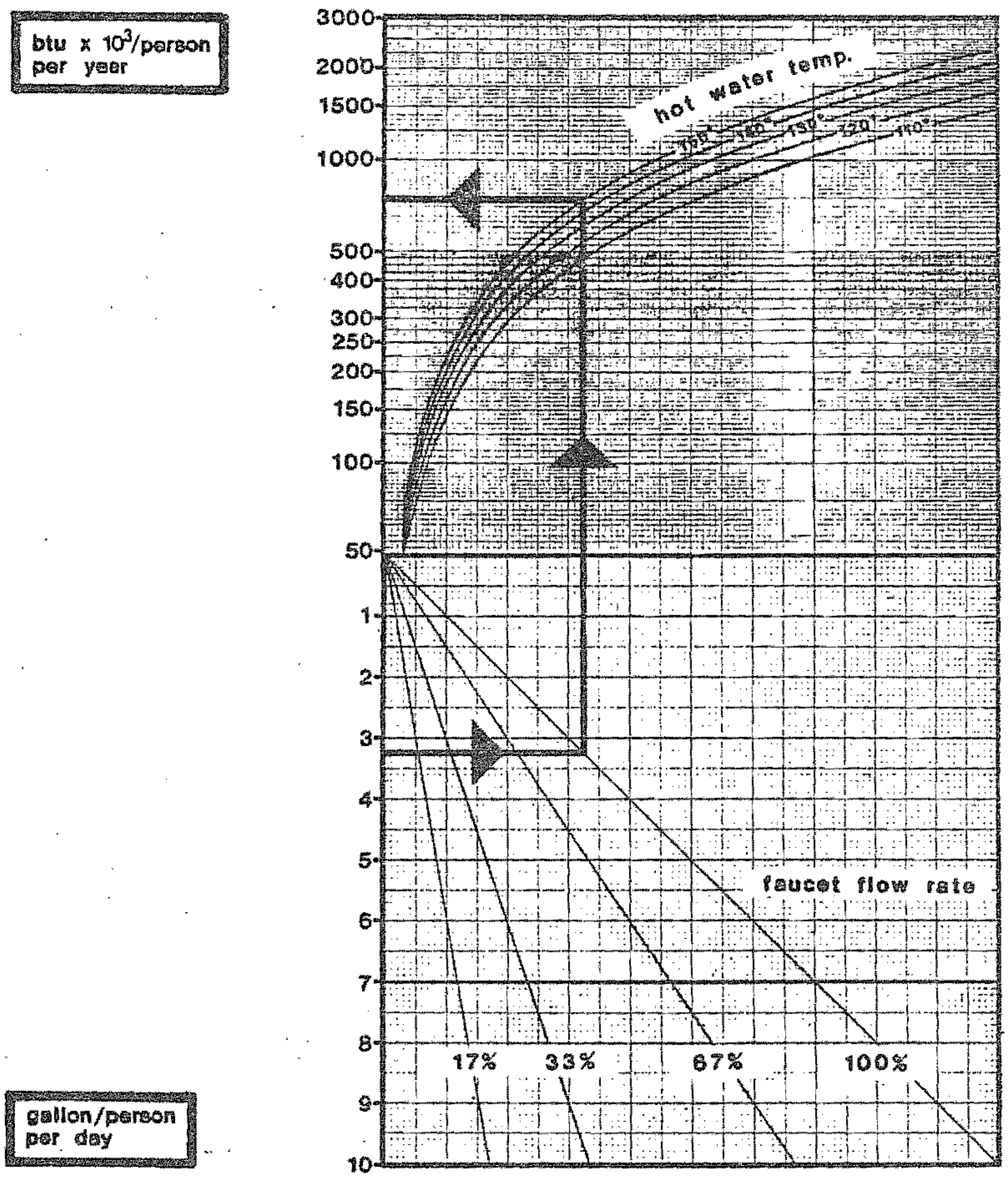

Figure #19 <u>Engineering Data</u>

Method: Straight heat transfer calculations

Assumption: Users open faucet for a set amount of time regardless of flow rate.
i.e. Washing hands is based on the time it takes rather than the water quantity.

The actual amount of energy required to supply the total load depends upon the seasonal efficiency of the heater, "E", which varies with the type of heater and the fuel used. On a seasonal basis, the following are average efficiencies:

a) Oil-fired heating boilers used year round, but with domestic hot water as the only summer load = .45.

b) Oil-fired heating boilers used year round with absorption cooling in the summer = .7.

c) Gas-fired heating boilers used year round, but with domestic hot water as the only summer load = .50.

d) Gas-fired heating boilers used year round with absorption cooling in the summer = .75.

e) Separate oil-fired hot water heaters = .70.

f) Separate gas-fired hot water heaters = .75.

g) Separate electric water heaters = .95.

h) Separate coal fired water heaters = .45.

To determine actual energy consumption, divide the value obtained from Figure 19* by the appropriate efficiency or use the following formula:

$$\text{Yearly BTU's} = \frac{QxTd}{E}$$

Example:

An office building has 500 occupants, each of whom uses 3 gallons of hot water per day for 250 days each year. The temperature of the water as it enters the heater is 60°F. (an average for the year) and it must be heated to 150°F. in order to compensate for a 20°F. drop during storage and distribution, and still be delivered, at the tap, at 130°F. Hot water is generated by an oil-fired heating boiler, used year round with domestic hot water as the only summer load. The fuel is #2 oil, which contains 138,000 BTU's to a gallon.

* If incoming temperature differs from 50°F., adjust valve before dividing. If incoming temperature is 60°F., for instance, at a generation temperature of 150°F., multiply value by $\frac{150-60}{150-50}$.

Building load

Q = 500 occpt x 3 gal./day/occpt x 250 day/yr. = 375,000 gal./yr.
1 gal. = 8.3 lbs., therefore
Q = 390,000 gal./day x 8.3 lbs./gal - 3,112,500 lbs/yr.
Td_B = 130°F. - 60°F. = 70°F.
Yearly BTU's - 3,112,500 lbs. x 70°F. - 217,875,000

Parasitic load

Td_D = 150°F. - 130°F. = 20°F.
Yearly BTU's = 3,112,500 lbs. x 20°F. - 62,250,000

Total load

Yearly BTU's = 217,875,000 + 62,250,000 = 280,125,000

Total energy used

$E = .45$

$$\text{total BTU's} = \frac{280{,}125{,}000}{.45} = 622{,}500{,}000$$

Total fuel consumption

$$\text{Yearly gallons} = \frac{622{,}500{,}000 \text{ BTU's}}{138{,}000 \text{ gal.}} = 4{,}511$$

To calculate the amount of fuel needed at a reduced delivery temperature, 90°F., for example, perform the following procedure:

$$4{,}511 \text{ gal.} \times \frac{90°\text{F.}}{130°\text{F.}} = 3{,}123 \text{ gal.}$$

This is actually a conservative figure, as the total savings in heating, storing, and distributing the water would include reduced storage and distribution losses as well.

Table 2 indicates the yearly energy loss in BTU's for various sizes of tanks, located in a space with an ambient temperature of 65°F., and with fiberglass insulation.

TABLE 2

Insulation Thickness	Tank size in gallons	BTU's in millions/year. Lost at Hot Water Temperatures of: 100°F	120°F	160°F
1"	50	1.9	3.0	5.2
	100	3.0	4.7	8.2
2"	250	3.1	4.9	8.4
3"	500	3.1	4.9	8.4
	1,000	5.2	8.2	14.1

Costs for insulating hot (or cold) water tanks with 3# density fiberglass - foil scrim craft facing, finished with pre-sized glass cloth jacket - are as follows:

Material Thickness	Cost/sq. ft. of Surface Area
1"	$2.60
1-1/2"	$2.70
2"	$2.95
3"	$3.60

ECO 12 REDUCE THE QUANTITY OF DOMESTIC HOT WATER USED

A primary benefit of reducing the quantity of hot water used is that energy consumption will be decreased to the same extent as with an equal percentage reduction in temperature.

A secondary benefit is the reduction in raw source energy which occurs because less water needs to be treated in the water supply treatment and sewage treatment plants, whether on-site or off-site. For municipal facilities, the diminished energy requirements will result in lower operating costs than otherwise possible, which in turn will mean that less taxes will be needed to support the facility. In areas where there is a charge based on total water consumption flowing into the sewer, the reduction in consumption of water will result in direct savings, as well. Water consumption can be lowered to 1-1/4 or 1-1/2 gallons per person per day in office buildings today without inconvenience to the occupants. Additional opportunities to reduce water consumption are summarized in the guidelines.

Example:

An office building has 500 occupants, each of whom uses 3.5 gallons of hot water per day for 250 days each year. The water, as it enters the heater, is at 40°F., and it is heated to 150°F. The separate gas-fired heater has an efficiency of 0.75.

Enter Figure 19 at 3.5 gal./person per day. Follow the example line intersecting with the 100% flow rate and 150°F. temperature lines and read yearly energy used of 800 x 10^3 Btu per person per year.

Re-enter Figure 19 intersecting with the 33% and 120°F. lines and read yearly energy used of 190 x 10^3 Btu/person/yr.

Savings: The energy saved equals 800-190 or 610 x 10^3 Btu/person/year and for 500 people, the total is 5 x 610 x 10^3 or 305 x 10^6 Btu/year.

$$\frac{305 \times 10^6}{138{,}000 \times 0.75} = 2{,}947 \text{ gal.}$$

Convert to Cost: At $0.36/gal., the savings is 0.36 x 2,947 or $1,061 per year.

Results: Energy Saved - 2,947 gallons/year
Dollars Saved - $1,061/year

ECO 13 IMPROVE THE EFFICIENCY OF THE STORAGE AND DISTRIBUTION SYSTEMS

Repair and replace all torn insulation to reduce heat loss. All measures to improve the efficiency of both space heating and domestic hot water heaters are noted in Section 4 , "Heating", and the measures to reduce heat loss from piping are detailed in Section 4 , "HVAC Systems and Distribution".

ECO 14 GENERATE HOT WATER MORE EFFICIENTLY

All of the measures for improving combustion units for space heating apply equally well to hot water heaters. Keep in mind, however, that when more than one heater, be it boiler or hot water heater, is installed on a project, it is more efficient to operate one for the total load if it can carry it, rather than to operate all boilers at partial loads.

The greater opportunities for conserving energy by improving the efficiency of the hot water generator, after normal service operations and minor modifications have improved the existing equipment to the extent possible, will require major modifications or the replacement of equipment.

ECM- 2 details these opportunities which include the following:

-Provide a separate hot water heater for summer or year round use.
-Heat hot water by use of rejected heat from refrigeration system condenser water or hot gas heat exchangers.
-Heat hot water with recovered energy from incinerators, heat pipes, hot water heat exchangers, or heat pumps.
-Replace resistance electric hot water heaters with gas or oil heaters or heat pumps.
-Add separate booster heater for kitchen or laundry service.
-Heat hot water with condensate return to steam operated systems.
-Heat hot water with solar water heaters.

GUIDELINES TO REDUCE ENERGY USED FOR DOMESTIC HOT WATER

REDUCE DOMESTIC HOT WATER TEMPERATURE:

-Where possible, use cold water only for hand washing in lavatories when cold water temperature is 75°F. or above. This is most readily accepted in retail stores, religious buildings, owner-occupied small office buildings and in washrooms used primarily by the public on an infrequent basis.
-Where tenants insist upon hot water for hand washing, heat tap water to 90°F.
-Do not maintain an entire hot water system at the same temperature required for the most critical use.

Do not heat water for hand washing, rinsing or cleaning to the same temperature required for dishwashing sterilization.
-If the space heating boiler is also used to supply domestic hot water, lower the aquastat setting in the summer time to 100°F. The same setting should be used for storage tank temperature control, summer and winter.

-Where higher temperatures are required, at a dishwasher, for example, a small gas or electric booster used only as needed saves more energy than a large storage tank, piping and distribution system which heats all domestic hot water in the building to the most critical temperature.

- -Use cold water detergents for laundries and laudromats and set water temperature to 65°F. -70°F.
- -Refer to Health or Food Handling Codes, if applicable, for minimum temperature specifications.

REDUCE HOT WATER CONSUMPTION:

- -Insert orifices in the hot water pipes to reduce flows.
- -Install spray type faucets that use only 1/4 gallons per minute (gpm) instead of 2 or 3 gpm, at a cost of about $50 a unit.
- -Install self-closing faucets on hot water taps.
- -In buildings with cooking facilities that are used only periodically, such as meeting rooms in religious buildings, shut off the hot water heating system, including gas pilots where installed, when the facilities are not in use.
- -Re-examine the need to heat entire tank of water when only a small quantity or no hot water is needed.
- -Simplify menus to reduce the need for large pots and pans that require large amounts of hot water for cleaning. Where practical use short dishwashing cycles and fill machine fully before use.
- -Reduce the number of meals served and/or serve more cold meals to reduce the hot water requirements for dishwashing.
- -In areas where water pressure is higher than a normal 40 to 50 lbs., restrict the amount of water that flows from the tap by installing pressure reducing valves on the main service. Do not reduce pressure below that required for fire protection or for maintaining adequate pressure on the top floor for flushing.
- -Refer to Plumbing Codes, if applicable, for hot water supply requirements.

REDUCE SYSTEM LOSSES

- -Repair insulation of hot water piping and tanks or install it where missing (unless piping and tanks are located in areas which require space heating or aire air-cooled).
- -Where forced circulation of hot water is used, shut off the pump when the building is unoccupied; when hot water usage is light consider using gravity circulation without the pump.
- -Flush water heater during seasonal maintenance of heating systems.
- -Repair leaky faucets.
- -Repack pump packing glands of recirculation hot water heaters to reduce leaking of hot water.
- -For boilers with immersion tankless domestic hot water coils, make sure boiler water covers coils.

SECTION 4 - C

COOLING AND VENTILATION

INDEX

COOLING AND VENTILATION

A. BACKGROUND

The annual consumption of energy for cooling and ventilation can be reduced by applying the same three major categories as for heating and ventilation:

1. Reduce the "building"* cooling load.

2. Reduce the distribution system load.

3. Increase the efficiency or performance of the primary energy conversion equipment.

Categories 1 and 3 are addressed in this section and Category 2 in Section 4 , "HVAC Systems and Distribution".

B. THE "BUILDING" COOLING LOAD

Two components - sensible or dry heat, and latent heat, a function of the heat content of the moisture in the air - determine the "building" cooling load. To maintain comfort, the dry bulb temperature which measures sensible heat, and the wet bulb temperature (or the relative humidity), which measures latent heat, must be controlled. Because, for most comfort cooling installations, air is dehumidified when it is cooled, separate control of the relative humidity is not usually required.

Average temperature difference between indoor and outdoor conditions is one of the factors which defines the sensible heat gain portion of the annual "building" load; reduce this load by maintaining higher indoor temperatures for as long a period as possible during the cooling season, whenever further operation of the mechanical refrigeration system would be required to maintain a lower one. When the sensible heat gain is decreased, reduce the amount of cool supply air accordingly to realize additional energy savings in fan horsepower.

The cooling load, is in part, due to conductive heat gain from outdoors to indoors, through the building envelope.

The average difference in temperature between indoors and the exterior surfaces of the walls and roof depends upon outdoor dry bulb temperatures and the amount of solar radiation impinging upon the outside walls and roof (and warming

*"Building" cooling load is used to identify the loads to maintain interior conditions and should not be confused with "room load" which is standard terminology for building loads not including the ventilation load.

them to a level - termed "sol-air" temperature - which is most often above ambient temperatures). To conserve energy, shut off, during unoccupied periods, the refrigeration system and its auxiliaries (chilled water and condenser water pumps, cooling towers and air cooled condensers) and maintain, during occupied periods, a dry bulb temperature of 78°F. or higher. Maintaining even higher temperatures in less critical spaces will conserve more energy. If the relative humidity in the building is permitted to rise to 55% (the usual level is 45 to 50%), or to fluctuate normally (within the limits set by the refrigeration system's ability to maintain wet bulb temperatures), considerable energy will be conserved. The system requires power to remove moisture which originates from internal loads - people and cooking - and from outdoor air as it infiltrates and/or ventilates the building. See Figure 20 for "Recommended Cooling Season Indoor Temperature and Humidity".

"Heat gain" - a term used to quantify the amount of heat which is added to a space and must be removed to maintain desired space conditions - is an addition to the cooling load. Solar heat gain through windows frequently constitutes a major portion of the sensible heat "building" cooling load. The benefits from using the sun to reduce the heating load in the winter are considerable, but remember to block it out in the summer. Solar control devices which can be adjusted either to accept or block sunlight reduce energy consumption year'round.

Just as ventilation and infiltration add to the heating load in the winter, they also increase the cooling load in the summer. Outside air must be cooled and dehumidified. Maintaining higher indoor temperatures and relative humidity reduce the cooling load contributed by infiltration and ventilation as well as conductive heat gains. However, whenever outdoor air is cool enough to lower the indoor temperatures, it may be advantageous (and energy conserving) to cool or precool the building at night, using an economiser cycle, without mechanical refrigeration. When the wet bulb (W.B.) temperature of the outdoor air is lower than the W.B. temperature of the return air from the interior spaces, an enthalpy controller will open the outside air dampers and close the return air dampers to take in 100% outdoor air; the controller saves power for the refrigeration system. Internal heat gains-heat emitted from electric lighting fixtures, business machines, motors, cooking equipment and people form a large part of the total cooling load.

Reducing the "building" cooling load by a fixed percentage allows further savings of energy since distribution loads can be decreased accordingly. A reduction in the flow of cool air or chilled water to meet the reduced load and an increase in the suction temperatures at which the refrigeration chillers or compressors operate (improving their Coefficient of Performance - C.O.P.) will result in significant savings - less horsepower per ton of refrigeration as well as less tons to be produced.

C. DISTRIBUTION SYSTEM LOADS

The distribution system may carry chilled water to units in the spaces to be conditioned (fan coil, induction, or small air handling units) or to remote air handling units (which supply air, via ducts to local registers and diffusers). In some systems the compressors discharge a vaporized refrigerant to a condenser, when it is condensed to a liquid; then, it is allowed to expand directly in a cooling coil which cools or dehumidifies circulating air. In all cases, air may be circulated from the conditioned space, from outdoors, or from a mixture of both: the air is supplied after it is filtered, cooled and dehumidified in the air handling unit or air-handling section of the air conditioning system.

Piping and duct losses - heat gain and water or air leakage - increase the distribution loads, and as a result, the load on the primary energy conversion equipment. See Section 4 , "HVAC Systems and Distribution" for energy conservation opportunities and guidelines to reduce distribution system losses.

D. PRIMARY ENERGY CONVERSION EQUIPMENT

Energy is used to supply the cooling "building" and distribution loads. In the form of heat, energy operates absorption refrigeration units, and as electricity, it operates reciprocating, centrifugal or screw type compressors and/or chillers. The refrigeration equipment produces either chilled water or, in the case of direct expansion refrigeration units with air handling units, cooled and dehumidified air. (Note: Refrigeration equipment is often referred to as the "high" side of the refrigeration cycle.) The air-cooled or water-cooled condensers of the refrigeration equipment control the condensing temperature of the system - the lower the condensing temperature, the more efficient the refrigeration system. The manner and conditions under which air cooled condensers or evaporative condensers with cooling towers are operated exert a significant influence on the energy required to run the refrigeration units. The efficiency of the refrigeration system is expressed as a coefficient of performance (C.O.P.).

The capacity of the system is measured in tons of refrigeration; one ton will produce a cooling effect equal to 12,000 Btu's/hr. Seasonal C.O.P. is the ratio of the tons of refrigeration produced, expressed in Btu's, to the energy required to operate the equipment, also in Btu's. If one kilowatt hour of electricity (equivalent to 3,412 Btu's) is required to produce one ton of refrigeration (12,000 Btu's) the C.O.P. is $\frac{12,000}{3,412} = 3.52$. To improve the C.O.P. - reduce energy usage - lower the condensing temperatures and/or raise the suction temperatures. The opportunities to do either depend upon load reduction and upon the operation and maintenance of the equipment, outlined in ECO's 20 and 21. The opportunities to improve C.O.P. by reducing distribution loads are outlined in Section 4, "HVAC Systems and Distribution".

E. ENERGY CONSERVATION OPPORTUNITIES

ECO-15 TURN OFF COOLING SYSTEM DURING UNOCCUPIED HOURS

Turning off the entire air-conditioning system, at night and during days when the building is unoccupied, generally will save energy. Manually shut down cooling or condenser fans, chilled water and condenser pumps, and supply and exhaust fans as well as chillers or compressors. If the cooling tower fans and pumps are interlocked with the compressors, they will shut off automatically when the compressors are shut off. Shut down boilers which supply steam or hot water to absorption units; do not maintain boiler water temperature or steam pressure when absorption units are inoperative. If, after shut down, the air conditioning system is not capable of achieving and maintaining temperature and humidity conditions in hot spells, install a control to activate the equipment a few hours before occupancy instead of operating the system all night or throughout the entire weekend.

In geopraphic areas such as parts of Arizona or California with a large diurnal swing (large temperature difference within 24 hours), night operation of the refrigeration system for periods of the summer may be economical. If climatic conditions at night permit lower condensing temperatures, perform an analysis to indicate whether energy can be saved by operating the refrigeration system at night to precool the building or to store chilled water in the piping system.

An engineering and economic analysis, comparing refrigeration operation and economiser cooling is necessary to determine the mode of operation which will result in minimum energy consumption.

ECO-16 USE OUTDOOR AIR FOR COOLING

A. Night and Unoccupied Periods

When nighttime outdoor temperatures are below indoor temperatures by 5° or more, shutting off the refrigeration system and using outdoor air for night cooling will save energy in most areas of the country. The opportunities to use outdoor air for cooling during unoccupied periods depend upon the length of time that the outdoor air temperature is below 73°F. In most areas there will be no advantage to bringing in outdoor air above that temperature; heat from the fan motors will raise the air temperature 2 to 3°; and the power required to drive the fans will outweigh any savings due to precooling and reduced operation of the refrigeration system. The temperature at which outdoor air cooling is advantegeous may be even lower in large buildings which have high velocity systems, as the power requirements for fan motors in these systems are higher.

In buildings which have operable windows, however, night cooling, even at higher outdoor air temperatures, is worthwhile, as fan motors need not be operated.

If the dry bulb temperature of the outdoor air is above indoor temperature, the wet bulb temperature of the outdoor air can be higher than the room wet bulb temperature. There may be periods when air at higher wet bulb temperatures, introduced directly into spaces that have been cooled during the day, will cause condensation on walls or furnishings. Maintaining higher space temperature conditions, 78°F. and above, will minimize the amount of time that this could occur and all but elimiante the constraint in most areas of the country. Even in humid climatic zones, wet bulb temperatures above 78°F. occur for relatively few hours at night; the need to limit economiser operation exists only during those hours.

Where there are no automatic controls to operate an economiser cycle, operate dampers and fans manually, or consider installing controls.

To fully utilize outdoor air for cooling, it may be necessary to install return air and outdoor air dampers, and provide a means of relieving air pressure. Some possible options include partially opening some windows, operating an exhaust system, or installing some propeller type exhaust fans in the wall. Refer to ECM- 2 for more details on economiser or enthalpy control.

B. Occupied Periods

During occupied periods, the opportunities to use outdoor air for cooling depend not only on outdoor dry bulb temperature, but also upon the wet bulb temperature; if outdoor air is brought into the building above 66° F.W.B. (the equivalent to the wet bulb temperature when the spaces are maintained at 78°D.B. and 55% R.H., it adds to the cooling load. The wet bulb temperature is a measure of the total heat content of the air. If the wet bulb temperature is lower than 66°F., outdoor air can be introduced through the cooling coil, with the refrigeration system in operation in any quantity. At less than 66°F W.B. outdoor air, in fact, will reduce the cooling load. For many existing systems, however, (even when the temperature of outside air is less than 66°F. W.B.) the cooling coils are not designed to be able to handle outdoor air at temperatures above 85°F. D.B. and still maintain room conditions at 78°F. D.B. - this, despite the fact that outdoor air at less than 66° W.B. actually has a lower total heat content than room air. Figure 9 indicates for areas all over the country, the number of wet bulb degree hours below 66° W.B. when the dry bulb temperature is less than 85°F. in the summer. If a building is in a location where there are 3,000 or more such degree hours, an enthalpy controller will be a good investment. Denver, Colorado, on a seasonal basis, has low wet bulb temperatures, and it would appear that it would be more economical to utilize 100% outdoor air through the air conditioning coils in the daytime, rather than to recirculate air. Summer outdoor dry bulb temperatures in Denver, however, often rise above 90°F. If the existing coils have not been selected to reduce the temperature of outdoor air at those times, they will be incapable of handling the conduction, solar and internal heat gains which occur. To conserve energy in this type of a climate, open the outdoor air damper fully except when indoor dry bulb temperatures cannot be maintained. Operating systems manually to reflect temporary conditions and conserve energy is sometimes difficult but the effort yields significant savings. Automatic controls are available to optimize the operation of most systems and to meet varying and selective conditions. Refer to ECM-2 for details.

ECO - 17 INCREASE INDOOR TEMPERATURE AND RELATIVE HUMIDITY LEVELS DURING OCCUPIED HOURS*

The air conditioning systems in many buildings were designed to maintain 72° to 75°F. D.B. and 50% R.H. during peak loads in the cooling season. They are operated to maintain those levels at peak conditions, and to achieve even lower levels during the part load conditions which occur most of the time.

Maintain dry bulb temperature and relative humidity for various spaces at the levels suggested in Figure 20, "Recommended Cooling Season Indoor Temperature and Humidity" to reduce the cooling load and energy and operating costs. Realize even greater savings, without serious discomfort, by maintaining higher levels in areas which are only occupied for short periods of time.

If unoccupied periods in these areas exceed 60% of the day, shut off the cooling unit or close registers, grilles and diffusers; allow temperature and humidity to rise when the areas are unoccupied. (Auditoriums, corridors, cafeterias and conference rooms are all spaces frequently unoccupied for most of the day.)

Increasing the indoor temperature and humidity levels from 74°D.B. and 50% R.H. to 78° D.B. and 55% R.H. will save approximately 13% of the energy required for cooling. The exact amount depends upon the amount of ventilation air and infiltration which enters the building; the conduction losses, solar heat gain, and internal loads of the building; and the type of air conditioning system it has.

Use the multipliers in the following table to determine the amount of energy saved (in Btu's per hour) per 1,000 CFM of outdoor air (ventilation plus infiltration) by raising the dry bulb temperatures at constant relative humidities. (All other factors are considered constant, and since the effect of raising the dry bulb temperature on conductive heat gain is actually negligible, it has been disregarded here.)

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*With terminal reheat systems in operation, the indoor space conditions should be maintained at lower levels to reduce the amount of reheat and save energy. If cooling energy is not required to reduce the temperatures, maintain 74°F. D.B. instead of 78°F. See Section 4, "HVAC Systems and Distribution" for discussion of terminal reheat systems and guidelines for operation.

TABLE I

Relative Humidity	50%	60%	70%
Dry Bulb Temperature			
72°F.	0	0	0
73°F.	2,700	2,433	3,000
74°F.	2,657	2,400	3,257
75°F.	3,000	2,572	3,000
76°F.	3,000	2,572	3,000
77°F.	3,000	2,572	3,429
78°F.	3,000	2,572	3,429

Example:

Project the savings achieved, in cooling outdoor air, by raising the indoor dry bulb temperature from 72° F. to 78°F.

Type	- Office, 40 hours occupancy
Annual WB degree hours above 66°F. WB	- 8,000
Total outdoor air including infiltration	- 10,000 CFM
Relative Humidity	- 50%

From Table I, in the 50% RH column, determine that raising the DB temperature from 72° to 73° saves 2,700 Btu's/hour/1,000 CFM, from 73° to 74°, 2,657; and from 74° to 75° 75° to 76° to 76° to 77°, and 77° to 78°, 3,000 Btu's/hour/ 1,000 CFM. To calculate savings over total temperature change, add the 6 figures together:

2,700 + 2,657 + 3,000 + 3,000 + 3,000 + 3,000 =
17,357 Btu's/hour/1,000 CFM

For an outdoor air rate of 10,000 CFM, savings will be:

10 x 17,357 = 173,570 Btu's/hour

For 40 hours of cooling per week, and a cooling season of 20 weeks, yearly savings will be:

173,570 x 40 x 20 = 128 x 10^6 Btu's/hour fig. 20

SUGGESTED INDOOR TEMPERATURE AND HUMIDITY LEVELS IN THE COOLING SEASON

I. Commercial Buildings — Occupied Periods

	Dry Bulb Temperature *	Minimum Relative Humidity
Offices	78°	65%
Corridors	Uncontrolled	Uncontrolled
Cafeterias	75°	55%
Auditoriums	78°	50%
Computer Rooms	75°	As needed
Lobbies	82°	60%
Doctor Offices	78°	55%
Toilet Rooms	80°	
Storage, Equipment Rooms	Uncontrolled	
Garages	Do Not Cool or Dehumidify.	

II. Retail Stores — Occupied Periods

	Dry Bulb Temperature	Relative Humidity
Department Stores	80°	55%
Supermarkets	78°	55%
Drug Stores	80°	55%
Meat Markets	78°	55%
Apparel	80°	55%
Jewelry	80°	55%
Garages	Do Not Cool.	

* Except where terminal reheat systems are used.

Savings: Energy saved for a mechanical refrigeration system with a C.O.P. of 2.5 will be:

$$\frac{139 \times 10^6}{2.5} = 56 \times 10^6$$

$$\frac{56 \times 10^6 \text{ Btu's/year}}{3{,}413 \text{ Btu's/KWH}} = 16{,}408 \text{ KWH/year}$$

Energy saved for an absorption refrigeration system with a C.O.P. of 0.68 will be:

$$\frac{139 \times 10^6}{0.68} = 204 \times 10^6 \text{ Btu/year}$$

If this energy would have been supplied by a steam boiler with a seasonal efficiency of 60%, $\frac{204 \times 10^6 \text{ Btu's}}{0.6 \times 138{,}000 \text{ Btu's/gallon}} = 2{,}463$ gallons

Assuming a cost for electricity of $0.4/KWH, savings for the mechanical system will equal:
.04 x 16,408 = $656/year
At an oil cost of $0.36 per gallon, savings for the absorption system will equal:
.36 x 2.463 = $887

If the relative humidity in the building is allowed to rise from 50% to 70%, the savings are calculated as follows:

Enter Figure 21 at 8,000 WB degree hours. Follow the example line with the 50% RH line and the 40 hour line and read yearly energy used at 22.5×10^6 Btu/year/1,000 CFM.

Re-enter Figure 21 intersecting with the 70% RH line and read yearly energy used at 16×10^6 Btus/year/1,000 CFM/

Savings: The energy saved equals 22.5 - 16 or 6.5×10^6 Btu's/year/1,000 CFM. For 10,000 CFM, the total reductions in energy input are 7,618 KWH/year and $305 for a mechanical refrigeration system and 1,160 gallons of oil/year and $415 for an absorption refrigeration system.

Results: Energy Saved - 7,618 KWH/year or 1,160 gallon/yr.
Dollars Saved - $305 or $415

cooling

yearly energy used
per 1000 cfm to maintain
various humidity conditions

fig. 21

dubin-mindell-bloome-associates
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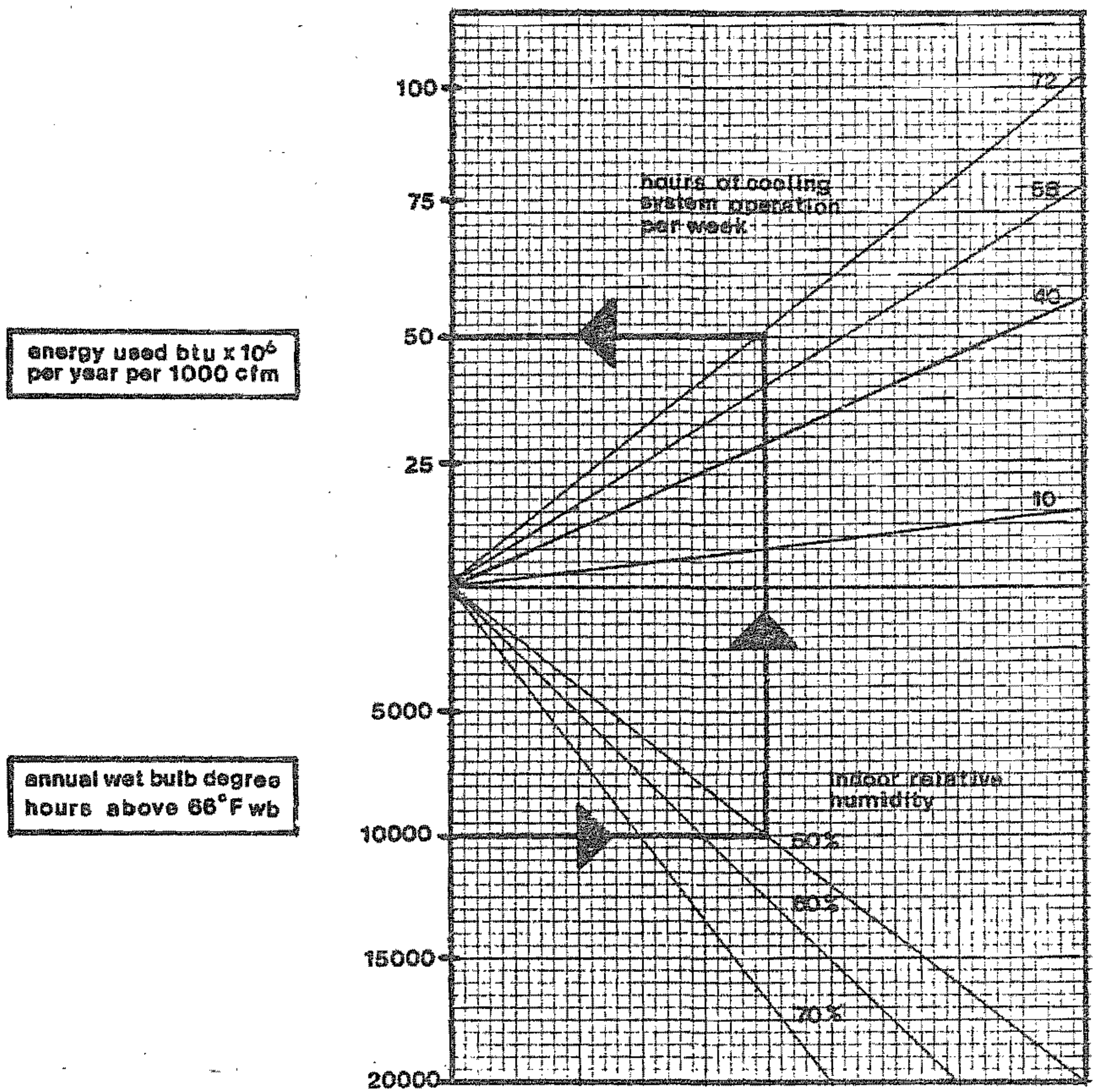

Figure #21 Engineering Data

Weather data from Figure #8

WB degree hours based on 12 Mos/yr, 8 Hr/Day

Energy used is a function of the WB degree hours above the base of 66°F, the RH maintained the No. of hours of controlled humidity. The base RH is 50% which is approximately 78°F DB, 66° WB. The figure expresses the energy used per 1000 CFM of air conditioned or dehumidified. An analysis of the total heat content of air in the range under consideration indicates an average total heat variation of 0.93 Btu/lb for each degree WB change at constant DB temperature and that the total heat varies nearly directly with RH. One thousand CFM is equal to 4286 lb/hr so each degree F WB hour is equal to 4286 x 0.93 or 3986 Btu. The lower section of the figure shows the direct relationship from the base of 50% RH and the upper section proportions the hours of system operation with 56 Hr/Wk being 100%.

ECO-18 REDUCE VENTILATION RATES DURING OCCUPIED PERIODS*

Except where outdoor air can be used productively for economiser cooling (and the temperature and enthalpy are suitable as described in ECO-15 above), cooling and dehumidifying outdoor air consumes large quantities of energy. Any measure that reduces the quantity of ventilation to a minimum and is compatible with physiological needs, will result in substantial energy and dollar savings. Refer to Figure 16, "Suggested Ventilation Standards" for both summer and winter periods. The suggestions for ventilation discussed in Section , "Heating and Ventilating" apply, generally to the cooling season, as well. Some codes permit further reductions in ventilation rates if the air is cooled. During the cooling season, the enthalpy difference between the outdoor and indoor air determines the quantity of energy required to cool and dehumidify the ventilating air to indoor conditions. As enthalpy, or total heat, is very closely approximated by wet bulb temperature, the difference in wet bulb temperature between outdoor air and room conditions can be used to determine the energy required for cooling and dehumidification.

To determine the approximate yearly energy savings resulting from a reduction of outdoor air, first detemmine how much air is being introduced into the building, and second, determine the minimum quantity that legally, must be introduced into the building. The difference determines the potential reduction of ventilation air and energy savings. For the cooling season, use Figure 21 to determine the energy required to cool and dehumidify a given amount of ventilation air. The following example indicates the method to be used to determine the savings.

Example:

Building Type	-	Office
Location	-	Miami, Florida
Occupied Hours/Week	-	40
Number of Occupants	-	667
Indoor Relative Humidity	-	50%
Annual et Bulb Degree Hours Above 66°F	-	18,500

*Also read "Heating and Venfilating", ECO-6, guidelines.

Determine energy saved by reducing outdoor air from 30 CFM/person to 8 CFM/person (mixed population of smokers and non-smokers).

Determine total CFM reduction:

30 - 8 = 22 CFM/person x 667 people = 14,674 CFM. Enter Figure 21 at 18,500 degree hours, intersecting with the 50% RH and 40 hour lines, follow the example line and read yearly energy used of 52.4 x 10^6 Btu/year/1,000 CFM.

Savings: The total energy saved is 14.5 times 52.5 x 10^6 Btu/year. If cooling is by a mechanical refrigeration system with a C.O.P. of 2.5, the reduction in energy input is $\frac{771 \times 10^6}{2.5} = 308 \times 10^6$ Btu/year

$\frac{308 \times 10^6}{3,413} = 90,243$ KWH/year

If an absorption machine is used, the reduction in energy input is $\frac{771 \times 10^6}{0.68} = 1,134 \times 10^6$ Btu/year

and if this energy is supplied by a steam boiler with a seasonal efficiency of 65%, the gallons of oil saved is

$\frac{1,134 \times 10^6}{0.65 \times 138,000} = 12,642$ gallons/year

Convert to Cost: At $0.04/KWH, the savings for the mechanical refrigeration system are 0.04 x 90, 243 = $3,609/yr. At $0.36/gal. the savings for the absorption system are 0.36 x 12,642 = $4,551/year.

Results: Energy Saved - 90,243 KWH/year or 12,642 gal/yr.
Dollars Saved - $3,609/year or $4,551/year

If, in the previous example the refrigeration system had been operating nights and weekends with the 30 CFM/person ventilation rate, the savings due only to shutting off the outdoor air during unoccupied periods and reducing it from 30 CFM/person to 8 CFM/person for 40 hours per week would be about $4,460 per year with electric refrigeration and $7,000 per year with absorption refrigeration. These figures do not include the additional savings (in power) which would accrue from not operating the refrigeration system and its auxiliaries during unoccupied periods. If a refrigeration system is operated at night for precooling, or to handle late evening events, shut off the outdoor air intake.

ECO-19 <u>REDUCE INFILTRATION RATES</u>

Leakage or infiltration of air into the building, as described in Section 4., "Heating and Ventilating", adds, to the same extent as an equal amount of ventilation air, a load on the "building" cooling system. Generally, because wind velocities are lower in the summer, the infiltration rates are somewhat lower as well. They may still, however, be a significant factor in the magnitude of the cooling load. Infiltration imposes an added load on the distribution system. Unlike ventilation, which is not a "space" or "room" load, infiltration is an additional room load, and the sensible heat component of infiltration increases the amount of air which must be circulated (as the amount of air circulated in a cooling system depends only on the magnitude of the room sensible heat load). Because infiltration occurs for 24 hours per day, it creates a load during the night which must be removed the next day by the refrigeration equipment. In retail stores, the greatest amount of infiltration occurs through door openings. Refer to EMC-2 for information on infiltration rates through door openings and the installation of revolving doors as a measure to reduce it.

Determine infiltration rates through windows by using Figure 18, and calculate the cooling load for any given amount of infiltration converted to CFM by using Figure 21.

From all causes, the infiltration rate for most buildings is between 1/2 and 1 1/2 air changes per hour, depending upon the condition of the doors and windows, length of cracks, height of the building, and the number of door openings. (See Section 4, "Heating and Ventilation", ECO-5). To convert air changes per hour to CFM, multiply the building volume (area per floor, times the number of floors, times the ceiling height of one floor) by the number of air changes per hour, and divide by 60. For example a building of 10 stories with 10,000 square feet of floor area per story, a floor to ceiling height of 10' and 1 1/2 air changes per hour would have:

$$\frac{10 \times 10 \times 10{,}000 \times 1.5}{60} = 25{,}000 \text{ CFM}$$

Use Figure 21 to determine the cooling load due to the air quantity in CFM for any location.

Weather stripping and caulking (usually done to reduce infiltration rates in the winter) will reduce the summer cooling load. To determine the savings in energy and dollars during the cooling season for reduced infiltration due to window leakage, use the method indicated in the following example.

Example: Determine the crack area first. Use the identification profiles to gather pertinent data.

Building Type	-	Offices
Building Size	-	100' x 50', 4 floors

Building Location	-	Topeka, Kansas
Wet Bulb Degree Hours Greater than 66°F.	-	3,000
Wind Speed	-	8 mph
Wind Direction	-	SW
South Windows	-	5' x 3'; 28 total
West Windows	-	5' x 3'; 56 total

Window Type: double hung, loose fitting.

Determine the crack length/window
Each Window perimeter = 5+5+3+3+3(center joint)=19 feet
Total crack length - 19 x 84 windows = 1,596 feet

Determine from Figure 18, the rate of infiltration:
Per foot of crack = .9 CFM/ft.
Total infiltration = 1,596 x .9 = 1,436 CFM

Determine from Figure 18, the new rate of infiltration per foot of crack if windows are weather stripped = 0.1 CFM/ft.
Therefore total infiltration = 1,596 x 0.1 = 159.6 CFM
Infiltration Reduction = 1,436 - 160 = 1,276 CFM

Determine additional cooling energy required:
Enter Figure 21 at 3,000 degree hours and intersecting with the 60% RH and 40 hour lines, follow the example line and read yearly energy used of 7.5×10^6 Btu/year/1,000 CFM.

Savings: The total energy saved is $1{,}276/1000 \times 7.5 \times 10^6$ 9.6×10^6 Btu/year. For mechanical refrigeration system, the reduction in energy input is $\frac{9.6 \times 10^6}{2.5 \times 3{,}413} = 1{,}125$ KWH/yr.
For absorption system, the reduction in energy input is $\frac{9.6 \times 10^6}{0.68} = 14.1 \times 10^6$ Btu/year and,
For steam boiler supplying the steam and gallons of oil saved is $\frac{14.1 \times 10^6}{0.65 \times 138{,}000} = 161$ gallons/year

Convert to cost: At $0.04 KWH, the savings for the mechanical refrigeration system are $0.04 x 1,125 = $45/years
At $0.36/gallon, the savings for absorption system are 0.36 x 161 - $58/year.

ECO-20 REDUCE SOLAR HEAT GAINS

Solar heat gain is a major contributor to the cooling load in all parts of the country where the ratio of window to wall area (on the east, west, and south facades) is 20% or more with clear unshaded glass, and 50% or more with any type of glass exposed to direct sunlight. Solar radiation on the roof (which receives the most in the summer) and on the east, west, and south walls increases the outside surface temperature and heats the surfaces. The increase in heat transmission through the surfaces which then occurs is in excess of conduction which would have resulted from temperature difference between indoors and outdoors alone.

Solar radiation on skylights and windows is transmitted through the glass almost instantaneously. Annually, almost 80 percent of all the solar radiation striking a vertical single sheet of clear glass surface is transmitted through it. It constitutes an addition to the cooling load, but a reduction of the heating and electric loads (if lights are turned off when daylight is available). Conservation measures that reduce solar heat gain include shading the interior or exterior of the glass and treating it to increase its reflective properties. Evaluate devices that prevent solar radiation from entering the building in hot weather, against the need for solar heat in cold seasons.

Solar shading devices on the exterior of the building are more effective than inside blinds, drapes, or reflective coatings or heat absorbing or reflective tinted glass. Refer to Figure 22 for the relative effectiveness of various shading devices. Achieve external solar control through the use of trees that shade the building surfaces, horizontal exterior louvers, or eyebrows on the southern exposure and vertical and horizontal fins or extensions to shade the east and west facing glass surfaces. Install thin sun screens on the exterior face of the window to reduce solar heat gain by 50 to 75%. Sun screens cause the loss of some natural lighting and the blocking of some of the useful sun rays in the winter; however, sun screens on windows that are subjected to winter winds (usually from the west) reduce heat loss considerably in the winter as well as heat gain in the summer. Sun screens are commercially available for about $3.50/per square foot of glass surface.

Use internal shades, venetian blinds, curtains or sun screens (similar to the exterior type which can be removed in the winter) to reduce solar heat gain in the summer and still permit direct radiation to enter in winter. To install venetian blinds costs about $1.60/sq.ft. in small quantities down to about $1.00/sq.ft. for 400 windows, or more.

Painting the exterior surface of the exterior walls with white coatings to increase reflectivity is not so effective as increasing the emmissivity of the exterior roof surface. Using light colored coatings or cooling the roof with a roof spray are two options. However, measures to increase emissivity and reduce cooling loads for exterior surfaces which have a mass of 50 to 100 lbs/sq.ft., and/or which are insulated to a U factor of .1 or lower are ineffective. It is also difficult to maintain the light color on roofs in urban areas.

ECO-21 <u>REDUCE INTERNAL HEAT GAIN</u>

Internal heat gain (from lights, business machines, computers, motors, occupants, and in some buildings, ovens, ranges and refrigeration units) make up a major portion of the cooling load in many buildings. Except in small restaurants which can have major heat gains from cooking equipment, heat gain from lighting is the most significant.

Guidelines to reduce illumination levels, in the many buildings which are overlighted, to more reasonable levels are described in Section 4, "Lighting". The reduction of lighting is a simple and effective way to reduce the cooling load. The following example indicates the potential savings for many buildings, from decreasing cooling load by reducing lighting.

Example:

First determine the approximate length of the cooling season based on past experience.

From the Identification Profile:

Building Type	-	Office
Building Location	-	New York
Building Size	-	50,000 sq. ft.
Lighting Intensity	-	4.5 watts/sq.ft.

The building has a total of 1,400 fixtures with 4-40 watt lamps in each. If 2 lamps are removed from 75% of the fixtures, then the reduction in watts = 1,400 x .75 x 2 x 40 = 84,000 watts or 84KW. The present total wattage = 225,000 and the new total = 225,000 - 84.000 = 141,000 watts or $\frac{141,000}{50,000}$ = 2,8 watt/sq.ft.

The heat gain from lights is reduced by 84KW for each hour of operation during the cooling season, or 84 x 3,413 = 286,692 Btu/hr.

fig. 22

SHADING COEFFICIENTS

GLASS	
1/8" Clear Double Strength	1.00
1/4" Clear Plate	0.93 - 0.95
1/4" Heat Absorbing Plate	0.65 - 0.70
1/4" Reflective Plate	0.23 - 0.56
1/4" Laminated Reflective	0.28 - 0.42
1" Clear Insulating Plate	0.80 - 0.83
1" Heat Absorbing Insulating Plate	0.43 - 0.45
1" Reflective Insulating Plate	0.13 - 0.31

SHADING DEVICE	WITH 1/4" CLEAR PLATE GLASS	WITH 1" CLEAR INSULATING GLASS
Venetian Blinds - Light Colored, Fully Closed	0.55	0.51
Roller Shade - Light Colored, Translucent, Fully Drawn	0.39	0.37
Drapes - Semi-Open Weave, Average Fabric Transmittance and Reflectance, Fully Closed	0.55	0.48
Reflective Polyester Film	0.24	0.20
Louvered Sun Screens - 23 Louvers/In.	0.15 - 0.35	0.10 - 0.29
- 17 Louvers/In.	0.18 - 0.51	0.12 - 0.45

If the cooling season is 100 days long, and occupancy is 8 hours per day, the yearly reduction in heat gain = 286,692 x 100 x 8 = 229 x 10^6 Btu/year. With a mechanical refrigeration system, the reduction in energy input =

$$\frac{229 \times 10^6}{2.5 \text{ (Average C.O.P.)}} = 91.6 \times 10^6 \text{ Btu/yr or } \frac{91.6 \times 10^6}{3413} = 26{,}838 \text{ KW/yr}$$

At 5 cents/KW, a savings of \$0.05 x 26,838 = \$1,342 for refrigeration (plus approximately \$600/yr additional savings in fan and motor horsepower for the auxiliaries). If an absorption refrigeration system were used, the reduction in energy input =

$$\frac{229 \times 10^6}{.60} = 382 \times 10^6 \text{ Btu/yr.}$$

Assuming that heat is supplied to the absorption unit by steam boiler with seasonal efficiency of 65%, then the gallons of #2 oil saved =

$$\frac{382 \times 10^6}{.65 \times 138{,}000} = 4{,}459 \text{ gallons.}$$

At \$0.36 per gallon, the savings would be .36 x 4,259 = \$1,533/yr

It is very important to keep in mind that a reduction in lighting intensity not only reduces the cooling load, but also reduces the building electrical consumption throughout the year.* In this case, the reduction amounts to 84 KW x 2,100 hrs/yr (occupied time) = 176,400 KWH at \$0.05 KWH = \$8,820.

Whenever motor operated equipment which is located in air conditioned spaces is operated for fewer hours, the cooling load is reduced by about .8 KW, or about 2,500 Btu's per horsepower hour. In office buildings, equipment consumes an average of 0.75 watts /sq. ft. of floor area. For a building of 50,000 sq. ft. calculate savings from a reduction in operating time from 8 to 7 hours per day as follows: 50,000 x 3/4 x 1 hr. = 37,000 watt hours/day. Multiply by a conversion factor to get equivalent Btu's: 37,500 x 3.4 = 127,500 Btu's per day. This is equivalent to about 10 ton hours, or 50 tons hours per week. If the air conditioning system uses 1 1/4 KW/ton, the savings for a 30 week cooling season would be 30 x 50 x 1.25 = 1,875 KW hours. In New York electricity is now about 5 cents/KW, so the savings there would be \$94/yr. This may seem small compared to the savings which can be accomplished by reducing the lighting intensity, but the results of many small measures add up to significant totals. Calculate the savings in cooling energy for any building in the same manner.

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*By re-arranging tasks and removing fluorescent tubes from non critical areas, it is usually possible to maintain the same footcandles on critical tasks. See Section 4 , "Lighting", ECO's 31 and 34.

ECO-22 REDUCE CONDUCTIVE HEAT GAIN TRANSMISSION THROUGH THE BUILDING ENVELOPE

The conduction of heat from outdoors to indoors is only a significant portion of the cooling load when the building is one or two story with black uninsulated roof and has low internal heat gains. The difference between outdoor and indoor dry bulb temperatures is smaller during the cooling season (especially if indoor conditions are maintained at 78° or higher).

Insulation, added to reduce heat loss in the winter, will have a small added benefit in the summer. ECM-2 includes a section on insulation and storm sash, roof sprays, and reflective roof and wall surfaces showing the relative benefits of each for both heating and cooling. Roof insulation will cost from $2.00 to $3.00 per sq. ft. depending upon type and construction details.

ECO-23 IMPROVE THE CHILLER AND COMPRESSOR PERFORMANCE

A building may have one or more types of chillers and/or compressors installed that may operate at the same time or sequentially. All have some common features, but there are differences, expecially between electric compression refrigeration systems and absorption chillers, which make each type unique. Identify the systems in the building and enter the information in the proper spaces, Figure 11. The characteristics and services of each type are listed below to assist in the identification process. Since most of the measures to improve chiller and compressor performance should be done by competent service or engineering personnel, seek their help at this time if your own maintenance department is not able to analyze and modify the equipment operation and maintenance.

The performance, or seasonal efficiency, of an existing refrigeration system can be increased by 1) changing the mode of operation and the operating conditions to conform more closely to the part load conditions which are the rule, rather than the exception, in virtually all buildings 2) improving maintenance and service procedures.

1. Types of Mechanical Compression Refrigeration Systems

Mechanical compression refrigeration systems all have compressors to raise the gas refrigerant pressure and temperature, condensers to reject the heat of compression and change the state of the refrigerant from a gas to a liquid, and evaporators to absorb heat from the refrigerant to chill water or air.

a. Compressors may be:

   Reciprocating
   Centrifugal
   Positive displacement screw
   Fully or partially sealed hermetic compressors.

b. Compressors may be driven by:

   Electric motors
   Diesel or gas engines
   Steam Turbines

c. Condensers may be:

   Water-cooled shell and tube
   Water-cooled evaporator type
   Air-cooled

d. Evaporators may be:

   Shell and tube water chillers
   Direct expansion coils in HVAC duct systems or air handling units.

If the present refrigeration system includes steam turbine-driven or gas or diesel engine-driven mechanical chillers, consider reclaiming waste heat from the exhaust steam or the hot exhaust gases and using this as the source of energy for an absorption machine or to heat domestic hot water. Because this suggestion involves capital expenditure, it will be dealt with more fully in ECM-2.

Unitary air conditioning systems (such as window air conditioners, through-the-wall units, packaged heat pumps, and 3 to 150 ton self-contained packaged air conditioners) have electric-driven compressors; the smaller sizes are equipped with reciprocating or hermetically sealed compressors, and the larger sizes with centrifugal or positive screw displacement type. The incorporation of compressor, condenser, evaporator (cooling coils), filters and supply fans in one insulated casing, characterizes all of these units.

The same types of components are often used in "built-up" systems. Each component or group of components may be installed either in one package or in locations which are remote from each other but inter-piped to form an operating unit.

Larger "central-station" systems include reciprocating compressors (of up to 150 tons capacity) and/or centrifugal compressors (from 100 to 8,000 tons in size), screw type compressors, and, as later described, absorption chillers. Each has separate air or water-cooled condensers, and separate air or water-cooled condensers, and separate air handling unit or fan coil units with filters and cooling coils. They serve one area directly, or multiple areas through a duct system. Any of the three types of drives (listed in b above) may be used with all compressors and chillers except the absorption type.

Large chillers with double bundle condensers and/or evaporators are large heat-pump type installations. The C.O.P. of the refrigerating machine can be measured as:

$$\frac{\text{Heat absorbed in evaporator}}{\text{(Heat rejected in condenser-Heat absorbed in evaporator)}}$$

Typical values for C.O.P. range from 2 to 5 at full load. Air-cooled condensers are in the lower range. When refrigeration units are operated as heat pumps, the C.O P. increases, since the heat rejected from the condenser is put to useful work for heating.

The C.O.P. is related directly to evaporating and condensing temperatures which, for a water chiller with cooling tower, are typically 40°F. and 100°F. respectively. If the evaporating temperature can be raised (by using chilled water at a higher temperature of, for instance, 50°F., instead of 40°F) and/or if condensing temperatures can be reduced, then the C.O.P. will increase and a greater cooling effect will result from the same power input. Consider each individual refrigeration machine separately to determine the extent to which its C.O.P. can be increased; in general, however, raising the chilled water temperature 10° and reducing the condensing water temperature 10° will result in an increase in efficiency of approximately 20 or 25%. At part load conditions, this increase in efficiency is more marked; on a seasonal basis it will have a greater effect in conserving energy than would be indicated by consideration of full load operating conditions only.

2. <u>Characteristics of Absorption Chillers:</u>

Absorption chillers achieve a cooling effect without the use of mechanical compression; instead, they use heat directly as the driving force. They normally include a heat activated generator-absorber, shell and tube condenser, and shell and tube evaporator. Water is used as a refrigerant with an absorbant such as lithium bromide. The C.O.P. of an absorption machine is not as favorable as that of a mechanical chiller and will normally be in the order of .67. Absorption machines are particularly sensitive to condensing temperature and will show a good improvement in C.O.P. at lower condensing temperatures, but take care - if condensing temperatures are too low the absorbant for most existing absorption units will crystallize. If the absorption machine is operated from waste heat, run it (to be more economical) as close as possible to its maximum output and modulate other mechanical refrigeration machines, if installed, according to load. Refer to manufacturers for information on specific machines before implementing a program to lower condensing temperatures.

3. Improving the Efficiency by Raising Evaporator Temperatures

The evaporator temperature is a function of operating mode and maintenance. All measures to reduce the loads, as discussed earlier in this section, provide opportunities to raise the temperature for the peak loads, and present even greater opportunities for part load conditions. Adjustments for load often permit an increase in the supply air temperatures even with a reduction in the total amount of air circulated. This will increase the evaporating temperature and suction temperature of a direct expansion system, and conserve power for the compressor. Raising supply air temperatures with chilled water systems permits higher chilled water temperatures, higher evaporator temperatures, higher suction temperatures, and a reduction in power used by the chiller.

Systems with an inadequate charge of refrigerant and fouled evaporator surfaces have a greatly reduced refrigerating capacity and waste energy.

4. Increasing Efficiency by Lowering Condenser Temperatures

The condenser temperature is a function of the outdoor or ambient D.B. conditions (for operation of the air cooled condensers) and W.B. conditions (for operation of the cooling towers or evaporative condensers) and of the condition and operating mode of the air cooled condensers, cooling towers and shell and tube water cooled condensers.

Cooling towers, air cooled condensers, and evaporative condensers were usually selected initially, to provide a given condensing temperature for maximum expected outdoor conditions; consequently, they will provide lower condensing temperatures when outdoor conditions are below the maximum expected level. Maximum cooling load, however, usually occurs at the same time as maximum outdoor conditions. Rather than allow chiller operation to follow the load, it is often more effective to operate chillers at full load in the morning - when outdoor wet bulb temperatures are low, and low condensing water temperatures can be obtained from the cooling tower.

5. <u>Description of Cooling Tower Operation</u>

Cooling towers lower the temperature of condenser water by direct evaporation of the water to outdoor air. The condenser water is sprayed over a series of baffles or fill, and then drains by gravity into a sump. Outdoor air is drawn through the tower and passes over the fill and is then discharged to the atmosphere. The intimate mixing (though counter flow of air and water) promotes evaporation of the condenser water, increasing the moisture content of the air. Each pound of water evaporated removes 1,000 Btu's of heat from the condenser water system. The rate of evaporation is directly affected by the wet bulb temperature of the incoming air and the condenser water temperature. The difference between these temperatures is known as the "approach" temperature; cooling towers are commonly sized for 10°F. approach (i.e. if the design outdoor wet bulb is 75°F., the lowest temperature condenser water that can be obtained from the cooling tower at its full rating will be 85°F.). Any reduction in condenser water flow rate or air flow rate through the tower, or any fouling or blocking in the fill will reduce the tower's effectiveness and increase the approach temperature, thus increasing the condenser water temperature, which in turn lowers the chiller efficiency.

Because water is constantly being evaporated in the tower, total dissolved solids in the condenser water system increase and promote scaling at the spray nozzles and on the baffles and/or fill. Scale formation on the spary nozzles will not only reduce the quantity of water flow, but will also inhibit the fine atomized spray necessary for evaporation. Clean spray nozzles carefully to remove all scale and dirt. Remove scale formation on the fill either manually (by chipping away) or chemically. Correct rates of blow down will hold total dissolved solids in the condenser water system to a tolerable level and correct water treatment will prevent scaling both in the tower and in the refrigeration machine.

If the cooling tower is located in an area that experiences strong sunshine, there is a danger that rapid algae growth will clog spray nozzles and coat the fill, reducing the tower's efficiency. If the cooling tower is contaminated with algae or bacterial slime, have it thoroughly cleaned with chlorine and flushed through to remove all deposits; then institute periodic treatments with algicides. To inhibit the growth of algae, it is helpful to shade the cooling tower from direct sunlight.

In addition to increasing the efficiency of the compressor or chiller system by improving the performance of the cooling towers and air cooled condensers, it is also possible to reduce the energy consumption of the tower itself. The opportunities are listed in the summary of guidelines later in this section.

If the existing cooling towers are at or near the end of their useful life, consider replacing them with larger or more efficient cooling towers that will give lower approach temperatures. As this involves capital expenditure, it will be dealt with fully in ECM- 2.

6. Description of Air-Cooled Condensers

Air-cooled condensers discharge heat to a flow of air through a finned coil containing the hot refrigerant gas. the rate of heat rejection is directly affected by the dry bulb temperature of the air stream and by the efficiency of the heat transfer surface. In geographic locations that experience long periods of high dry bulb temperatures, the efficiency of an air-cooled condenser can be increased by using the cool exhaust air from the building as a source of cooling air for the condenser.

Because it forms part of the refrigerant system, the air-cooled condenser (with its connecting pipework) imposes a resistance to refrigerant flow and, therefore, increases the pressure at which the compressor must operate. Condensers are frequently installed in locations remote from the refrigeration compressor, but often they can be easily relocated to reduce the length of connecting pipework. Any reduction in pipework length will decrease the loss, and increase the efficiency of the refrigeration machines.

Air-cooled condensers, serving process refrigeration equipment, such as food display cases (See Section 4 "Commercial Refrigeration") are frequently located with the refrigeration compressors in a store room where heat builds up and reduces the efficiency of condensing units.

7. Maintenance Procedures:

Each individual piece of equipment that comprises a chiller system has built inefficiencies. If they are minimized, the total efficiency of the unit will increase. Leaks from the refrigerant high pressure side of the system will reduce the refrigerant charge and, hence, the refrigeration effect that can be obtained for a given power input. Leaks on the low pressure refrigerant side (if the pressure is sub-atmospheric) will allow the entry of air into the refrigerant system. Air is comprised of non-condensable gases and will reduce both the rate of heat transfer of the condenser and evaporator and, again, the refrigeration effect available for a given power input. Check the refrigerant system first, therefore, to ensure that it contains a full charge of refrigerant and that all non-condensable gases are removed. Then check the system for leaks, using a Halide lamp or other similar equipment. Common sources of leaks include shaft seals, inlet guide vane seals, valves and pipe fittings.

Compressor prime movers and drive trains, if poorly maintained, can absorb as much as 15% of the total energy input into the compressor. Examine speed reducing gear boxes for quality and quantity of lubricating oil, gear backlash and wear, thrust bearing condition and main bearing condition. Check "V" belt drives for correct tension. Replace frayed belts or belts with a frayed driving surface. Where multiple belts are used, all belts should be replaced at the same time, or different tensions will result, causing loss of transmission efficiency.

Maintain water-cooled shell and tube condensers to give the greatest rate of heat transfer. Heat transfer is inhibited if the tubes become fouled with scale or bacterial slime. Reducing the condenser fouling factor from .002 to 0005 will result in approximately a 10% increase in efficiency. Where it is accessible, remove scale from the tube surface by chipping it, by chemical means, or by a combination of both. Once the tubes are clean and free of scale, enforce a policy of correct water treatment. The appropriate type of water treatment depends largely on the quality of water, which varies in different geopraphic locations. Remove bacterial slime from the condensers by flushing and chemical treatment and prevent its reappearance by periodic shock treatments with bactericides and algicides such as chlorine. Select the frequency and type of treatment to suit local conditions. By maintaining the heat transfer surfaces in shell and tube condensers, a supermarket in Atlanta, Georgia, of 50,000 sq.ft., equipped with a 200 ton centrifugal electrical chiller could reduce the annual power requirements from 600,000 to 540,000 KWH. The maintenance program would entail cleaning the surface twice yearly to reduce the average fouling factor to .0005. At 4 cents/KW, a savings of 10% in annual energy usage saves $2400 per year.

Water-cooled shell and tube evaporators are not as prone to scale or bacterial fouling as condensers, but they should be inspected and, if necessary, cleaned. If the fouling factor of a water-cooled evaporator decreases from .002 to .0005 the efficiency of the machine will increase by approximately 14%.

Direct expansion evaporator coils, installed in duct systems, quickly become fouled with dust, particularly if the filtration systems are ineffective. Inspect these coils on a periodic basis and clean them with steam or compressed air jets.

GUIDELINES TO REDUCE ENERGY USED FOR COOLING

USE OUTDOOR AIR FOR COOLING

-Use outdoor air for economiser cooling whenever the enthalpy is lower than room conditions during occupied periods, and whenever the dry bulb temperature is 5°F lower than indoor design conditions during unoccupied periods. (If the dry bulb temperature is only 2 to 3° lower than room temperature, heat from absorbed fan horsepower will eliminate the value of outdoor air cooling.)

-Use operable windows, without fan operation, for outdoor air cooling. Outdoor temperature during unoccupied periods, should be below room D.B. and during occupied periods below room D.B. and W.B. conditions. (Unfavorable acoustics and air quality may preclude implementation of this option.)

-If cool outdoor air is available, consider cooling and building well below normal during the night and early morning hours preceding any day that is expected to be extremely hot.

-Whenever the volume of outdoor air is increased for economiser cooling, and if there is no exhaust system which can handle an equal quantity of air, provide pressure relief.

REDUCE VENTILATION RATE DURING THE COOLING SEASON

-Refer to guidelines to reduce ventilation rates during the heating season.

-When the enthalpy of the outdoor air, on a seasonal basis, is lower than room conditions, outdoor air dampers should be fully opened. Close them only at times when the enthalpy of the outdoor air is higher, or dry bulb temperature of outdoor air is above 85°F.

-Check local and state codes to determine if ventilation rates can be legally lowered when spaces are air conditioned.

-Do not reduce ventilation rate when outdoor air can be used for economiser or enthalpy cooling.

-Refer to ECM- 2 for energy recovery "heat" exchangers for latent and sensible heat exchange between exhaust air and outdoor air for ventilation.

REDUCE INFILTRATION RATES DURING THE COOLING SEASON

-Before investing any money to reduce infiltration rates, perform an analysis for both heating and cooling.

-Whenever infiltration rates are reduced for winter conditions, additional benefits accrue from reducing the cooling load in the summer.

-In areas of the country which experience fewer than 10,000 wet bulb degree hours, energy conserved by weatherstripping windows and doors and/or caulking window frames does not generally justify the cost. In climatic zones which experience a greater number of wet bulb degree hours, make an engineering analysis of weatherstripping and caulking to reduce cooling loads.

-The rate of infiltration in stores through door openings may be considerably higher than leakage through windows or cracks. Refer to ECM- 2 for infiltration rates through doors and an analysis for vestibules and revolving doors in all climates.

-Refer in Section 4, "Heating" to "A Summary of Guidelines for Reducing Infiltration Rates" for additional guidelines.

CONTROL SOLAR HEAT GAIN

-In hot weather, adjust existing blinds, drapes, shutters or other shading devices on windows to prevent penetration of solar radiation into the building. (In the case of certain types of shading devices, this modification may conflict with requirements to utilize natural illumination; an engineering analysis of relative energy consumption due to solar radiation loads versus artificial illumination loads may be required).

-Install blinds, drapes, shutters, or other shading devices on the inside of all south, east and west facing windows which are subject to direct sunlight in hot weather and/or exposed to a large expanse of sky. (Fire codes may limit the use of some materials. Where dependent on natural light, do not reduce available light below statutory limits.)

-Use lightweight drapes, with reflective properties for effective solar radiation control. (Again, check fire codes before selecting appropriate material.)

-Use vertical or horizontal reflective blinds. (Vertical blinds or louvers generally are most effective on the west and east sides of a building; and horizontal blinds are most effective on the south side.) PVC vertical louvers cost between $2.90 and $2.30 per square foot.

-Add a reflective film coating to the inside surface of glazed areaa on the south, west and east windows. (Where dependent on natural light, refer to occupational regulations or health and safety codes before drastically reducing it.)

Note: Reflective mylar sheets (or rolls) and plexiglass sheets are available from a number of manufacturers at relatively low cost. Not only do they help control solar radiation, but they may also increase the strength and resistance of glazed areas. The thicker materials are good wind insulators - a 1/4 inch sheet of plexiglass is as good as a single pane of glass. Available in different colors, the films, depending on quality and make, allow a maximum transmission of from 55 to 90 Btu's/hr/sq.ft. The maximum heat transmitted in Btu/sq.ft. for a clear single pane of glass is 215 Btu/hr/sq.ft. The films transmit 9 to 33 percent of the visible light spectrum and reflect 5 to 75 percent of the solar radiation which strikes them.

For example, reflective coating on the south, east or west exposure glass that reduced solar radiation by 50 percent would save from 30,000 to 50,000 Btu's.sq.ft. window per season, in hot weather, for energy required for space cooling. (The value is higher in northern latitudes and lower in southern latitudes because of the angle of the sun striking vertical surfaces.) The cooling load can be reduced by about 3 ton hours/sq.ft. of glass per year by proper use of shading devices. In southern climates, the north facing glass can receive a surprising amount of diffuse solar radiation. If heat gain from north windows is excessive, treat them similarly to the other exposures.

-It is not cost effective to add storm sash solely to reduce solar heat gain.

-Skylights on a roof transmit between two and four times as much solar heat in the summer time as an equal area of east or west facing glass. Exterior solar control over skylights is most effective, and permits solar radiation and daylight to enter when desirable. Interior shades with mylar reflective coatings cost about $3 per sq. ft. to install and reduce solar heat gain in the summer by up to 80%. White paint on the exterior of skylights, venetian blinds or sun screens can also be employed to reduce solar heat gain.

-Do not prune trees which shade the building in the summer.

REDUCE INTERNAL HEAT GAIN

-Turn off unnecessary lights and heat producing equipment.

-Reduce lighting levels by removing lamps. See Section 4 , "Lighting", ECO's 31 and 35.

-Exhaust the heat from ovens, ranges, and motors directly outdoors when the enthalpy of the outdoor make-up air is lower than the enthalpy of the space.

-Refer to Section 4, "Commercial Refrigeration" for guidelines for supermarkets and other areas with commercial refrigeration.

-See "A Summary of Guidelines to Reduce Usage and Operating Time", in Section 4, "Power".

-Insulate hot surfaces of tanks, piping and ducts which are in air conditioned spaces.

-Disconnect dry type transformers which are in conditioned spaces when there are no operating loads.

REDUCE CONDUCTIVE HEAT GAIN THROUGH THE BUILDING ENVELOPE

-In climates without a significant heating season adding a storm sash or double glazing is not usually economically feasible.

-Do not confuse solar radiation heat gains through windows with conductive gains . Solar radiation control cannot be neglected.

-Make an engineering and economic analysis before insulating walls or roof, installing a roof spray, or treating exterior surfaces to increase emissivity.

-Insulate roofs, or ceilings below roofs, which have a U factor of greater than .15 to improve U factor to .06.

CONSERVE ENERGY BY OPERATION AND MAINTENANCE

1. Increase Evaporator Temperature -

-Raise supply air temperature

-Raise chilled water temperature

-Operate one of multiple compressors and chillers at full load, rather than two or more at part loads.

-Maintain full charge of refrigerant.

-Maintain evaporator heat exchange surfaces in clean condition

-Maintain higher relative humidity levels in air conditioned space.

-See Section 4, "HVAC Systems and Distribution" for specific measures which will result in lower evaporator temperatures and for measures to re-schedule chilled water temperatures.

-Clean all cooling coils, air and liquid sides.

2. Reduce Condensing Temperatures -

-Clean all condenser shells and tubes

-Clean all air cooled condenser coils and fins on a regular basis with compressed air or steam jets.

-Remove obstructions to free air flow into cooling tower and fans.

-Direct cool exhaust air from the building into the air intake of air cooled condensers or cooling towers. Refer to ECM- 2 for details.

-Under light load conditions, when the refrigeration load is small and the ambient wet bulb temperature is likely to be low, the cooling performance of the tower will exceed the needs of the refrigeration machines. Under these conditions the cooling tower fan or fans can be cycled on and off to maintain a desired condenser water temperature, thus saving the horsepower required to drive the fans.

-Adjust air flow and water rates to air cooled condensers and cooling towers to produce the lowest possible condensing temperature. Generally, the savings in refrigeration power will exceed any increase in added power for condenser fans or pumps.

-Use well water, if available, for condenser cooling.

-Shade cooling towers and air cooled condensers from direct sunlight.

-Remove bacterial slime and algae from cooling towers.

-Institute and maintain a continuous water treatment program for cooling towers.

-At partial refrigeration loads, operate cooling towers as natural draft towers with cooling tower fans turned off.

-Clean and descale spray nozzles, and descale fill in cooling towers.

-It is often more effective to operate chillers at full load in the morning when outdoor wet bulb temperatures are low, and low condensing water temperatures can be obtained from the cooling tower. Then, use the machine to sub-cool the building, turn the chiller off when wet bulb temperatures rise and allow the building temperature to drift up. In large buildings, the extensive chilled water piping system provides a degree of thermal storage.

3. Improve the Efficiency by Improved Maintenance Practices -

-Repair refrigerant leaks

-Lubricate speed reducing gear boxes

-Replace worn bearings

-Maintain proper tension on "V" belt drives

-Adjust water flow control valves to maintain lower condensing temperatures.

-If well water is used for condenser cooling, provide proper treatment to prevent scale build-up.

-Clean and replace, as necessary, all strainers to reduce resistance to refrigerant or water flow.

-Select a water treatment system for cooling towers that allows high cycles of concentration (suggested target greater than 10.7) and reduces blow-down quantity.

-Maintain boiler and burner efficiencies where steam or hot water is generated for absorption cooling units. Refer to Section 4 , "Heating and Ventilation"

-Many or most of the options can be implemented by the building maintenance staff. An alternative, however, would be to let a service contract. With an Inspection and Labor type service contract for servicing simple air conditioning and fan coil units on an annual fee basis to cover costs of labor (for inspection, maintenance, breakdown repair) and material (such as filters, oil, grease, etc.), typical costs might be:

A/C Units

System Tonnage	2.5	5	7.5	10	15	20	25	30	40
Price	$ 168	202	253	308	410	495	595	685	865

Fan Coil Units

System Tonnage	1/2	3/4	1	1 1/2	2
Price	$ 25	35	45	70	95

-Confirm adjustments with mechanical and occupational codes.

SECTION 4-D

DISTRIBUTION AND HVAC SYSTEMS

INDEX

DISTRIBUTION AND HVAC SYSTEMS

A. BACKGROUND

The "parasitic" distribution loads for individual or various combinations of heating, cooling and ventilation systems depend upon (1) the performance, for air systems, of the terminal room devices, air handling units and duct work systems, which, with the fan and motor performance influence the amount of energy required for air; (2) the terminal devices and piping for hot water systems, which, with pump and motor performance, influence the amount of energy required for hot water circulation and (3) the piping and appurtenances for steam systems, which impose a heating load on the burner-boiler system.

The same system may handle the heating, cooling, and ventilation loads at separate times or concurrently, to serve common or separate areas of a building.

Consider the opportunities for HVAC systems and distribution in the following distinct but related areas:

a) Improve the performance of the terminal devices to reduce their resistance to fluid flow and increase their heat transfer characteristics.

b) Lower the resistance to flow in duct and piping systems to reduce the required horsepower for fans and pumps.

c) Modify the control systems and modes of operation of air handling and piping systems to reduce simultaneous heating and cooling.

d) Decrease fluid leaks and thermal losses from piping, air handling equipment, and other vessels holding hot or cold water, air, or steam.

e) Improve the performance of fans, pumps and motors by maintenance and operating procedures.

f) Reduce the hours of fan and pump operation.

If boilers are used to generate hot water or steam for any HVAC systems in your building, refer to "Heating", ECO 10 for guidelines on the primary energy-conversion equipment and ECOs 26 and 27 below for guidelines on piping, pumps and appurtenances.

Refer to Section 4 , "Cooling", ECO 23 for suggestions for compressors, chillers, condensers and cooling towers and for cooling equipment not included in this section, and refer to ECO 25 below for guidelines on duct work and fans.

Even though an individual building does not have all of the systems discussed, read all of the ECOs and guidelines. Many energy conservation opportunities are common to a number of systems, but for simplicity, have been noted only once. For instance, thermal losses through the casings of air handling units, mentioned under "Single Zone Duct Systems", are valid for each type of system in ECO 24.

Before making changes to equipment, control cycles, or air or water flow quantities, and if the building personnel are not experienced or qualified to implement them, consult an air conditioning and heating service maintenance company, or an HVAC engineer to analyze proposed changes and perform the work.

ECO 24 REDUCE ENERGY CONSUMPTION THROUGH OPERATION AND/OR MAINTENANCE OF SPECIFIC HVAC SYSTEMS.

a) Direct Hot Water or Steam Systems employ direct radiation, fin tube convectors, fan coil units, cabinet heaters, or fan driven horizontal or vertical unit heaters with hot water, steam or electric coils.
Fan coil units, and induction units equipped with heating coils, are used for both heating and cooling.

b) Single Zone Duct Systems deliver warm air from a furnace (see Section 4 , "Heating", ECO 10) or from an air handling unit or section of a package air conditioner. The same system, when equipped with cooling coils, is used to deliver cool and dehumidified air as well as warm air through common duct work.

Control cycles may provide fluids (hot water, steam, refrigerant or chilled water) to the coils continuously, may modulate the flow, or may cycle it on and off. At the same time, the fan may be on continuously, modulating, or cycling on and off in accordance with room temperature demands and fluid flow. The characteristics and performance of each sytem vary widely and preclude a general rule for the optimal control cycle, but any measure which prevents simultaneous heating and cooling, and delivers warm or cool air to spaces in accordance with thermal needs, rather than in bursts of over-heated and over-cooled air, is more efficient and provides more comfort to occupants.

Fan and motor performance are discussed in ECO 25 below and Section 4, "Power", ECO 41, respectively.

c) Terminal Reheat Systems are commonly used and very wasteful. Basically, supply air is cooled to a fixed point (usually 55°F.) The cool air is supplied through ducts to all outlets, individually or in groups, where it is then reheated to a temperature compatible with the demands of that space. Under partial or light loads, most or all of the re-heat coils will still be operating because the supply air is too cold for direct use in certain parts of the building. Only under peak cooling loads do the majority of reheat coils turn off.

To conserve energy, reduce the supply air quantity and reset the temperature to a higher level. Raise the temperature in increments of 3°F. to determine the highest supply temperature which will maintain satisfactory room conditions.

-Terminal reheat systems were usually installed to control dehumidification. Wherever dehumidification can be eliminate and zone control can be satisfactorily maintained (or is not needed), operate the terminal reheat system on a temperature demand cycle only; considerable energy will be saved.

Refer to ECM 2 for further conservation options by major modifications to, or replacement of, terminal reheat systems.

d) Dual-Duct Systems, as the name implies, have two ducts, one trunk to supply warm air and the other to supply cool air to mixing boxes which then deliver air in one duct to the conditioned space. Warm and cool supply air is proportioned in the mixing boxes at the point of use, to provide supply air to the room at the temperature which meets the thermal demand. This type of system, while not usually described as a terminal reheat system, does, in fact, operate essentially on the same principles. Air is cooled down to a fixed level and then reheated to the point of use by being mixed with warm air. It is, inherently, a wasteful system.

e) A Multi Zone Unit, with the exception of new ones which incorporate recent changes, normally consist of a fan which discharges air either through a cooling coil to a cold deck or through a heating coil to a hot deck. Both hot and cold decks are equipped with modulating dampers that automatically control the quantities of hot and cold air to one supply duct serving the space. This system is also a form of reheat; the overheating and overcooling of the supply air carries the penalty of inherent waste of energy.

In many units the dampers, which control the quantity of hot or cool air, leak. As the system compensates for the additional cool or hot air it wastes energy.

f) Induction Systems, normally found in large office buildings, include an air handling unit which supplies cooled or heated primary air at high pressure to individual induction units normally located on the outside wall in each room or zone. The flow of high-pressure air through a nozzle system in the unit induces a flow of room air through a cooling or heating coil unit. The room air then mixes with the primary air to provide supply air at a temperature to meet the heating or cooling load within the space. Typically, the ratio between primary air and induced air is 1:4.

The major causes of high energy use with induction systems are:

1) The horsepower to maintain the high pressure to deliver primary air and induce room air flow through the unit.

2) Simultaneous heating and cooling in a "terminal reheat" type of cycle.

3) Restriction in air passages impeding the flow of room air through the coils.

4) Dirty coils which reduce heat transfer to room air, and also impose an extra load on the primary air system to compensate for the reduced induction effect.

g) <u>Variable Air Volume Systems</u> (VAV) include an air handling unit which typically supplies either heated or cooled air at constant temperatures to variable air volume boxes for each zone or for each individual outlet. Variable air volume boxes regulate the quantity rather than the temperature of the warm or cool air supplied to the space in the heating or cooling season, respectively. Varying air quantity with the appropriate supply temperature is one of the most efficient modes of operation in terms of energy usage. Run the fan at full volume only when all VAV dampers are fully opened.

Fan volume is not controlled in some systems. When full volume is not needed in the conditioned spaces supply air is dumped into a ceiling plenum the air is returned to the supply unit by inlet openings in the return air side of the air handling unit. This "dump" system is necessary because virtually 100% of the supply air passes over direct expansion coils. This VAV system is not as efficient as a fan controlled type but it does save energy by effectively reducing the static pressure of the system.

h) Fan Coil Systems are comprised of one or more fan coil units set up to be two, three or four pipe systems; each unit contains a fan which blows air through heating and/or cooling coils into a single outlet to supply a zone or room. Typically, the heating and cooling coils are controlled to maintain a supply air temperature to meet zone heating or cooling loads. However, in many systems the fan speed can be manually controlled - high - medium - low - to control heating or cooling output. Often fans are operated at low speeds to reduce noise.

For those fan coil systems which have separate coils for heating and for cooling, it is important to prevent simultaneous heating and cooling, and a "terminal reheat" type of operation.

i) Window and Through-the-Wall Air Conditioners have similar self-contained compressor air-cooled condensing units. They may be equipped with electric coils for heating, or, in the case of through-the-wall units, coils supplied with hot water or steam from a central source.

Because both systems are relatively inefficient during the cooling cycle (due to small - usually undersized-condensers), maintenance of coil surfaces, previously discussed for other types of equipment with evaporator and condenser coils, and reduction of operating hours are very important.

Most of the older unitary conditioning units have a low cooling EER (Equivalent Efficiency Rating) - sometimes as low as 5 or 6 Btu's/Watt. If these units are at or near the end of their useful operating life, replace them with new units having an EER rating of 9 or more. New units now in the development stage, will produce an EER of 15 or more. Units with electric resistance heating coils for winter use, consume a large amount of energy for tempering or heating. If the existing units to be replaced are equipped with electric resistance heating coils for winter use, exchange them with air-to-air heat pumps, which provide for 1.75 to 3 times as much heat per KW input as resistance heaters. Outdoor air blowing into the room directly through the coils of the unit or through cracks around the frame of window air conditioners and through-the-wall units, can be a major source of infiltration and heat load in the winter. If not used for heating, remove window units and store them in the winter, or caulk cracks and cover units with fitted enclosures made for that purpose.

j) Unitary Heat Pumps are either of the air-to-air, or water-to-air type. The older air-to-air models have the same built-in condenser and evaporator inefficiencies as room air conditioners (refer to i) above). The water-to-air heat pump operates at lower condenser temperatures which are more efficient. All guidelines for condensers, compressors, evaporators, and fans apply to both types.

During the cooling season, improve the operating efficiency of air-to-air heat pumps by shielding the condenser air intakes from direct sunlight and directing cool exhaust air from the building to the condenser air inlet.

Where possible, follow the options for pumps, piping, fans and duct systems outlined in ECO's 25, 26 and 27 below for heat pump installations.

ECO-25 REDUCE ENERGY CONSUMPTION FOR FANS

To the extent possible, reduce resistance to air movement throughout the HVAC system, reduce quantity of air supplied to or returned from conditioned spaces, and limit the periods during which fans operate. Ordinarily, the three steps provide for maximum savings when taken sequentially.

Implementing energy conservation methods which reduce the heating and/or cooling loads first will then permit reducing the volume of air handled by the HVAC systems. Whenever the volume of air is reduced, the resistance to air flow in that section of the system is also reduced, since the resistance of any system depends upon the quantity of air circulated in the system as well as the characterisitics of the various portions of the system including:

a) Intake louvers and air outlet duct caps or elbows

b) Heating and cooling coils

c) Filters

d) Ductwork system, balancing dampers, and exhaust hoods

e) Registers, grilles, and diffusers

f) The fan scroll and housing

If, as is often the case, the original HVAC system has been oversized for the contemplated loads (due to a conservative "safety" factor in the design, or a built-in reserve for the future), or if the original loads have been reduced, the opportunities to reduce the air volume will exceed that which would result from a further reduction in "building" loads only.

Reducing the resistance to air flow in an existing system results in an increase of air delivery which, in turn, permits a reduction in fan speed to bring air volume down to the original level. Because for multi-vane centrifugal fans, (the type most commonly used in HVAC systems), the power input (BHP) varies directly with the cube of the speed, any reduction in speed, which is proportional to air volume, results in a very sizable decrease in power input.

The basic fan laws for centrifugal fans follow:

1) the volume varies directly with the speed

2) the pressure varies directly with the square of the speed

3) the power input (BHP) varies directly with the cube of the speed

4) the volume varies directly with the square of the pressure

If it is possible to reduce the volume of air in a system by 10%, the savings in power will be about 27%.

To conserve energy for fan horsepower, first reduce heating and cooling loads, second, reduce the resistance to air flow in each of six areas (a-f) listed above, third, measure the increased volume which results and determine the new air volume required to meet new loads, fourth, reduce fan speed accordingly, and fifth, change the motor if necessary. Use Figures 23 and 24 (for forward-curved and backward-curved multi-vane blowers, respectively) to determine potential savings.

ventilation

yearly energy consumed
centrifugal fans
forward curve blades

fig. 23

prorate input/output scales
for larger volumes

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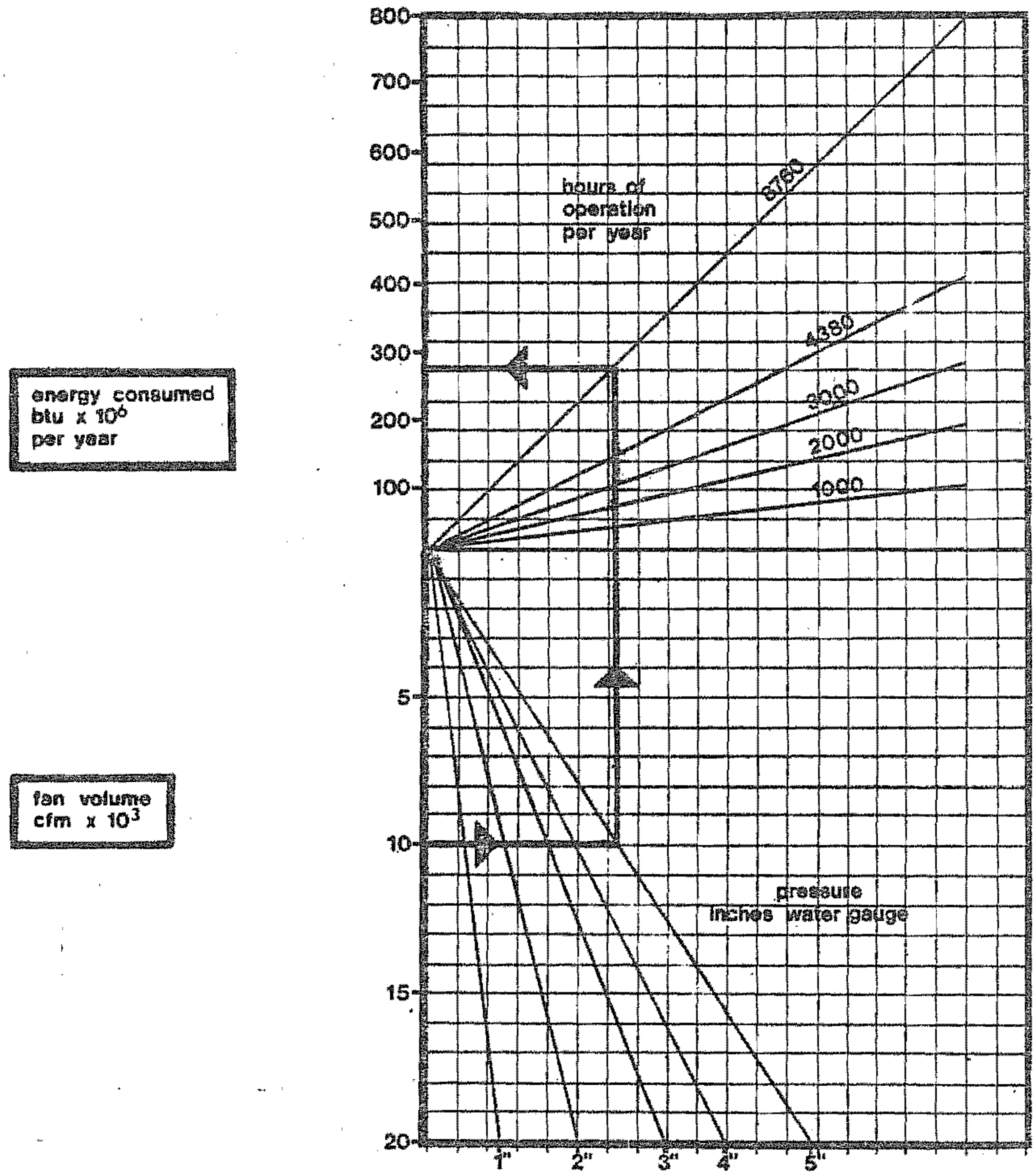

FIGURE #23 Engineering Data

Source: Manufacturers fan capacity tables for forward curve centrifugal fans.

ventilation

yearly energy consumed
centrifugal fans
backward curve blades

fig.24

prorate input/output scales
for larger volumes

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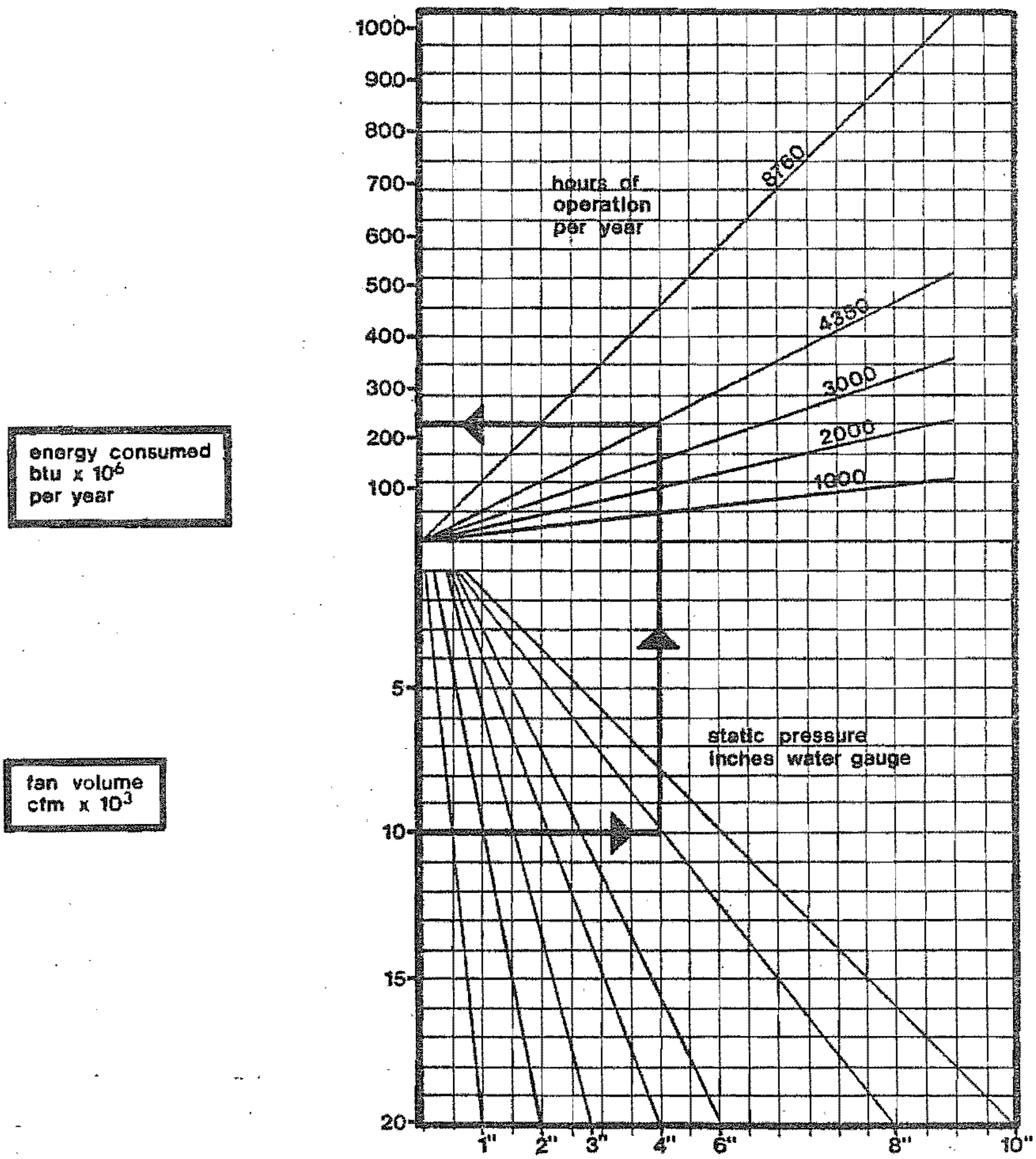

FIGURE #24 Engineering Data

Source: Manufacturers fan capacity tables for backward curve centrifugal fans.

Example:

A building has a heating load of 620,000 Btu/hr. and a fan volume of 15,000 cfm. Energy conservation measures have been implemented to reduce the heating load to 510,000 Btu/hr. If the temperature drop remains the same, the volume of air required to meet the reduced load is 12,340 CFM. In addition, system resistance has been reduced by modification to filters and heating coils.

Initial system characteristics were measured at 15,000 CFM and 4" w.g., point A in the diagram above. The measurements taken after lowering system resistance were 16,620 CFM and 3.8 "w.g., point B on the new system curve.

Now the fan speed is to be reduced to give the new required volume of 12,340 CFM. The new pressure at this volume is measured at 3.27", point C.

Assuming a backward curve fan operating 4,380 hours per year, use Figure 24 to determine energy savings.

Enter Figure 24 with the initial conditions of 15,000 CFM at 4" w.g. and read that yearly energy consumed is 170×10^6 Btu. Re-enter Figure 24 with the final conditions of 12,340 CFM at 3.27" w.g. and read yearly energy consumed at 110×10^6 Btu.

Savings: The energy saved equals 170-110 or 60×10^6 Btu/yr or -

$$\frac{60 \times 10^6}{3,413} = 17,580 \text{ KWH/year}$$

At $0.03/KWH, the savings is 0.03 x 17, 580 or $527 per year.

Results:	Energy Saved	17,580 KWH/year
	Dollard Saved	$527/year

ECO-26 REDUCE ENERGY CONSUMPTION FOR PUMPS

Pumps used to circulate hot water, chilled water and condenser water are generally of the centrifugal type and are governed by the same basic laws of operation as fans. Any reduction to system resistance will result in energy savings, providing the pump flow rate is held at the same level. With variable speed pumps, adjust for any increase in pump flow rate due to reduction in system resistance by reducing the speed of the pump (as described for fans). With direct drive pumps (for which it is not so easy to reduce the speed), reduce the flow rate by replacing the impeller or reducing its' size.

Balancing valves are normally installed and adjusted toward the closed position to achieve the desired flow in any given circuit. The precise position of the balancing valves is a function of the resistance of the longest or index circuit.

If resistance in this circuit is decreased, all balancing valves can be opened proportionately, reducing the overall resistance to water flow and the pumping energy requirements accordingly. To realize these savings substitute sections of larger size pipes for portions of the index circuit. Boilers, chillers, heating and cooling coils, valves, and strainers all affect resistance to flow, as well. Refer to sections of the manual dealing with these types of equipment for specific suggestions.

In the case of strainers, the quantity of dirt they contain and the condition of the filtration media, often rusty, corroded, and deformed, determine resistance. Inspect these items, and clean or replace them on the basis of a regular maintenance schedule.

ECO-27 <u>REDUCE DISTRIBUTION THERMAL AND PIPING LOSSES</u>

In addition to frictional resistance, energy losses from piping systems occur in the form of heat gain to chilled water and heat loss from hot water or steam systems. Pipe insulation, which normally keeps these losses to a minimum, frequently becomes damaged. Inspect each piping system; where no insulation exists, add it, and where it is damaged, make all necessary repairs. The heat energy loss from bare pipe and insulated pipe can be calculated from Table 1. Determine the annual loss for any system by comparing the losses (per foot of pipe) for bare pipe to those for insulated pipe. Multiply the unit loss, first, by the total number of feet in the system; then, by the difference, in °F., between hot water temperature and ambient air temperature; and finally, by annual hours of operation.

TABLE 1

HEAT LOSS THROUGH PIPES

(Based on an ambient temperature of 68°F and a K for insulati(n = 0.3)

Pipe Size (In.)	Bare Pipe	Insulation Thickness 1/2	3/4	1	1 1/4	1 1/2	1 3/4	2
1/2	0.63	0.163	0.135	0.116	0.105	0.098	0.091	0.086
3/4	0.76	0.191	0.155	0.135	0.120	0.110	0.103	0.096
1	0.93	0.211	0.179	0.153	0.136	0.125	0.115	0.108
1 1/4	1.14	0.263	0.210	0.178	0.158	0.143	0.132	0.122
1 1/2	1.27	0.287	0.232	0.194	0.172	0.154	0.142	0.132
2	1.53	0.345	0.271	0.229	0.198	0.178	0.163	0.151
2 1/4	1.87	0.425	0.325	0.270	0.237	0.210	0.190	0.175
3	2.15	0.487	0.368	0.309	0.251	0.214	0.211	0/195
4	2.65	0.600	0.447	0.375	0.305	0.279	0.252	0.231
5	3.2	0.663	0.500	0.407	0.346	0.305	0.271	0.245
6	3.7	0.852	0.628	0.536	0.432	0.379	0.341	0.305
8	4.75	1.090	0.828	0.650	0.549	0.486	0.433	0.388
10	5.75	1.341	0.990	0.778	0.678	0.580	0.511	0.457
12	6.75	1.550	1.152	0.920	0.802	0.664	0.604	0.541

Estimated costs for insulating hot and cold water pipes with pre-sized fiberglass material with a standard jacket are listed in Table 2.

Pipe Sizes	Price per L.F. Installed Insulation Thickness:	
	1"	1 1/2"
	$	$
1/2"	1.35	2.05
3/4"	1.40	2.10
1"	1.45	2.15
1 1/4"	1.50	2.20
1 1/2"	1.55	2.25
2"	1.60	2.35
2 1/2"	1.65	2.45
3"	1.70	2.50
4"	2.00	3.05
5"	2.25	3.15
6"	2.55	3.30
8"	3.15	4.20
10"	3.85	5.00
12"	4.50	5.60
14"	5.20	6.45
16"	6.00	7.20
18"	6.70	7.60
20"	8.25	8.50
24"	9.00	9.70

Table 2

For costing purposes, add to total lineal feet of piping three (3) lineal feet for each fitting or pair of flanges to be insulated.

Example:

Bare pipe 4", 300' in length
Ambient air temperature: 60°F., hot water temperature: 200°F.
Operating time: 200 days, 24 hours a day
Heat loss from bare pipe: 2.65 Btu/ft/degree temperature difference
Annual heat loss for bare pipe = 300 x 2.65 x (200 - 68) x (200 x 24) = 504 x 10^6 Btu's

Example con't.

If hot water is generated by an oil-fired boiler with 65% seasonal efficiency, the energy used would be $\frac{504 \times 10^6}{.65 \times 138,000}$ = 5,619 gallons
Cost/yr. @ 36¢/gal. = 5,619 x .36 = $2,023/yr.
If 1-1/2" fiberglass insulation were used, the yearly heat loss would be 300 x .305 x (200-68) x (200 x 24)= 57 x 10^6 Btu/yr. The energy used would be Gal. of Oil= $\frac{57 \times 10^6}{.65 \times 138,000}$ = 647 gallons
Cost/yr = 647 gal. x 0.36 = $233
Yearly savings in fuel $2,023 - $233 - $1,790
Initial cost to install 1-1/2" insulation = 300 x $3.05/ft.= $915
Pay back period .51 years

Table 3 indicates the costs of steam leaks in a 125 psi system at $4/1,000 lbs.

Size of Office	Lb. Steam Wasted Per Month	(Per Month) Total Cost	(7 Months) Total Cost
1/2 inch	708,750	$2,040	$14,280
3/4 inch	400,000	1,600	11,200
1/4 inch	178,000	712	5,000
1/8 inch	44,200	176	1,232
1/16 inch	11,200	45	315
1/32 inch	3,000	12	84

For steam at 50 lbs. pressure, the waste is about 75% of the figures given; at 20 lbs. it is about 50%, and at 5 lbs, the loss is about 25%.

Steam traps are installed to remove condensate, air and carbon dioxide from the steam utlizing unit as quickly as they accumulate. With time, internal parts begin to wear and the trap fails to open and close properly. Among other undesirable effects on system performance and maintenance, malfunctioning steam traps reduce fuel economy and equipment capacity.

steam traps

steam loss through leaking steam traps

fig. 25

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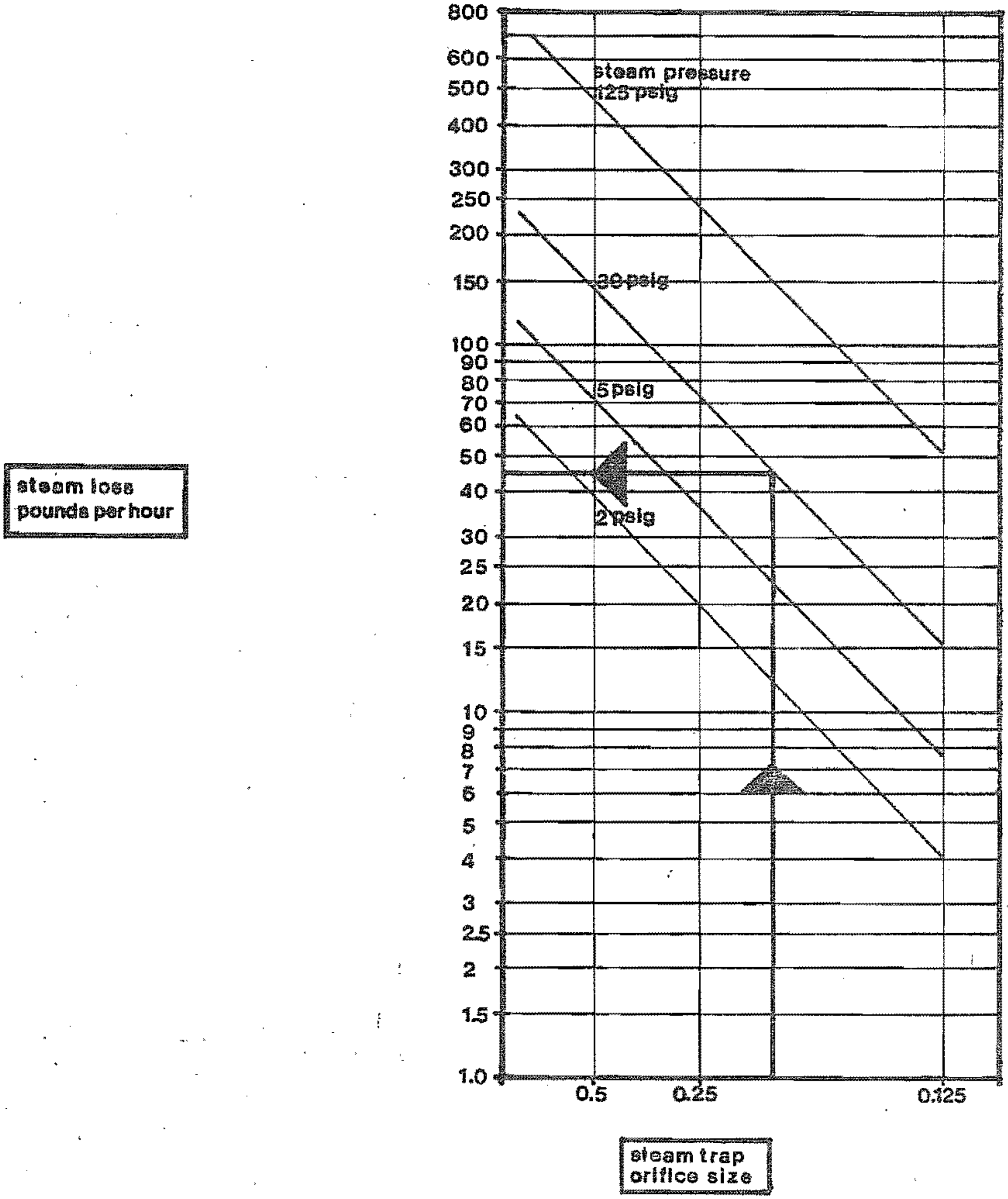

FIGURE #25 Engineering Data

Source: Manufactuers data

The following example illustrates the use of Figure 25 to determine the amount of steam lost through leaking steam traps.

Example:

> Assuming a 30 psig system with 0.125 inch orifice traps, the loss from Figure 25 is 15 lbs. of steam per hour per trap.
> At 1,000 Btu/lb., and if the steam is being produced by a boiler burning light oil with an efficiency of 70%, the energy input is equal to $\frac{15 \times 1,000}{0.7}$ = 6,987 gal/yr
> At $0.36/gal. this amounts to 0.36 x 6,987 = $2,515/yr potential savings if all traps are replaced.
> Results: Energy Saved 6,987 gal/yr
> Dollars Saved $2,515/yr

GUIDELINES TO REDUCE ENERGY USED FOR DISTRIBUTION AND HVAC SYSTEMS

HEATING SYSTEMS

- Clean the air side of all direct radiators, fin tube convectors and coils to enhance heat transfer.
- Keep radiators free from blockage. A one foot clearance in front of convectors, radiators, or registers is desirable. Heating systems, particularly hot water or electric baseboard radiators and low level warm air supply registers, work more efficiently if they are not blocked by furniture. Keep all books or other impediments from blocking heat or air delivery from the top of horizontal shelves or cabinets which enclose radiators, fan coils, unit ventilators or induction units.
- If radiator is set directly in front of a window where the glass extends below the top of the radiator, or in front of an uninsulated wall, insert a one inch thick fiberglass board panel, with reflective coating on the room side, directly between the radiator and the exterior wall to reduce radiation losses to the outdoors.
- Vent all hot water radiators and convectors to assure that water will completely fill the interior passages.
- Check radiator steam traps to assure that they are passing only condensate, not steam.
- Make sure that all fans, frequently inoperative in unit heaters, fan coil units, and unit ventilators are running normally to increase the heat transfer rate from heating coils.
- Use electric or infrared units as spot heaters for remote areas, a reception desk in a large lobby, for example, rather than operating an inefficient central system for a small area in the building.
- In the public spaces of all buildings such as lobbies, corridors, stairwells, vestibules and lounges - conserve

energy as follows:

> Where heat is provided by a unitary terminal equipment valve, turn off such equipment and remove the handles from control valves. If balancing cocks are included, turn them to the "off" position. In each stairwell of multi-level buildings, shut off all but the unit located at the bottom. Turn off heat in vestibules and foyers.

-Overhead unit heaters should direct heat to floors. Add directional louvers to focus heat to floor or area requiring heat; where possible draw return air from floor.

<u>SINGLE ZONE DUCT SYSTEMS</u>

-Maintain filters to reduce resistance to air flow, permitting a reduction in the time that the blower and the primary heat or cold-producing equipment run to satisfy room loads. Where possible change filters to low resistance type. A V type arrangement, if space permits, will provide more filter surface and less resistance, and thus requires less frequent cleaning than a straight single panel filter.

-Clean coils of lint and dirt to increase heat transfer efficiency in air handling units.

-To reduce heat loss and heat gain, repair insulation where torn, or insulate the exterior surfaces of casings where insulation is not on the interior surface. Units located outdoors on-grade or on the roof, or in non-conditioned spaces should be insulated with the equivalent of 3" of fiberglass.

-The relationships between the supply air temperature and quantity, and the chilled or hot water temperature and quantity, and space loads cannot be oversimplified in an energy use analysis.

The further relationship between fluid temperatures and flow and the primary energy-conversion equipment can be understood only after a thorough seasonal analysis of all factors considered together. However, consider the following:

1) Lowering supply air temperatures in the winter conserves energy, reduces "parasitic" loads by reducing thermal losses from the duct and piping systems, and improves the efficiency of the boiler

or furnace. It also reduces or eliminates wide swings in the space temperature because of overheating. However, the equipment may operate for a longer period of time and/or require a larger volume of air and more horsepower, thereby cancelling some or all of the savings in energy gained by reduced thermal losses.

2) Raising supply air temperatures in the summer conserves energy by reducing heat gain in ducts and piping, and by improving the efficiency of the chillers or compressors whenever they are in operation. Over cooling is minimized and wide temperature swings are eliminated but, again, a greater amount of supply air may be required to handle the load, necessitating more fan horsepower and/or longer periods of operation for fans, blowers, chillers, and condensers or cooling towers. In general, however, operation at the higher air temperature will prove to be more efficient.

-Where electric coils are used, operate the coils in stages, rather than all off - all on. Take care that coils are not on when air is not circulating, or they will burn out.

-Where humidity control is not essential, consider using the cooling coil for both heating and cooling by modifying the piping connections and removing the heating coil. The benefits are (1) the elimination of the heating coil reduces total system resistance to air flow and allows a lower fan speed.to achieve the same volume through-put of supply air with less fan horsepower; and (2) when used for heating, cooling coils, which typically have a much greater surface area for heat transfer than heating coils, allow considerably lower water temperatures for a given heat output. The reduction in water temperature, in turn, minimizes heat losses from the system and allows more efficient operation of the boilers.

-Maintain the hot water and the chilled water at constant flow, but reset for part load conditions of more that 2 hours duration.

Adjust the temperature to provide the desired supply air temperature (which can vary with small load changes) and reduce the heat gains and heat losses of the piping systems.

-Avoid simultaneous heating and cooling except when required for humidity control in critical areas.

Do not operate a large system to meet the needs of a small area for humidity control.

TERMINAL REHEAT SYSTEMS

- Shut down system completely at night, weekends, and other occupied periods.
- Raise the supply air temperature to allow the use of higher chilled water temperatures which in turn will increase the efficiency of the chiller.
- Reduce supply air quantity.
- Operate on demand schedule, without reheat, whenever reheat has been used for humidity control in comfort applications.
- Operate on demand schedule without reheat when zone control can be sacrified.
- Relax humidity requirements and allow the relative humidity to drift naturally up to 65%.
  Higher relative humidity levels will reduce the need for low supply air temperatures allowing the suction temperature of the refrigeration unit to rise, decreasing energy required for refrigeration.
- Schedule supply air temperature according to the number of reheat coils in operation. If 90% of the reheat coils are working, the supply air temperature is too low and should be reset to a higher level until the number of reheat coils in operation falls to about 10%.
- Ensure that simultaneous heating and cooling cannot occur by providing interlocks between the heating and cooling control systems.

DUAL-DUCT SYSTEMS:

- Refer to "Terminal Reheat Systems" for general recommendations applicable to dual-duct systems.
- Raise the temperature of the cold duct and lower the temperature of the warm duct.
- Under conditions where there is no cooling load, close off the cold air duct, turn off the cooling systems, and then operate as a single duct system by rescheduling the warm duct temperature according to heating loads only.
- Under conditions where there is no heating load, close off the warm air duct, shut down the heating system and, by rescheduling the supply air temperature according to cooling loads, operate the system with the cool air duct as a single duct system.
  Note: Dual duct systems are usually designed so

that either of the ducts can handle 80% of the total air circulated. Reducing the system to single duct operation, therefore, is likely to reduce the total quantity of air circulated and save a corresponding amount of energy. While the reduction may not affect space conditions adversely, it could possibly introduce noise problems requiring adjustment of dampers and/or fan speeds and acoustical treatment of the terminal boxes.
- Repair leaking dampers in mixing boxes.
- Do not bleed air into mixing box in the cooling mode in order to control dehumidification.

MULTI-ZONE UNITS:

- Set controls to reduce the hot deck temperature and increase the cold deck temperature.
- If not so equipped, provide the heating coils with an automatic control valve that will modulate to reduce the hot duct temperature according to demand. The valve is arranged so that when all hot duct dampers are partially closed, it will progressively reduce the hot duct temperature until one or more zone dampers is fully open.
- Provide the cooling coils with an automatic control valve that will modulate the cold duct temperature according to demand. When all of the cold deck dampers are partially closed, the valve will raise the cold duct temperature until one or more of the zone dampers is fully opened.
- Repair leaky valves and dampers.
- Shut off the fan and all control valves during unoccupied periods in the cooling season.
- Shut off the cooling valve during unoccupied periods in the heating season.

INDUCTION SYSTEMS

- Refer to "Terminal Reheat Systems" for general measures, also applicable to induction systems.
- Reschedule the temperature of the heating water and the cooling water according to the load. If the building has a light cooling load, the chilled water temperature should be raised, if the building has a light heating load the hot water temperature should be lowered. Avoid simultaneous heating and cooling in any one zone.
- Typically, the primary supply air temperature is maintained at constant levels for cooling and heating which

necessitates reheating or recooling by the individual units to meet fluctuating load conditions. The system operates essentially as a reheat or recool system with the inevitable consequence of wasted energy. To reduce this waste, schedule the temperature of the primary supply air at the air handling unit according to load; i.e. under light heating load conditions, the primary air heating coil should be modulated to reduce the supply air temperature and under light cooling load conditions, the supply air cooling coil should be similarly modulated to increase the supply air temperature. Achieve the modulation preferably by adjusting water temperatures (rather than water volumes) to the central coils. Chillers and boilers will operate closer to their peak efficiency.

- Remove lint screens in induction units and clean coils regularly.
- During unoccupied hours in the heating season, realize a major opportunity for saving fan horsepower by shutting off the primary air supply system and operating the heating coils in the induction units as convectors.

<u>VARIABLE VOLUME SYSTEMS</u>

- When dampers begin to close (indicating that the requirement for supply air has decreased) reduce the fan volume (and the corresponding fan power input) to the point where one or more VAV dampers are fully open again. Adjust fan volume with either inlet vortex dampers or a variable speed driver such as a multi-speed motor or SCR control. If controls of this type do not exist in the building, refer to ECM-2 for installation details.
- Rescedule the supply air temperature to the point where the damper of the variable air volume box serving the zone or room with the most extreme load is fully open. Maintaining constant supply air temperature, even when all VAV dampers are partially closed is wasteful, as it increases the duct heat losses or heat gains and precludes the advantages which accrue from hot or chilled water temperature modifications. (Before reducing fan volume and/or rescheduling supply air temperature, carry out an analysis to determine the optimal levels of adjustment for the individual building.)
- Lower the hot water temperature and raise the chilled

water temperature according to thermal demands.
- Reduce total volume of air handled by system.
- Insure all VAV boxes operate in accordance with room requirements to prevent overheating or overcooling.
- Be sure, when resetting air volumes and where outdoor air is supplied by the same system, that code requirements for outdoor air are still met.

FAN COIL SYSTEMS

- Refer to "Heating Systems" and "Single Zone Duct Systems" for general recommendations applicable to fan coil systems
- Where a large number of fan coils are used in a building, the coils are provided with heating and cooling media of constant temperature, and control is achieved by varying flow rates through the coils. Consider adjusting the heating and cooling systems according to load. For example, when the heating load is light, and most of the heating control valves which vary the flow rate are partially closed, reduce the hot water temperature until one or more valves is fully open.
- In mild winter weather, and at night, shut off fans and permit the coil to operate as a convector. In severe winter weather, when the building is unoccupied but must be heated, or when excessive noise is not a problem, operate fans at high speed.
- Clean filters and coils.
- Close outside air dampers anytime infiltration equals ventilation requirements, or block off permanently.
- Block off inlets where no dampers are installed if infiltration meets ventilation requirements.
- Keep air outlets and inlets free of obstrucions.
- Where fan coil units are not located in conditioned areas, insulate casings to reduce heat loss/gain.

WINDOW AND THROUGH-THE-WALL UNITS

- Clean condenser and evaporator coils and intake louvers.
- Caulk openings between unit and window or wall frames.
- Remove units or cover them with plastic hood during the winter.
- Provide thermostatic control or timers to shut them off automatically.
- Turn off cooling unit and fan when leaving the space.
- Outdoor air inlets to units with resistance heaters are usually fixed, bringing in outdoor air whenever the units are operating. Close these inlets when unit

is not in operation or block off entirely if infiltration meets outdoor air requirements.
-See discussion above and ECM- 2 for replacement of inefficient units.

REDUCE FAN POWER BY REDUCING SYSTEM RESISTANCE

-Most duct systems are provided with balancing dampers which ensure the correct flow of air to each register or diffuser. The method of balancing which probably was used originally was to first determine the longest run, which normally had the highest resistance to air flow, and then to leave the balancing dampers in that run in a wide open position and close all other balancing dampers to achieve the required air flows. Thus, the shorter the run to any particular outlet, the more closed its balancing damper and the greater loss of power across it. Reduce resistance in the longest or index circuit so that all balancing dampers can be open, and total system resistance reduced. Further reduce resistance within all other branches or portions of the system.
-Remove unnecessary dampers or other obstructions from both supply and return air ductwork.
-Eliminate high resistance turns and elbows. One bad fitting may increase the entire system resistance by more than 1/2" S.P.
-If the majority of dampers in an air system are closed or partially closed to "balance" the system, consider reducing the total air volume and opening some of the dampers to save fan horsepower.
-Clean filters, blower fan wheels and fan scroll blades frequently to reduce friction.
-Replace filters which have low efficiency and high resistance with filters offering less air resistance and greater efficiency.
-Clean the air side of all coils in air handling units. Cleaning coils also increases their efficiency so that less energy for operation of the heating or cooling primary equipment is required.
-Seal and caulk leaking joints in ductwork, air handling units, and flexible duct connectors.
-Although air leakage from the ventilating system does not increase the resistance to air flow as such, it does waste

energy in two other ways:

1) It increases the total quantity of air handled by the fan over and above that required to meet the room temperature.
2) It increases the quantity of air that must be cooled or heated resulting in an expenditure of energy over and above that which otherwise would be required to meet desired room conditions.

Air leakage in the longest or most resistant duct run imposes a particularly large resistance load on the entire system since all other runs must be dampered down.

-Where direct drive fans are used and it is difficult or costly to change fan speed or motor, blank off unused portions of exhaust hoods in kitchens and cafeterias to reduce air volume and horsepower.

-Insulate ductwork where heat losses occur. Insulate ductwork used for air conditioning where it passes through non-conditioned spaces and picks up heat.

REDUCE FAN POWER BY REDUCING AIR VOLUME

-Reduce air volume by reducing the speed of rotation -

1) Where motor sheave is adjustable, open the "v" to reduce its effective diameter and adjust motor position or change belts to maintain proper tension.

2) Change motor sheave if no further adjustment is possible.

3) If motors are variable speed, set controller for reduced speed.

-After implementing changes to the system to decrease the required fan horsepower, the existing motor may be too large. If the full load on the motor is less than 60% of the name-plate rating, consider changing the motor to a smaller one. (Further guidelines for motors are included in Section 4 , "Power" ECO-41).

-If the fan is direct drive, changing the speed of rotation is expensive. However, electric motors also tend to be oversized and if the system resistance is reduced significantly, the next size smaller motor, running at a slower speed, may well be suitable. In this case, calculate the savings that will accrue due to reduced power requirements to determine whether changing motors to achieve the speed reduction is economical.

-Losses in the drive train and bearings can, if maintenance is poor, amount to as much as 20% of total power input. Examine all bearings for wear and resistance to movement. Excessive belt tension will also impose an added load on the motor. Adjust or replace slipping fan belt drives.

-Operate exhaust systems intermittently to reduce total operating time. In many buildings the toilets and other areas require full exhaust for limited periods only. With proper programming and wiring to integrate the operation of exhaust fans and dampers with light switches, an office building with a system which exhausts 100 CFM through each of 20 toilet rooms, could reduce its exhaust to an average of only 400 CFM throughout the day.

REDUCE POWER FOR PUMPS

-Regularly adjust all pumps to control leakage at the pump packing glands. Curtail excessive waste of water by repacking, not only to conserve water and reduce losses, but also to avoid erosion necessitating costly repairs of the shaft.
-Reduce water flow where the terminal heating device can deliver heating or cooling adequately with the lower rate. For a chilled water system, take care to avoid reducing flow to the point that a lower suction temperature must be used. In general, the energy consumed at that lower suction temperature to reduce chilled water temperature (to maintain temperature or humidity control) would outweigh the energy saved by reducing the power for pumping.
-Globe valves can be used to restrict flow and save some energy, but since most hydronic systems are equipped with direct drive pumps, it is not possible to reduce the pump speed when the system friction is reduced by opening valves or removing resistances; use globe valves to restrict flow and save some energy. It is often possible to replace the pump impeller to save motor horsepower. Refer to pump maufacturers information for instructions.
-Refer to ECM-2 for changes to variable speed pumps, modular pumping and impellers.
-Check the power input to the pump motor against the nameplate rating. If the motor is drawing less than 60% of the rated input, analyze the potential energy and cost savings with a smaller motor and pump against the initial cost of replacement. See ECM-2 for details.

PIPING SYSTEMS

-Repair torn or missing insulation on water and steam piping which pass through unconditioned spaces.
-Insulate piping, valves, fittings and heat exchangers where heat is lost to unconditioned spaces or where heat lost from the pipes adds to the summer cooling load.

-Insulate cold piping used for air conditioning where it passes through uncooled spaces and picks up heat.
-Protect pipe insulation from water and moisture to preserve its thermal resistance qualities.
-Check for high temperature differences in heating and cooling heat exchangers, which may be an indication of air binding, clogged strainers, or excessive scale.
-Repair leaks in and/or replace steam traps. Confirm the location of a leaking trap by testing the temperature of return lines with a surface pyrometer and measuring temperature drop across the suspected trap. Lack of drop indicates steam blow-through. Excessive drop indicates the trap is holding back condensate.
-Chilled water and hot water systems require near complete elimination of air: check vents before reducing water temperature to improve cooling performance or increasing water temperature to meet room heating loads.

SECTION 4-E

COMMERCIAL REFRIGERATION SYSTEMS

INDEX

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COMMERCIAL REFRIGERATION SYSTEMS

A. BACKGROUND

Commercial refrigeration systems account for as much as 50% of the total annual energy consumption in some supermarkets, and a significant amount of the energy consumed in cafeterias and restaurants. The actual energy usage is analogous to usage by air conditioning systems; total quantity depends upon the "produce" load, (the equivalent to the cooling system's "building" load), the distribution or "parasitic" load, and the seasonal efficiency of the primary conversion equipment, which in this case consists of the compressors.

To "produce" load is a function of the mass of the materials to be cooled, the temperature difference between the refrigerated materials and the ambient conditions and the period of time that the conditions are maintained.

The "distribution" load is a function of the performance of the refrigeration distribution system (refrigeration, piping, valves, controls, cold air ducts and diffusers) and the performance (seasonal efficiency) of the refrigerators, cold display cases, and other cold storage boxes.

The performance of the compressors, as noted in Section 4 , "Cooling", ECO-22 is contingent upon the condition and operating mode of the evaporator, condensers, motors and drives and the performance of the air-cooled condensers. Review that section of the manual, as many of the energy conservation opportunities and options detailed there are applicable to commercial refrigeration systems as well.

Since commercial refrigeration units must operate at suction (evaporator) temperatures lower than those of evaporators of air conditioners they use more energy per tin of refrigeration produced - the C.O.P.* is lower. Because the commercial refrigeration system operates for the entire year - and conditions must be maintained for 24 hours per day - any measures to increase the C.O.P. will be even more productive per ton of refrigeration than equivalent measures

*Section 4 , "Cooling" has an extensive discussion of C.O.P.

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for improving the C.O.P. of air conditioning systems. A supermarket, with a 150 ton air conditioning system driven by a 150 H.P. motor, could have 200 H.P. of installed commercial refrigeration consuming from 2 to 6 times as much energy as the air conditioning system.

B. ENERGY CONSERVATION OPPORTUNITIES

ECO-28 REDUCE ENERGY CONSUMPTION FOR COMMERCIAL REFRIGERATION GUIDELINES TO REDUCE ENERGY CONSUMPTION FOR REFRIGERATION:*

- Use night covers over cold products, but be careful to avoid compressor damage or frost build-up on product.
- Do not permit refrigerated products to stand in the aisles, on docks, or anyplace where they will warm up, and create an additional refrigeration load when the products are placed in fixtures. Reduce the volume of items requiring cold storage.
- Avoid setting controls (pressure and temperature) any lower than necessary. Too often, a freezer may be operating at -30°F. air temperature when most often a -10°F. or higher is all that is necessary.
- Keep products below clearly marked load lines. An overloaded display case decreases product quality and increases energy use as much as 10 to 20% for each fixture by:
  a. Increasing the amount of store air mixing with fixture air, thereby increasing load on compressor.

  b. Increasing running time of compressors.

  c. Increasing fixture temperature.

  d. Increasing loss of refrigerated air out of fixture.

  e. Increasing defrost requirements consuming extra energy to clear frost from coils.

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* Many of the items suggested are from recommended guidelines in "Retail Food Stores Energy Conservation", from the Commercial Refrigerator Manufacturers Association.

-Turn off refrigeration for cutting rooms, prep rooms, and some display fixtures, such as meat cases, when not in use. Put all food products in coolers where possible.
-Where possible, construct a tight partition or hang a heavy drape from roof to floor between sales and storage areas and maintain storage areas at 60°F or lower in winter, to prevent interchange of air.
-Keep return grilles of fixtures clear of stacked products, otherwise refrigerated air will flow into aisles.
-As customers shop from fixtures throughout the day, repack product displays and keep them below load lines.
-With multi-shelf fixtures, follow the recommendations of manufacturers in regard to shelf position and size to prevent increased refrigeration loads.
-Consider reducing - or turning off entirely - the internal shelf lights to reduce both refrigeration requirements and the lighting load.
-Automatically shut off all prep rooms at night and weekends. Set up for automatic startup when required.
-Consider unloading meat and produce display and shut off refrigeration at night and weekends. Set up on time clock to automatically turn off at closing and on in the morning, early enough to allow fixture temperatures to drop to the required level.

<u>IMPROVE PERFORMANCE OF EQUIPMENT THROUGH OPERATION AND MAINTENANCE</u>

Although some of the options listed below involve capital costs, they are included in ECM-1 because the payback periods should not exceed three years for any one option.

-If refrigeration load is decreased by any means, light reduction or case cleaning, for example, recheck temperature and pressure control setting to avoid freezing of products or short cycling of compressors. Enforce closed door rules when case is not in use, even for short periods of time.
-In multi-shelf low temperature equipment, check all fixtures for inoperative fan motors, often unnoticed, which affect efficiency.
-Minimize head pressure, to increase compressor capacities and reduce energy use, by increasing air supply over condenser. Clean condenser coils regularly. Maintain lowest head pressure at which the commercial refrigeration system can operate without

short-cycling or impairing expansion valve and coil efficiency. In cool months, set head pressure with controls:

a. Adjust hold back valves to control condenser surface, to lowest possible head pressure.

b. Set fan cycling with small differential and low cut-in point. Where more than one fan is used, consider cycling one or more fans.

-To prevent pressure drop and loss of compressor capacity avoid the use of suction line controls.
-Insulate suction and liquid line together, except where not recommended (hot gas defrost), to increase system efficiency.
-For systems where product is required at 32°F. or above, use time defrost rather than an added heat source. With existing equipment, disconnect the heater and reset the controls. Energy will be saved because the compressor does not operate and no electricity is used for defrost heaters.
-On forced defrost system, (electric or hot gas) use defrost terminating thermostat on each fixture to avoid over-defrosting individual fixtures and bring compressor back on as soon as all fixtures are satisfied.
-Consider demand defrost for all types of defrost systems. The number of defrosts is normally set up for the most adverse store conditons that may occur in a year. These conditons usually exist for only short periods of the year. Demand defrost compensates for these periods by causing fixtures to defrost only when it is required. Consult the fixture manufacturer before specifying demand defrost.
-Consider separate wiring circuit for anti-condensate heaters. Energy use by these heaters, which operate 24 hours a day, 365 days a year, is high, particularly on glass door freezers. Heaters are only required when humidity is high. Be aware, however, that most existing installations have fan and anti-condensate heaters on same circuit. Do not turn off the fan. Consider eliminating incandescent lighting over top display meat cases. In particular minimize spotlighting.
-Clean display fixture and cooler coil regularly. Be

sure to shut off refrigeration before using water for cleaning.

a. Use pressure spray to clean flues.
b. Remove discharge grilles to thoroughly clean inlet side (unseen from outside). A reduction of air flow can result in as much as a 10°F rise in product temperature and cause more frequent defrost.
c. Drain should be pressure flushed regularly to prevent build up in fixture bottoms.
d. Clean back side or inlet side of cooler units.
e. Check cooler door seals for loss of refrigerated air. Install spring-loaded door closers, reminder sign in plain view, buzzers, lights, etc., to be sure store personnel keep doors closed.

-Check all electrical circuits for power leak to ground. A leak to the ground may be small enough to go undetected for years with substantial accumulated loss of energy.

-Check all systems for correct refrigerant charge to avoid excessive compressor operation. Shortage will usually show up when low ambient air conditions exist.

-Where possible, provide staged cooling controls. Consider replacing one large compressor and coil with two or more circuits. Where possible, consider removal of hot gas bypass capacity control.

-Redirect outlets which are discharging into refrigerated fixtures.

SECTION 4-F

LIGHTING

INDEX

LIGHTING

A. BACKGROUND

Except in buildings that are electrically heated, electric lighting is one of the major uses of electrical energy and accounts for the most significant portion of total energy usage in offices and retail stores. When lights are left on in areas which are unoccupied or unused for lengthy periods of the week - in religious buildings and outdoor parking lots, for example, the inadvertent waste of energy often approaches or exceeds the amount of energy used by other building systems much of the week; the cost of this waste for one year may equal the initial cost of installing automatic controls to eliminate it.

Electric lighting is also the major contributor to internal heat gain in stores and core areas of office buildings. Because it increases the cooling load, electric lighting induces additional expenditure of energy to operate the refrigeration system, including air handling units, chilled water, and cooling tower or condenser fans.

To conserve energy for lighting and air conditioning:

1. Utilize available daylight more effectively for illumination.

2. Improve lighting system efficiency by increasing the light delivered to the task through more frequent fixture maintenance.

3. Switch off lights at night and in unoccupied areas during the daytime.

4. Reduce the levels of illumination at selected task locations, and lower them further between or beyond the tasks.

5. Relamp with more efficient light sources.

6. Modify the existing lighting fixtures and their location in the room to provide a greater amount and better quality of lighting.

7. Reduce the losses in the power distribution system which serves the lighting system. (When ballasts require replacing use high power factor type).

Office buildings and store sales areas are frequently illuminated at levels from 75 to 300 footcandles or more, requiring an average of 3 to 8 or more watts per square foot. In studies and design work for a number of projects (including the General Services Administration (GSA) energy conservation office building in New Hampshire, two Argonne National Laboratories offices, the Atomic Energy Commission office in Illinois and the New York Botanical Gardens office and laboratory in Millbrook, New York) Dubin-Mindell-Bloome Associates has found that a 2 watt per square foot average of good quality lighting is adequate for illumination in these office buildings and should be adequate for all new office buildings. Studies by Ross and Baruzzini, Consulting Engineers, for GSA and FEA confirm that adequate lighting can be provided in office buildings, utilizing only 2 watts per square foot lighting energy usage. Satisfactory illumination level for stores can also be possible within the 2 watt per square foot budget; in religious buildings, the budget can be even lower.

Without major modifications to both the pattern of lighting fixtures and the fixtures themselves,it may be possible to attain the 2 watts per square foot goal in existing offices and stores while maintaining proper lighting. If, however, the guide to illumination levels, Figure 26, is followed, average energy usage for lighting will approach the target.

Lighting levels on tasks, have traditionally been measured by footcandles. A room with a high level of footcandles, however, does not necessarily have a high level of effective illumination. Impediments to visual acuity, veiling reflection and disability glare, are not accounted for in footcandle measurements. The higher footcandle levels and added wattage may contribute ineffective illumination only.

The Illuminating Engineering Society (IES), which in the past has set lighting standards based on footcandles, in 1972 adopted the measure of effective light called Equivalent Sphere Illumination (ESI). ESI is a measure of lighting on tasks that accounts for both quality and quantity in the lighting system. Due to the complexity and time involved in E.S.I. calculations, consider using computer simulation programs now available, thru some fixture manufacturers, to approximate ESI footcandles. This method should be employed for areas with critical tasks. When high E.S.I. lighting valves are provided, they will yield very effective lighting at low energy input. Refer to ECM- 2 for further details.

Measures suggested here can provide for a lighting system with higher ESI footcandles. When there are opportunities to switch off or remove some lamps from fixtures, plan the eventual pattern of lighting fixtures to be that layout which locates the most remaining lamps just beyond the sides of the working edge of desks and task surfaces.

The simplest and most obvious option to save energy is to turn off lights when they are not needed and during unoccupied periods. Examine the building, first, to locate the areas where this can be done with available switches. ECM- 2 suggests the installation of additional switching where necessary to provide for switching of areas, utilization task lighting and more effective use of daylight.

Painting or covering walls, ceilings, and floors with light colored, more reflective finishes, and cleaning interior surfaces improves the effectiveness of any lighting system - daylight, electrical, or combination. Rooms with dark or dirty surfaces and furnishings, which absorb light, require either more lamps or lamps of higher wattage to maintain the desired level of illumination.

As a general rule, for all light sources except low pressure sodium, as the remaining useful life of the lamp decreases, its output of light, measured in lumens, decreases. This decrease is called the lamp lumen depreciation (L.L.D.)

Dirt accumulation on lamps, fixtures and lenses decreases the quantity of light falling on the task. This reduction of available light is called the Luminaire Dirt Depreciation (LDD) and combined together with the lamp lumen depreciation (LLD) comprises the maintenance factor (MF). The maintenance factor is used in lighting calculations to determine how many fixtures and lamps must be installed initially to give the designed illumination when lamp and dirt depreciation has occurred.

The installation will obviously provide more lumens on the task initially than required and if light fall-off can be reduced by improved maintenance, some of the fittings and lamps can be removed without reducing illumination below that required.

The discussions and guidelines of ECO's 29-36 reveal opportunities and options for lighting energy conservation which are in accord with the following principles and practices.

- -Illuminate specific task areas to that level, for each area, which provides adequate visual acuity, to perform the required task satisfactorily and reduce illumination levels in adjacent areas.
- -Provide artificial (electric) lighting only where and when it is required (to perform the task or for safety).
- -Consider all available light sources, including daylight, and select the most efficient that suits the application (highest lumen output per input watt.).
- -Institute a thorough maintenance program to sustain the highest value of light loss factor (L.L.F.)
- -Minimize power losses in ballasts and the distribution system.

ECO 29 <u>REDUCE ILLUMINATION LEVELS</u>

Conserve energy for lighting by reducing illumination levels where they need not be high and eliminating illumination where it is not needed at all. Consult Figure 26, "Recommended Lighting Levels" for suggested levels in specific areas of the building. If several tasks requiring different levels of illumination occur within the same space, first consider their visual severity and then modify maintenance procedures, redecorate the area, and implement changes to the lighting system while reducing illumination levels to the appropriate level for each task. A uniform modular lighting pattern of general illumination, throwing light equally on all areas regardless of task may waste up to 50% of the energy used for lighting in the building. Orient lighting to suit the tasks to be performed.

If one task with a critical lighting requirement is confined to a specific work area - i.e. drafting table, typewriter, desk top - in the midst of a larger work area with less critical requirements, provide a lower general illumination level for the overall area and a portable light at each critical task to raise the level of illumination locally (less than $25/lamp). Use fluorescent portable lamps in preference to incandescent.

In many cases it is less costly to move tasks to suit an existing lighting pattern than to add or rearrange fixtures. If task areas are widely dispersed, more light spills into adjoining areas where it may not be needed. Group tasks requiring similar lighting levels to limit the spill of higher level illumination and to allow lower lighting levels at less critical work areas.

Light levels in standard footcandles can be determined with portable illumination meters such as a photovoltiac cell connected to a meter calibrated in footcandles. The light meter should be accurate to about ± 15 percent over a range of 30 to 500 footcandles and ± 20 percent from 15 to 30 footcandles. The meter should be color corrected (according to the CIE Spectral Luminous Efficiency curve) and cosine corrected. Generally, measurements refer to average maintained horizontal footcandles at the task or in a horizontal plane 30 inches above the floor.

Measurements should be made at many repesentative points between and under fixtures, an average of several readings may be necessary. Daylight should be excluded during illumination-level readings for a true determination of level without light contribution from daylight.

The suggested illumination levels for office buildings, listed in Figure 26, agree closely with new standards recommended by G.S.A. for public office buildings. Keep in mind, however, that even lighting at lower intensities is very wasteful if lamps are burning when not needed.

fig.26

SUGGESTED LIGHTING LEVELS*

With proper attention to quality the following levels should generally be adequate for tasks of good contrast:

Circulation Areas between Work Stations: 20 footcandles.

Background beyond Tasks at Circulation Area: 10 footcandles.

Waiting Rooms and Lounge Areas: 10-15 footcandles.

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* Unless otherwise noted, all levels are average.

<u>Conference Tables</u>: 30 ESI footcandles with background lighting 10 footcandles.

<u>Secretarial Desks</u>: 50 ESI footcandles with auxiliary localized (lamp) task lighting directed at paper holder (for typing) as needed. In secretarial pools, 60 ESI footcandles.

<u>Over Open Drawers of Filing Cabinets</u>: 30 footcandles.

<u>Courtrooms and Auditoriums</u>: 30 footcandles.

<u>Kitchens</u>: non-uniform lighting with an-average of 50 footcandles.

<u>Cafeterias</u>: 20 footcandles.

<u>Snack Bar</u>: 20 footcandles.

<u>Testing Labs</u>: As required by the task, but background not to exceed 3 to 1 ratio footcandles.

<u>Computer Rooms</u>: As required by the task, (consider 2 levels, 1/2 and full). In computer areas, reduce general overall lighting levels to 30 footcandles and increase task lighting for critical areas for input. Too high a level of general lighting makes it difficult to read the self-illuminated indicators.

<u>Drafting</u>: Full time 80 ESI footcandles at work station, part time 60 footcandles at work stations.

<u>Accounting Offices</u>: 80 ESI footcandles at work stations.

Note: Where applicable, refer to health and safety codes and federal standards (OSHA) for minimum lighting specifications.

The goal of the above standards is to reduce store and office lighting energy usage to less than 2 watts/sq. ft. gross floor area, or 2.5 watts/sq. ft. net area and 1.5 watts/sq. ft. for religious buildings. To determine net area subtract from the gross building floor area, the corridors, storage rooms, lobbies, mechanical equipment rooms, stairwells, toilet rooms, and other unoccupied, or seldom occupied areas.

ECO 30 CONSERVE ENERGY BY TURNING OFF LIGHTS

Utilize Existing Switching

Contrary to common belief, letting a light burn rather than turning it off never saves electrical energy. When electric lighting is not required, switch it off.

Figure 27 indicates - for an office lighting system of 1,000 fluorescent luminaires each with +100 4' 430 MA lamps - energy usage when lights burn only when needed.

ECO 31 IMPROVE THE EFFECTIVENESS OF THE EXISTING LIGHTING INSTALLATION

Increase the effectiveness of the present lighting system, then reduce the number of wattage of lamps required to meet the suggested standards. In order to reduce the number and/or wattage of lamps, consider the following measures to increase the maintained footcandles provided by existing lamps and fixtures.

Improve the maintenance factor by regularly cleaning fixtures and lamps and instituting a relamping program. Clean a fixture, at the least, every time it is relamped. (When relamping and cleaning are combined, the additional labor is very small.) In extremely dirty atmospheres, clean fixtures between lamp replacements, as well. Clean the lenses and interior housings. Use an anti-static compound to reduce electrostatic dirt collection.

The approximate cost of cleaning ceiling - mounted 48" 4-tube fluorescent fixtures - or incandescent fixtures of similar size - varies as follows: (for rough estimate only)

Number of Fixtures:	10	50	100	200
Price	\$14.00	\$58.00	\$115.00	\$224.00

A group relamping program will give a higher level of maintained footcandles, because lamp lumens will not depreciate to the low levels apparent at the end of their lives. Refer to Figures 28 and 29 for the effects of lamp and fixture cleaning and improving the maintenance factor.

When there are no critical reading or writing tasks, and where some glare from exposed lamps is acceptable (check with codes, where applicable), remove louvers or lenses from fixtures. Consider this suggestion, for instance, in regard to corridors, storage areas, stores with high ceilings, equipment rooms, and snack bars.

Increase the reflectance of ceilings, walls, and floors by cleaning or by painting with colors of higher reflectances: more illumination on tasks, with the same lumen output, will result. Increasing the reflectivity of the interior surfaces may open the possibility of reducing the number of lamps and luminaires while maintaining recommended lighting levels. Greater reflectances enhance the performance of natural daylight as well as artificial lighting. For example, a 25 x 25-ft. room with a 9-ft. ceiling and a ceiling reflectance of 80%, wall reflectance of 70% and floor reflectance of 30% will provide 35% more footcandles (with no increase in power consumption) than the same room with a ceiling reflectance of 50%, wall reflectances of 30% and floor reflectance of 10%. Caution: high gloss finishes may reduce visual comfort by increasing glare. Discretion should be used when redecorating.

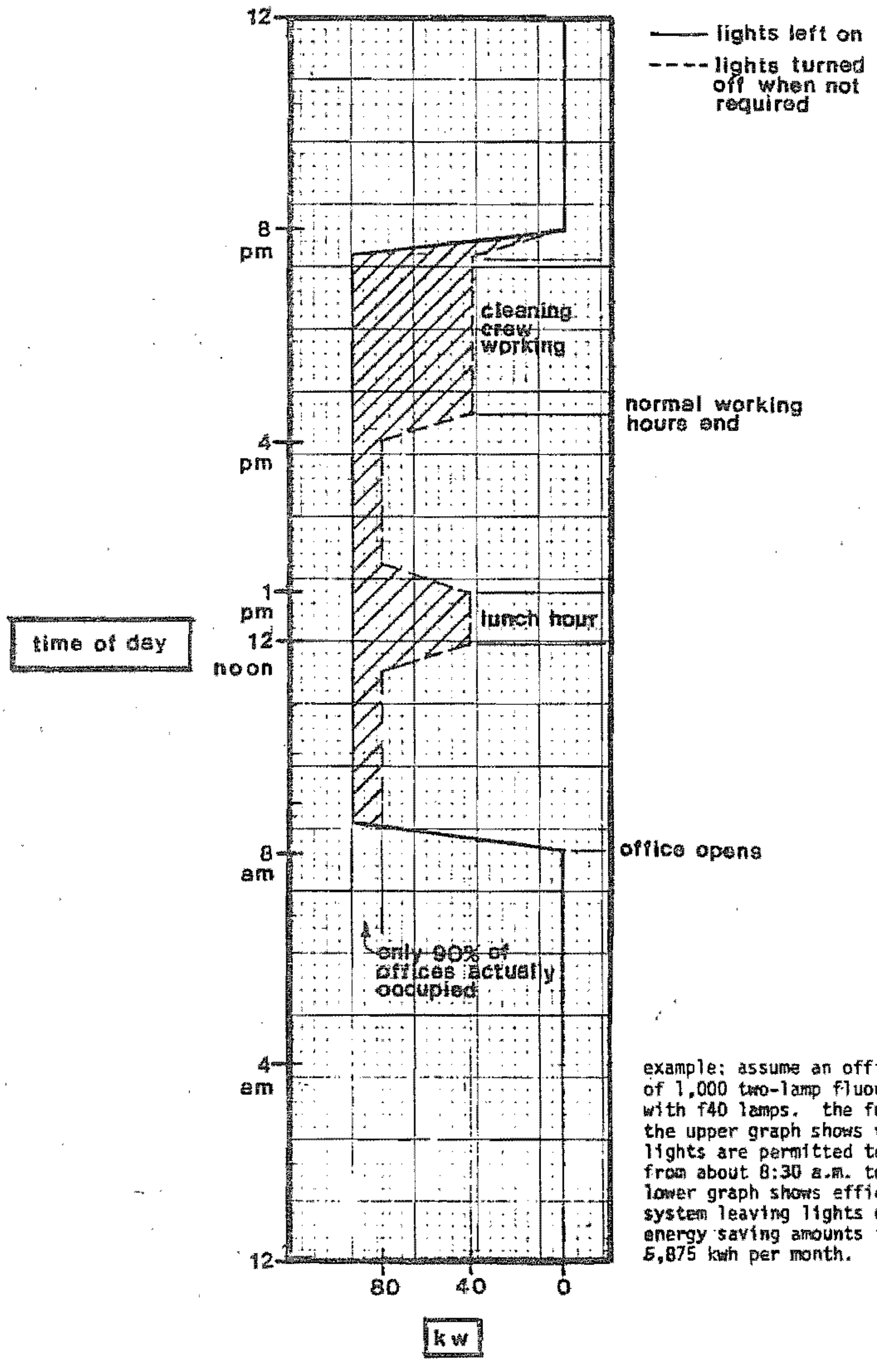
The approximate cost of applying one coat of flat paint on smooth finish ranges between 15 and 20¢ per square foot, depending on total square footage. (for rough estimate only).

ECO 32 USE DAYLIGHT FOR ILLUMINATION

Use windows effectively as a primary source of illumination in perimeter spaces. The amount of available daylight in a building is a function of operating hours, latitude, weather, time of year, air quality, window size and location, shading and glazing details, reflectivity of interior surfaces and furnishings. Control of natural light, for effective use and integration with artificial light, is important, because the amount of natural light available varies. Control may be manual or automatic. Often blinds or drapes, which should be closed only for short periods of excessive sunshine or glare, remain closed all day with the electric lights turned on, when daylight could be used. Emphasis should be placed on proper control of daylight; otherwise the heat gain imposed on the cooling system may outweigh savings in energy for lighting. Indirect daylighting, however, generates less heat per lumen of light than electrical lighting. When equivalent lumens from daylight replace electrical lighting, savings in cooling load will occur.

lighting the effect of turning off unnecessary lights on power consumption fig. 27

dubin-mindell-bloome-associates
consulting engineers



example: assume an office lighting system of 1,000 two-lamp fluorescent luminaires with f40 lamps. the full system uses 92 kw. the upper graph shows typical usage when lights are permitted to burn continuously from about 8:30 a.m. to 7:30 p.m. the lower graph shows efficient use of the same system leaving lights on only when used. energy saving amounts to 262.5 kwh daily or 5,875 kwh per month.

Figure # 27 Engineering Data

Graph developed from theoretical calculations based on typical office building practices.

lighting fixture cleaning cycle fig. 28

dubin-mindell-bloome-associates consulting engineers

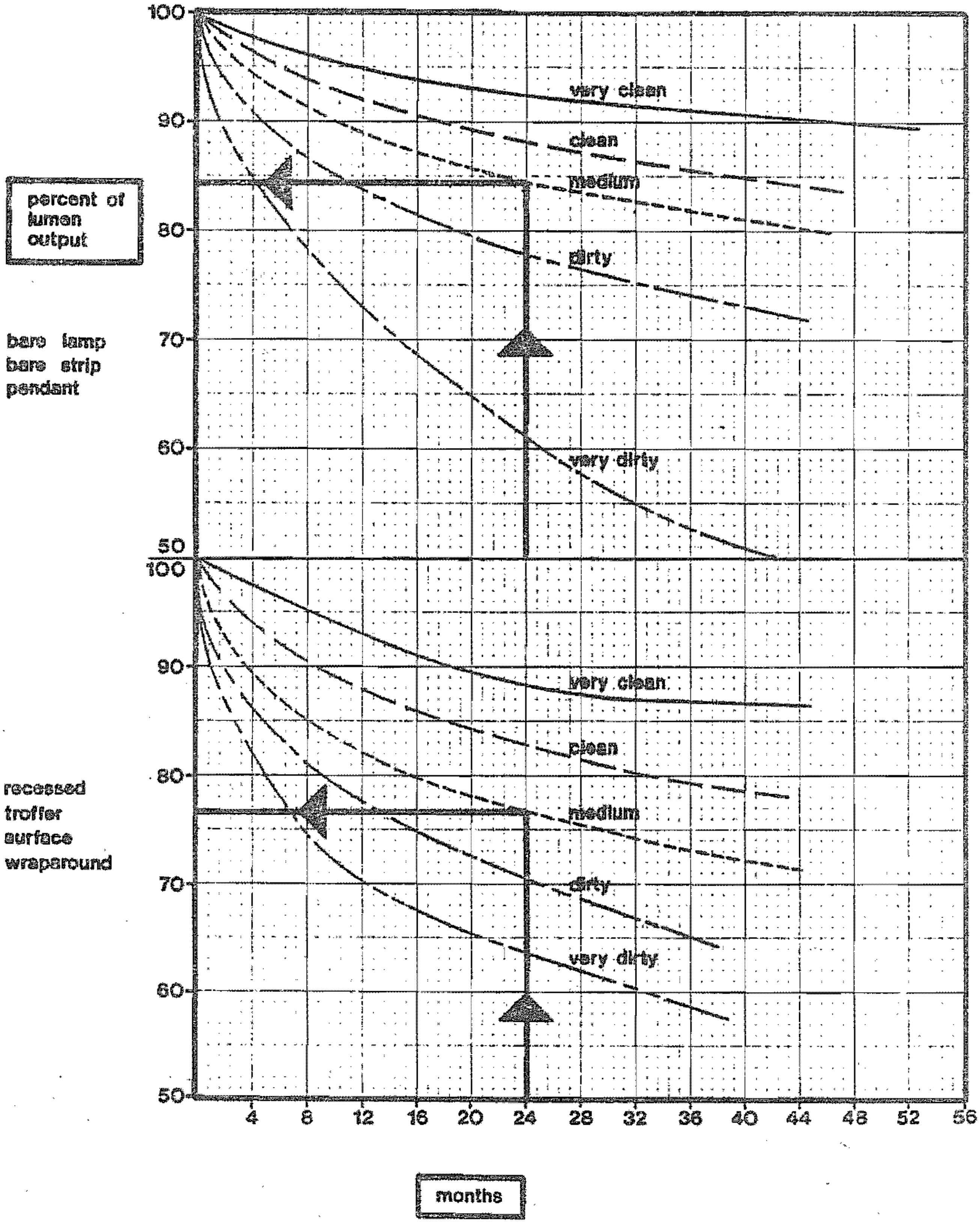


Figure #28 Engineering Data

Reference: I.E.S. Lighting Handbook, 4th edition 1968, page 9-17, figure 9-7 Illuminating Engineering Society 345 East 47th Street, New York, N.Y.

The data is computed from actual measurements of lumen output from lamps and fixtures exposed to various environments for different lenghts of time.

lighting fig. 29

example of maintenance factor effect on footcandles

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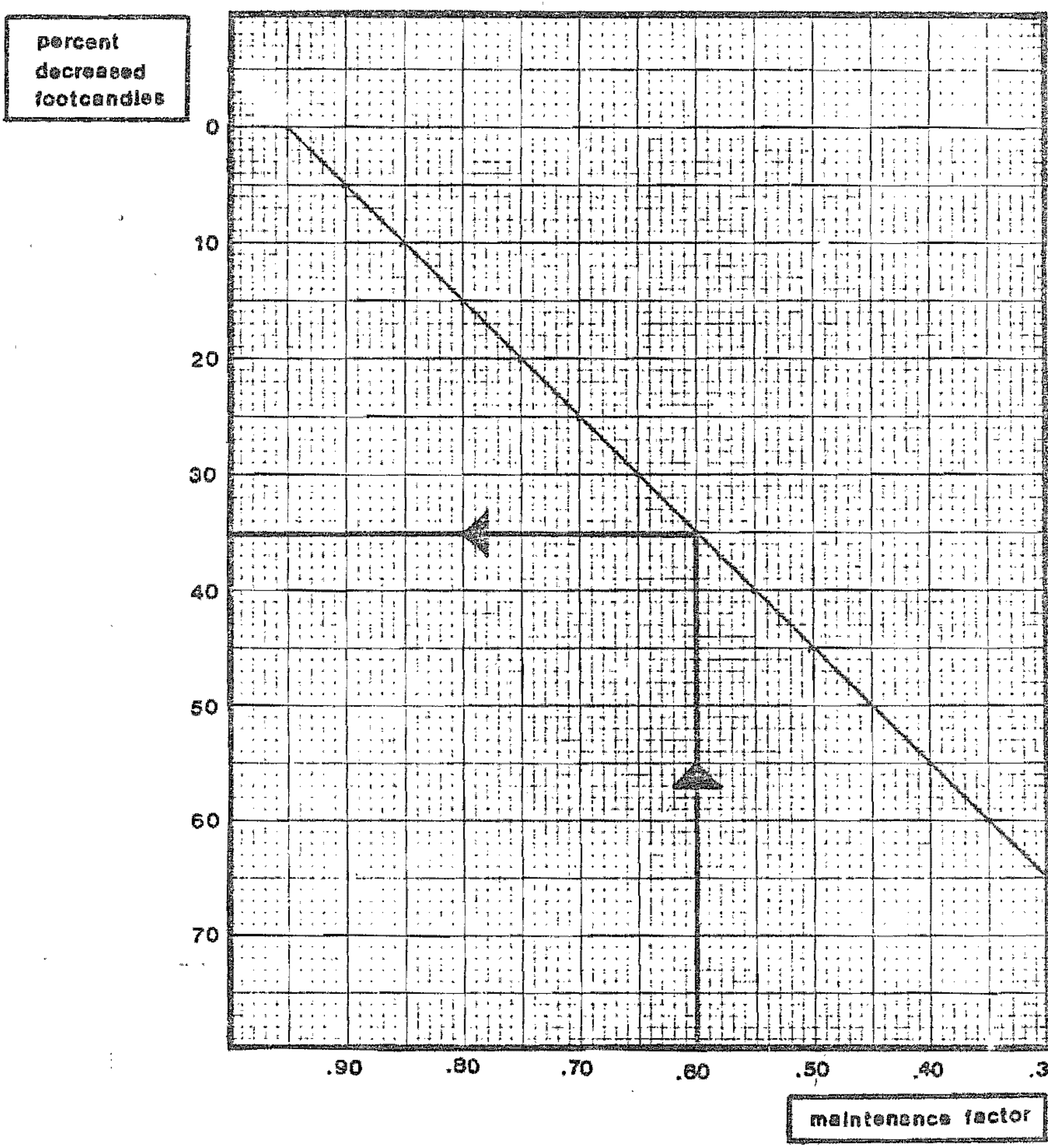

Figure #29 Engineering Data

Example Only - C.U. = Coefficient of Utilization
M.F. = Maintenance Factor

$$\text{footcandles} = \frac{\text{No. lamps (lamp lumens) No. fixtures (C.U.) M.F.}}{\text{area}}$$

$$\text{footcandles} = \text{M.F.} \left[\frac{\text{No. Lamps (lamp lumens) No. fixtures (C.U.)}}{\text{area}} \right]$$

footcandles = M.F. [constant - (for any specific area)]

Therefore, footcandles vary directly with maintenance factor

The luminous efficacy (lumens per watt) of various light sources as compared to daylight are shown below (no allowance for ballast of luminaires):

Low Pressure Sodium	183 lumens/watt
Natural light	120 lumens/watt (varies)
High pressure (HID)	105-120 lumens/watt
Metal halide	85-100 lumens/watt
Fluorescent	67-91 lumens/watt
Mercury vapor	56-63 lumens/watt
Incandescent	17-22 lumens/watt

ECO 33: <u>ADD SWITCHING AND TIMERS TO SHUT OFF LIGHTS</u>

If there are insufficient switches installed for unwanted lights to be turned off, consult an engineer, contractor, or utility company to determine the cost and procedures for installing additional switches. ECM- 2 includes further details.

There are many types of surface mounted flat ribbon conductors available for installation in existing spaces; they can be installed with the minimum dislocation of existing wiring or damage to interior decorations. Locate new switches near doors or where they are most convenient for occupant use: Switches in inconvenient locations will not be used. If switches are group-mounted lable each one to indicate the area it controls.

Provide time switches for areas which are commonly used for short times, and in which lighting is inadvertently but frequently left on. (i.e. reference rooms and stock rooms.) At a pre-determined time after the switch has been turned on, it will automatically shut off; if the area is to used for a long period of time, the switch can be manually overridden.

To ensure the success of any switching program, instruct all occupants in the use of available switching. Ensure that any changes to switching are in compliance with electrical codes.

ECO 34: <u>REMOVE UNNECESSARY LAMPS</u>

Remove unnecessary lamps when those remaining can provide the desired level of illumination. When removing fluorescent or high intensity discharge lamps, also remove the ballast (or disconnect it in place). If it is left connected to the power source it will continue to consume energy even though it serves no useful purpose. When two lamp fluorescent fixtures are mounted in a row, remove lamps in alternate fixtures of the rows (rather than removing one entire row) to derive higher quality lighting. In order to maintain the recommended lighting level it may be necessary, after removing some lamps, to use increased output lamps in place of some of the remaining lamps. Even so, the measure should result in net savings of energy. In many cases it will be possible to relamp the remaining fixtures with more efficient lamps to provide more lumens/watt -- increased illumination levels without increased wattage. Refer to Figure 30 to determine appropriate footcandle output with some common lamp replacements.

Lamp efficiencies vary between lamps consuming the same number of watts, and lamps of the same type. Different colors, shapes, gaseous fills, cathode construction and internal coatings cause those variations. For example, a fluorescent 40-watt, T-12 lamp, rated 430 millamperes, can have a rating from around 53 lumens to around 92 lumens per watt. Or, for example, a natural white color fluorescent lamp at 2100 lumens (53 lumens/watt) provides 1/3 less foot candles than cool white fluorescent lamps at 3200 lumens (80 lumens/watt.) In some cases, it may be desirable to relamp with lower wattage lamps as an alternative to removal of lamps.

An example of energy and money saved by removing two lamps from every other fixture (and disconnecting ballasts) is given below.

Example: BUILDING TYPE - RETAIL STORE

Number and type of fixtures (4-40W) 2' x 4'	375
Floor area	24,000 sq. ft.
Illumination level before change	100 FC
Hours of operation/yr.	3720 hours
Watts saved by the change = $100W \times \frac{375}{2}$ =	18,750 watts
Energy saved/yr. = $\frac{18{,}750W}{1000} \times 3720$ hrs. =	69,750 kwh

At an electricity cost of 4¢/KWH, dollar savings = 69,750 x .04

= $2790

Additonal savings in energy for cooling, due to reduced heat gain from lighting, will more than compensate for any loss of heat from lighting which occurs in the winter.

lighting

resultant footcandles & watts/sq.ft. for various lamp changes

fig.30

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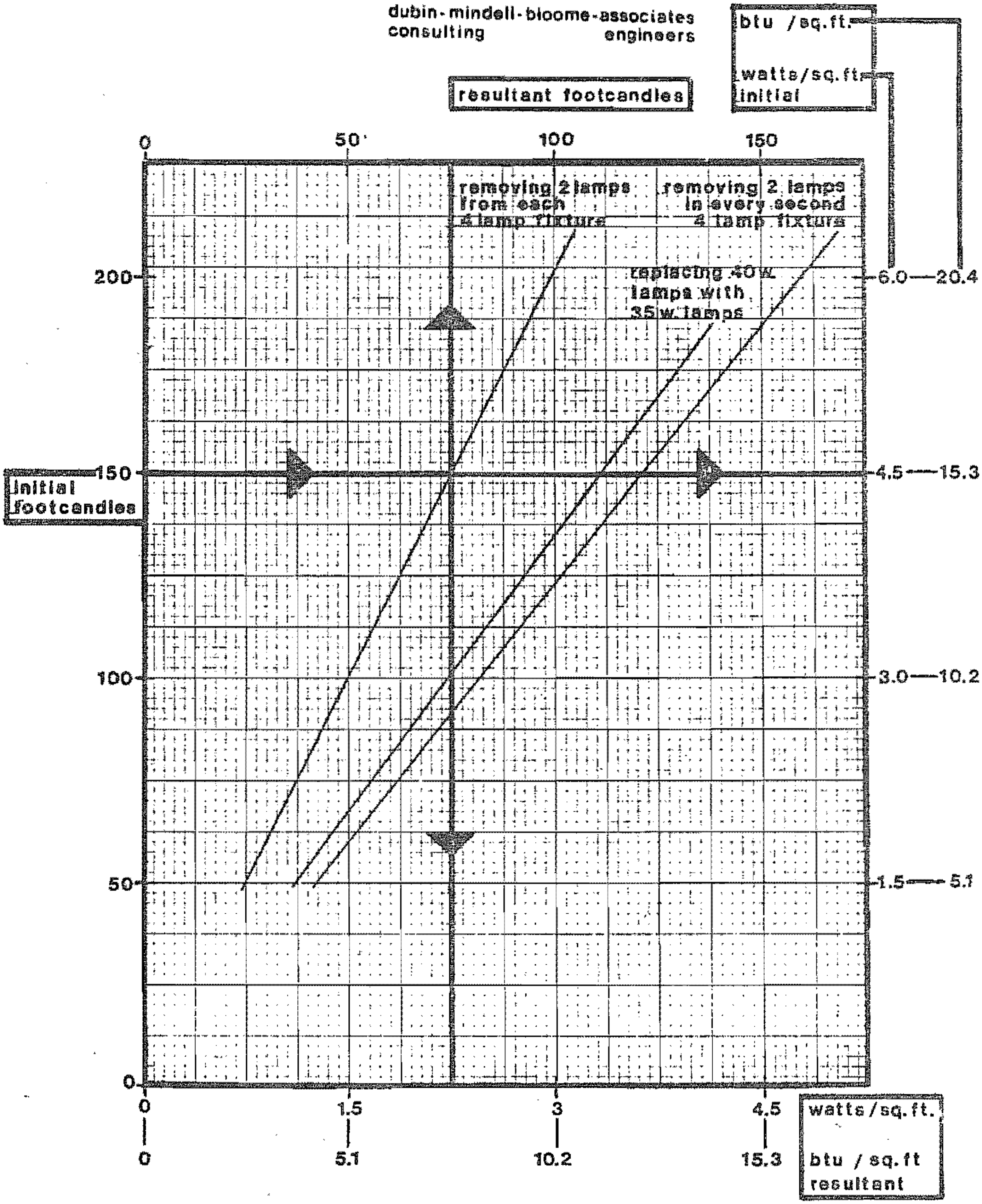

Figure #30 Engineering Data

This graph is derived from calculations based on manufacturers data and should be used only to obtain order-of magnitude savings that may be available.

C.U. = Coefficient of Utilization
M.F. = Maintenance factor

$$\text{footcandles} = \frac{\text{No. lamps (lamp lumens) No. fixtures (C.U.) M.F.}}{\text{area}}$$

$$\text{footcandles} = \text{No. lamps (C.U.)} \left[\frac{\text{(lamp lumens) No. fixtures (M.F.)}}{\text{area}} \right]$$

footcandles = No. lamps (C.U.) [constant - for any specific area]

Therefore, footcandles vary directly with No. lamps & C.U. Coefficient of utilization varies by only about 10%, hence, has been neglected for the approximation presented in this figure.

Since wattage consumption depends on the number of lamps and ballasts used; wattage consumption varies directly with number of lamps used.

ECO 35: REDUCE LIGHTING LOAD BY RELAMPING

Efficiency of lamps is measured in lumens or useable light produced per watt input. Selecting lamps with higher lumens per watt could permit the removal of some lamps, providing the lumens produce the required footcandles. More efficient lamps also impose smaller heat loads on the air conditioning system. In supermarkets and produce markets, reduced lighting reduces loads on commercial refrigeration systems as well. In winter, any heat lost by the reduction in wattage can generally be supplied more efficiently by the heating system itself.

When relamping, use more efficient light sources. Refer to Figure 31 for suggested changes to increase lighting efficiency without modifications to luminaires or ballasts.

The variation in efficiency of lamps (measured in lumens per watt) between incandescent lamps and high pressure sodium vapor lamps, is about 1 to 7 -- an extreme example. Proper application of lamps, however, precludes the higher efficiency lamps in all applications. For example, using a very bright concentrated light source, i.e. a high pressure sodium vapor lamp, in an office with a low ceiling would not provide comfortable lighting. Instead fluorescent lamps with outputs up to about 93 lumens per watt will be both effective and energy conserving. Or, for example, a 20-watt incandescent lamp in a fixture directly attached to a paper holder at a typist's desk could provide 60 footcandles on a manuscript with low ambient background lighting. It would require 100-watts of fluorescent lighting from a ceiling fixture, even though the fluorescent lamp produces more lumens per watt. Esthetics, size, efficiency, color, initial cost and operation and maintenance cost all help to determine choice of lamps. Energy conservation in fighting is not synonymous with sacrificing quality. Quality is not a measure of quantity only; it is obtained by intelligent application of the many interrelated factors. Correctly applied, energy conservation can increase the quality of lighting while reducing operating costs.

Generally, the lamp type recommended for each application in Table 1 is the most favorable for energy conservation.

TABLE 1

ENERGY CONSERVING LAMP APPLICATIONS

Lamp Type	Applications
Incandescent	1. Short time uses such as decorative display lighting or out-of-doors (Christmas trees).
	2. Religious worship halls.
	3. In projection lamps for illuminating work closets or other very confined spaces.
	4. Stage spotlighting.
	5. Where small light source are required to light the task.
Fluorescent	1. Offices and other relatively low ceiling applications.
	2. Flashing advertising signs.
	3. Service islands at service stations
	4. Display cases in stores.
	5. Desk lamps.
	6. Classrooms or training centers.
	7. Cafeterias (with color correction).
High Intensity Discharge	1. Stores and other relatively high ceiling applications.
	2. Auditoriums
	3. Outdoor area lighting
	4. Outdoor flood lighting
	5. Outdoor building security lighting
	6. Marking of obstructions

It is also desirable to adopt a group relamping program so that when a majority of the fluorescent tubes reach the point of only 70% of their rated output they will be replaced. Labor costs are generally less for group relamping than for individual relamping throughout the year.

ECO 36: <u>REDUCE POWER FOR LIGHTING BY REPLACING BALLASTS</u>

When the standard ballasts in existing systems fail or must be replaced, substitute high efficiency types.

For instance, in an installation of 1,000 2-lamp 40-watt fluorescent luminaires each ordinary ballast consumes 12 to 16-watts amounting to an annual energy consumption of 24,000 to 32,000 kilowatt hours in buildings operating 2,000 hours/year. On the other hand, an efficient ballast having only 10 watts loss will only use 20,000 kilowatt hours annually, for a savings of 4,000 to 12,000 kilowatt hours a year.

GUIDELINES TO REDUCE ENERGY USED FOR LIGHTING

TURN OFF LIGHTS

-Mark all ganged switches with identification of the lights controlled. Color code switches and institute a program of use. (i.e. Blue 7 a.m.-6 p.m., Red 9 a.m.-12/1 p.m.-4:30 p.m. etc.)

-Instruct occupants and maintenance personnel to switch off all lights which are not required, even for portions of the day, including lights for:

Storage rooms
Vending machines (Use vending machine illumination).
Mechanical equipment rooms
Auditoriums, conference rooms and cafeterias (when not used)
Meeting rooms (when not used)
Bulletin boards
Office directories
Unassigned office areas
Any areas where natural light is available
Loading docks.

-Turn off all lights other than those needed for security when the building is unoccupied.

-Substitute small table or floor-mounted lamps in lounge areas or waiting rooms and turn off modular ceiling fixtures.

-For cleaning which must be done at night, turn on lights only in that portion of the building which is being cleaned immediately.

-Switch off lights in each area when moving to the next.

-Turn off display case internal lighting (in food cases of a supermarket, for example) when premises are unoccupied.

-Turn off incandescent lighting over top display of meat cases in a supermarket.

-Turn off flood lighting which is strictly decorative.

-In kitchens, avoid keeping infrared food warming lamps on when no food is being kept warm.

-Turn off lights in areas of religious buildings which are not used during the week.

-Maintain hazard and egress lighting at all times as required by building and fire codes.

INCREASE THE EFFECTIVENESS OF THE EXISTING LIGHTING SYSTEM

-Clean and wash walls, ceilings and floors.

-When repainting, use light colored paint on ceilings, walls and floors but avoid objectionable specular reflections from gloss finishes. (Consult applicable fire codes for flame spread ratings of interior finishes.)

-When recarpeting or retiling, put in lighter colored carpets or tiles. (Consult local fire codes for ratings of materials.)
-When refurnishing, select lighter color furnishings.
-Remove partitions where no longer required. (Identify fire partitions and leave intact, as specified by building code. Also partitions may contain or retard noise deemed hazardous by federal standards (OSHA). If wall outlets with partitions are eliminated, electrical codes may require alternate outlets in floor.)
-Decrease partition heights where possible. (Again, check for compliance with building and fire codes, as well as occupational standards for noise, etc.)
-Lower luminaire closer to the lighting task especially in high bay areas such as storage and equipment rooms. (If alteration of ceiling assembly is involved check for compliance with fire ratings.
-Where possible change the relationships between the light source and task by moving the luminaire or relocating the task so that the light source is to one side of the task rather than directly in front of directly over it.
-Direct security lighting where it is most required, such as at windows and entrances, and reduce it where the security problems are minimal.
-For display or merchandising lighting, establish grouped, highlighted display islands where many products can be lit with the same lighting sources and reduce the total number of display islands.

MAKE BETTER USE OF DAYLIGHT

-Clean windows and skylights.
-Where practical, schedule periods of occupancy, cleaning and meetings to make maximum use of daylight.
-Locate tasks that need the best illumination closest to the windows, with the task-viewing angle parallel to the windows.
-Switch off electric lights in areas when natural light is available.
-Add additional switches to turn off electric lights where luminaire arrangement and circuiting permits. Refer to ECM-II for details on modifications to the switching system.
-Increase the interreflectances of interior surfaces.
-To reduce galre, rearrange work stations so that side wall daylight crosses perpendicular to the lines of vision.

-In the winter, open blinds and drapes even if space mildly overheats.

-In buildings without air conditioning systems, open blind and drapes in summer even if space mildly overheats.

-Block out or paint out surfaces of skylights which receive excess amounts of direct sunlight in the summer; leave other surfaces clear.

REMOVE EXCESS LAMPS

Removing both Lamps of a Two-Lamp Fluorescent Fixture

When removing both lamps, disconnect the black and white ballast power leads from the power supply. In addition to the wattage saved from the lamp removal, there will be savings in ballast wattage as follows:

LAMP TYPE	BALLAST WATTS SAVED
F40	7
Slimline	11-13
High Output (800 mA.)	12
High Output (1,500 mA.)	13.5

Removing Two Lamps in a Four Lamp Fluorescent Fixture or One Lamp in Three Lamp Fixtures

For rapid start 430 milliampere lamps in a four-lamp fixture, remove both inside lamps and disconnect power wiring to their associated ballast. (Savings will be lamp wattage plus ballast wattage). In a 3-lamp fixture remove the middle lamp.

Two lamps in a 2'wide fluorescent fixture is actually more efficient than four lamps in the same fixture. The resultant lighting levels using only two lamps will be greater than half the level if four lamps were used.

Removing One Lamp in a Two Lamp High Intensity Discharge Fixture

Removing a lamp from a two lamp mercury or metal halide ballast will generally cause no adverse effect. However, there will still be a current flow consuming as much as 20 watts in a 400-watt lamp ballast or 50 watts in a 1,000 watt lamp ballast, disconnect the ballast to save energy.

Removing a lamp from a two lamp high pressure sodium ballast for more than a short period of time will damage the starting circuit in the ballast because the circuit will operate continuosly with the lamp removed. A failed lamp can cause the same type of damage. Remove both lamp and ballast.

USE MORE EFFICIENT LAMPS

-Use a single, larger incandescent lamp where possible, rather than two or more smaller lamps. Higher wattage general service incandescent lamps are more efficient than lower wattage lamps. For example, one 100-watt (at 1,750 lumens outout) produces more light than two 60-watt lamps (at 2 x 860 lumens output per lamp = 1,720 lumens).
-Avoid multi-level lamps, where light levels are not often changed. The efficacy of a single lamp is higher per watt than a multi-level lamp. For example, a 50-100-150 watt multi-level lamp operating at 100 watts has an efficacy of 17.1 lumens per watt.
-Avoid replacing incandescent lamps by self-ballasted mercury vapor lamps, as they give less light than the same wattage incandescent.
-Avoid using extended service lamps except in special cases, such as recessed directional lights, where short lamp life is a problem. In those cases use one size smaller extended service lamp. For the same wattage, general service lamps at 750 to 1,000-hour life are more efficient than extended service lamps at 2,500 hours. An extended service lamp (100 watt) producing 14.8 lumens per watt will require 17.5% more power to provide the same lighting as a general service lamp (100 watt) producing 17.5lumens per watt. Most cost studies show extended service lamps are not economical.
-When relamping, replace 40-watt fluorescent lamps with 35-watt lamps to achieve a reduction in lighting level of approximately 18%, while saving 20% in fixture electrical energy.

USE MORE EFFICIENT BALLASTS

-When ballasts burn out, replace with the following:

For fluorescent lights, 430 milliampere, replace low power factor high-watt ballasts with high power factor (90% or more), low-watt ballasts. (Circuits with 50% power factor ballasts have 240% more energy losses in wiring than those with 90% power factor ballasts).

RELAMPING CHANGES TO INCREASE LIGHTING EFFICIENCY WITHOUT MODIFICATIONS TO LUMINAIRES OR BALLASTS

(All lamps operating at 120 volts)

Incandescent Lamps

Present Light Source | Replacement Light Source

Watts	Lamp Description	Lamp Volts	Lumens @ Socket Volts	Watts @ Socket Volts	Hrs. Life @ Socket Volts	Watts	Description	Lumens	Hours Life	Reduction in Watts
40	40 A/99	130	323	35	7,000	25	25 A	235	2,500	10
60	60 A/99	130	597	53	7,000	40	40 A	455	1,500	13
						40	40 A/99	420	2,500	13
75	75 A/99	130	770	66	7,000	54	54 A	775	3,500	12
						55	55A	670	2,500	11
						60	60 A	870	1,000	6
						60	60 A/99	775	2,500	6
100	100 A/99	130	1,147	88	7,000	75	75A/99	1,190	750	13
100	100 A21/99	130	1,109	88	7,000	75	75 A/99	1,000	2,500	13
150	150 A23/99	130	1,779	132	7,000	90	90 A	1,290	3,500	42
150	150/99	130	1,771	132	7,000	92	92 A	1,490	2,500	40
						100	100 A	1,750	750	32
						100	100 A/99	2,500	1,490	32
150	150 R/FL	120	1,870	150	2,000	75	75PAR/FL	765	2,000	75
150	150PAR/FL	120	1,740 ea	150 ea	2,000	250	Q 250 Par38	3,220	3,000	50
200	200 A/99	130	2,626	176	7,000	150	150 A	2,880	750	26
200	200/99 IF	130	2,510	176	7,000	150	150 A23/99	2,310	2,500	26
				135		135	135A	2,100	3,500	41
				41		138	138 A	2,300	2,500	38
						160	HSB160/SS/M	2,700	20,000	16

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fig 31

Incandescent Lamps

Present Light Source						Replacement Light Source				
Watts	Description	Lamp Volts	Lumen @ Socket Volts	Watts @ Socket Volts	Hrs.Life @ Socket Volts	Watts	Description	Lumens	Hrs. Life	Reduction in Watts
60	60/99IF Extendel Service	120	740	60	2,500	54	54/99IF Extended Service	645	2,500	6
60	60A19/35 Industrial Service	120	670	60	3,500	54	54A19/35 Industrial Service	590	3,500	6
100	100/99IF Exten-Ded Service	120	1,480	100	2,500	90	90/99IF Extended Service	1230	2,500	10
100	100A21/35 Extended Service	120	1,280	100	3,500	90	90A21/35 Extended Service	1090	3,500	10
150	150A/99IF Extended Service	120	2,350	150	2,500	135	135A/99IF Extended Service	1990	2,500	15
150	150A25/35 Industrial Service	120	2,150	150	3,500	135	135A25/35 Industrial Service	1790	3,500	15
300	300	120	4,900	300	3,000	250	250PS-35 Self-Ballasted Mercury	4800	11,000	50
1000	1000	120	18,300	1000	3,000	750	750R-57 Self-Ballasted Mercury	17650	15,000	250
1500	1500	120	28,400	1500	3,000	1,250	1250 Bt-56 Self Ballasted Mercury	38000	15,000	250

Figure 31, continued

Incandescent Lamps

Present Light Source						Replacement Light Source				
Watts	Lamp Description	Lamp Volts	Lumens @ Socket Volts	Watts @ Socket Volts	Hrs. Life @ Socket Volts	Watts	Description	Lumens	Hours Life	Reduction in Watts
300	300 M/99 IF	130	3,996	264	7,000	200	200A	4,010	750	64
300	300/99 IF	130	3,996	264	7,000	200	200A/99	3,410	2,500	64
						300	HSB 300/SS/M	7,800	20,000	0
300	300	120	5,820	300	1,000	300	HSB 300/SS	7,800	20,000	0
500	500/99 IF	130	6,984	440	7,000	300	HSB 300/SS	7,800	20,000	140
500	500/99 IF	120	9,070	500	2,500	450	HSB 450/SS	9,500	16,000	50
750	750/99	130	10,934	660	7,000	500	500	10,850	1,000	160
						500	500/99	9,070	2,500	160
						450	HSB 450/SS	9,500	16,000	210
750	750 R 52	120	13,000	750	2,000	750	HSB 750R/120	14,000	16,000	0
1,000	1,000/99	130	15,246	880	7,000	750	750	17,040	1,000	130
						750	750/99	14,200	2,500	130

Incandescent Lamps

Present Light Source				Replacement Light Source				
Watts	Description	Beam Candle-power	Hrs. Life	Watts	Description	Beam Candle power	Hrs. Life	Reduction in Watts
100	Reflector Floodlight R-40	800	5,000	75 PAR-38	Projector Floodlight	1,430	5,000	25
150	Reflector Floodlight R-40	1,200	5,000	100PAR-38	Projector Floodlight	2,230	5,000	50
150	Reflector Floodlight R-40	1,200	5,000	75 PAR-38	Projector Floodlight	1,430	5,000	75
150	Reflector Floodlight R-40	1,200	5,000	100 BR-40	Floodlight	1,200	5,000	50
200	Reflector Floodlight R-40	1,600	5,000	150PAR-38	Projector Floodlight	3,450	5,000	50
300	Reflector Floodlight R-40	2,450	5,000	200PAR-38	Projector Floodlight	4,560	5,000	100
500	Reflector Floodlight R-40	3,600	5,000	250PAR-38	Projector Floodlight	5,850	5,000	250

Figure 31, continued

Incandescent Lamps

Present Light Source				Replacement Light Source				
Watts	Description	Color	Lumens	Watts	Description	Color	Lumens	Reduction in Watts
40	F40T12-48"	CW	3150	34	F40/RS/EW	CW	2800	6
40	F40T12-48"	WW	3200	34	F40/RS/EW	WW	2900	6
75	F96T12Slim line	CW	6300	60	F96T12/EW	CW	5220	15
75	F96T12Slim line	WW	6400	60	F96T12/EW	WW	5340	15

Figure 31, continued

High Intensity Discharge Lamps

Present Light Source					Replacement Light Source					
Watts	Description	Color	Lumens	Hours Life	Watts	Description	Color	Lumens	Hours Life	Reduction in Watts
400	Mercury Vapor H33CD-400	Clear	21,000	24,000	300	Mercury Vapor H33CD-300	Clear	14,000	16,000	100
	H33G1-400/DX	Deluxe White	23,000	24,000	300	H33GL-300/DX	Deluxe White	15,700	16,000	100
400	Mercury Vapor		23,000	24,000	360	High pressure sodium		34,200	12,000	40
175	Mercury Vapor		8,500	24,000	150	High pressure sodium		12,000	12,000	25

SECTION 4-G

POWER

INDEX

POWER

A. BACKGROUND

The amount of electric power used within a building - measured in kilowatt hours (kwh) - depends upon (1) the demands of the systems which use power to supply the "building" load (lighting, heating, ventilating, cooling, domestic hot water, commercial refrigeration, elevators, escalators, business machinery, communications systems, cooking, snow melting and other processes), (2) the power losses of the conversion and distribution systems which supply those loads, and (3) the characterisitics of the electric service and distribtuion systems. The opportunities to reduce "building" and "parasitic" distribution loads have been detailed in other sections. As an example, when the quantity of water or air circulated in a HVAC system is reduced, less power is needed to drive fans and pumps and, accordingly, it is possible to reduce annual energy consumption even further. Improper distribution voltage, low power factor, transformers at inefficient loading points, losses from standby transformers, excessive operation of motors and equipment, improper control and low load factors of motors, and excessive voltage drop in undersized conductors or wiring are the major causes of the waste of electric energy. Reducing the kWh of electricity used by the building reduces the consumption of raw source energy (the amount of energy required to generate electricity at the power plant) by a factor of more than three. The boiler and generator losses at the power plant and transmission and distribution losses from the plant to the building account for about 70% of the energy used in generating electricity. Nationally, conserving electrical energy helps to conserve oil, gas, and coal supplies which are consumed in the generation of electricity at fossil-fueled power plants and in the mining and processing of uranium for nuclear plants.

Before changing or adjusting equipment or operating procedures, and if building personnel are inexperienced or not qualified to implement any options which are chosen, consult an electrician or electrical engineer to analyze the proposed changes and perform the work.

B. ENERGY CONSERVATION OPPORTUNITIES

ECO 37 REDUCE OPERATING TIME OF ELEVATORS AND ESCALATORS

The amount of power required annually to operate an elevator is a function of the height of the building, the number of stops, passenger capacity and load factors, and the efficiency of the hoisting mechanism. For example, a 2,500 lb. capacity "local" elevator making 150 stops per car-mile consumes about 5 kwh per car-mile, while an "express" elevator making 75 stops per car-mile consumes about 4 kwh. A 4,500 lb. capacity elevator in a 12-story department store stopping at every floor will use 13 kwh per car-mile. Consumption will vary between elevators of the same capacity depending on the type of hoisting motor and control, whether the elevator is hydraulic, geared or gearless and the kind of service and the amount of load offset by the counterweight. Select speeds that are as slow as possible, while keeping maximum waiting time to no more than 2 minutes. Seek the assistance of the elevator manufacturer or a consulting engineer to study the traffic patterns and to reschedule as necessary. Where multiple elevators are installed reduce the number in service during light traffic periods.

Assuming 35% equivalent full load operation, escalator energy consumption may vary from 1.3 kw per hour for a 32-inch wide model operating at 90 feet per minute with a 14-foot vertical rise, to . 3.0 kw per hour for a 48-inch wide model operating at 90 feet per minute with a 25-foot vertical rise. Escalators consume energy whether they are carrying passengers or not.

ECO 38 REDUCE ENERGY CONSUMPTION FOR EQUIPMENT AND MACHINES

Most buildings contain many electrically driven machines which are left switched on and idling but which are used only for short periods of time or when the building is occupied. Make an inventory of all office and business machines, convenience machines etc., and determine their true periods of use. Install time clocks to control machines such as automatic vendors. Encourage typists and clerks to turn off electric typewriters, desk calculators etc. when not actually in use.

ECO 39 REDUCE PEAK LOADS

Utility rate structures are based not only on the building's total usage of electricity, but also on its peak demand - which may occur for only a few hours once or twice each year, but which establishes demand charges for the rest of the months. Institute a thorough load shedding program to assign levels of priority to the equipment in the building. Manually shut off some of the equipment with large motors during periods of high electrical usage to reduce peak demand, save on operating costs, and conserve energy. Practiced on a large scale, load leveling reduces the peak demand of the generating plant and lessens the chance of brownouts, blackouts, and low voltage problems.

Consult with the utility which serves the building to analyze the rate structure and to determine when the peaks occur and how they can be reduced. The loads shed most readily include electric water heaters, domestic hot water circulators, air conditioning refrigeration units, large pumps, noncritical lighting, and elevators.

ECO 40 REDUCE TRANSFORMER LOSSES

Transformers reduce transmission and distribution voltage to equipment operating voltage. Heat generation and dissipation, due to electrical resistance in the transformer, results in electrical energy losses. Even when equipment served by the transformer is inoperative, some energy is lost unless primary power to the transformer is switched off. When the transformer serves loads which are not required for relatively extensive periods of time, complete disconnection from the primary power may be feasible. Take care, however, to avoid disconnecting transformers that feed clocks, heating control circuits, fire alarms, or critical process equipment. Potential savings are 3 to 4 watts per kilovolt amp (KVA).

Example:

Switch off a 150 KVA transformer for 12 hours/week-day at night, and 48 hours over the weekend (or a total of 108 hours/week and 5616 hours/year). Assuming savings of 4 watts per KVA, energy saved in one year will be:

4 watts/KVA x 150 KVA x 5616 hours = 3,369,600 watt hours or approximately 3370 kwh.

At an electricity price of 4¢ kwh, savings will be:
3370 kwh x 4¢/kwh = $135.80

ECO 41 IMPROVE THE EFFICIENCY OF MOTORS

Because original load calculation estimates are usually conservative, and when loads have been reduced through conservation measures, most motors are oversized for the equipment load they are serving. If the ratio of the motor loading to the motor's horsepower rating is small, the power factor will be low and the motor will operate inefficiently.

Undertake a comprehensive study of all the motors in the building to determine their load factors.

Gather and record the following information:

1. The equipment served by the motor.

2. The motor nameplate information for each motor, including: brand, type, frame, horsepower, speed or speeds, voltage phases and frequency, mounting, full load rating.

3. Measure with an ammeter and record the full load running current of each phase leg.

4. Measure with voltmeter and record the voltage at the motor when measuring running current.

5. Record pully size and type, i.e. V belt, chain, etc.

Find motor loading by multiplying the current draw, as recorded in item 3, above, by the voltage, item 4, and then dividing by 1000 to convert to kilowatt input. Convert nameplate H.P. rating (item 2) to kw by multiplying H.P. by 0.746. Then take the ratio of actual input to nameplate rating to determine the load factor on the motor.

Motors that are not loaded to at least 60% of their potential are relatively inefficient and reduce the power factor of the entire electrical system. Exchange underloaded motors with others on the premises to achieve as close to full loading on each motor as possible. If a motor needs replacement, consider interchanging motors then, too. For equipment which cycles on and off at short intervals heat build-up is a less critical problem than in other cases. The motor service factor establishes the maximum overload possible without exceeding the motor's temperature rating. Utilize this information (available through the manufacturer) when in the process of exchanging and interchanging the motors currently in use, and, for cycling equipment, select smaller motors, rated slightly below maximum load requirements and allow some overloading to occur.

Small split-phase or shaded-pole motors, often used in perimeter fan coil units, have low power factors and are inefficient. Turn off these motors during mild winter nights to permit the fan coil to operate by natural convection.

When evaluating the potential for larger savings, compare the cost of replacing inefficient motors with the savings in electrical operating cost which would be achieved with new motors. Refer to ECM 2 for procedure.

GUIDELINES TO REDUCE ENERGY USED FOR POWER

REDUCE ELEVATORS AND ESCALATOR OPERATION

- -Reduce the number of elevators in service during hours when majority of persons are not leaving or entering the building.
- -Turn off the motor-generator set located in the elevator machine room when not in use - nights, week-ends, holidays and slack periods during the day.
- -Turn off escalators to unoccupied floors of offices or retail store floors during renovations.
- -Operate demand escalators only during peak periods
- -Reduce speed of escalators and elevators.
- -Where security arrangements permit, encourage employees to walk up and down one flight of stairs rather than to use vertical transportation systems.
- -Consider turning off all down escalators during periods of light traffic.
- -Consider turning off up escalators on alternate floors during periods of light traffic.

REDUCE ELECTRICAL APPLIANCE AND MACHINERY OPERATING TIME

Turn off:

- -Coffee pots and food warmers when not in use.
- -Refrigerated drinking fountains at the end of normal business hours.
- -Refrigeration units (and consider disconnecting units at all times).
- -Vending machines at the end of the week where food spoilage is not a problem. Use time clock to turn on the vending machine in time for the soft drinks to reach 45°F. by Monday morning at employee arrival time.
- -Portable electric heaters, portable fans, typewriters,

calculators, and reproduction machines when not in use.
- Automatic window displays and revolving signs at the end of normal business hours (and consider further reductions in operating time).
- Electric heat tracing when there is no fluid flow in pipes and when the outdoor temperature is above freezing.
- Elevator fans where smoking is not permitted and where applicable codes allow.

Discourage Excessive Use of Equipment:

- Encourage employees to go to the cafeteria or canteen for coffee breaks rather than operating coffee percolators in offices.
- Encourage chefs to preheat ovens no earlier than neccessary and to forego preheating completely except for baked goods.
- Consider reducing the number of electrically powered business machines in use.
- Insulate cooking equipment in kitchens, when possible.
- Prohibit use of portable electric heaters and encourage employees to move to a different location on the floor. if drafts or cold radiation from windows are causing them discomfort.
- Where practical, substitute manual labor for electrical power, such as using manual labor to remove snow and ice rather than electric resistance snow melting systems.

REDUCE TRANSFORMER LOSSES

- De-energize transformers supplying unused offices or other areas.
- De-energize refrigeration chiller transformers during the heating season.
- De-energize heating equipment transformers during the cooling season.
- Where there is a bank or two or more transformers, operate transformers at the most efficient loading point.
- Reduce copper losses in the wiring - which increase with ambient temperature - by ventilating transformer vaults to reduce the ambient temperature.
- Shade outdoor transformer banks from solar radiation.
- De-energize dry type transformers serving convenience outlets when there is no load - at night and during weekends and holidays.

INCREASE MOTOR EFFICIENCY

Tighten belts and pulleys at regular intervals to reduce losses due to slip.
Lubricate motor and drives regularly to reduce friction.
Replace worn bearings.
Check alignment between motor and driven equipment to reduce wear and excessive torques.
Keep motors clean to facilitate cooling.
When replacing worn or defective motors, replace with motor sized as close to load as possible, and use the highest efficiency motor available.
Where it is impracticable to replace motors which have low load and power factors, use capacitors at motor terminals to correct the power factor to 90%.

APPENDIX A
COST INDICES

For the purpose of this study, nine cities have been considered as follows: New York, Chicago, Houston, Phoenix, Miami, Seattle, Los Angeles, Denver and Atlanta.

Labor rates, including fringes, as of January 1975 were tabulated for certain selected trades, which were likely to be used for the type of work envisaged in the study and using New York City as base 100, the relative labor index for the respective cities was calculated.

A list of basic materials was compiled and current prices for the items secured from suppliers in the respective cities, and again, using New York City as base 100, the relative material index was calculated.

On the assumption that labor/material content of construction is approximately 60/40 respectively, a relative combined cost index for the cities was calculated resulting in the following:

NEW YORK	100
CHICAGO	93
LOS ANGELES	93
MIAMI	89
PHOENIX	88
SEATTLE	82
DENVER	82
ATLANTA	80
HOUSTON	79

ESCALATION

Prices given for examples of work items in this volume are generally New York City area prevailing costs as of January 1975 (that is they have been calculated using materials and wages costs for the metropolitan area as of that date).

ESCALATION (Cont'd)

Continually increasing costs of both labor and material will rapidly outdate this information. The user is therefore advised to obtain updated local costs tailored to his specific work project by calling upon the services of a local professional consultant (Architect, Consulting Engineer, Cost Consultant) or general contractor.

Prior to taking this action however the user may wish initially to investigate the cost impact of any increase himself.

This may be done by consulting one of the professionally prepared construction cost indices such as those prepared by Boeckhs; F.W. Dodge Company; Marshall & Swift; Turner Construction Company or by consulting articles on cost escalation in trade journals such as Buildings; other building management journals and Engineering News Record.

The latter magazine, a McGraw-Hill publication (issued approximately every 8 to 10 days) would be available in the local technical library. Each issue contains a feature entitled "Construction Scoreboard" which details cost index data.

Using the Building cost index column the user can readily calculate the average percentage increase since January 1975 and multiply the adjusted example costs accordingly to establish an updated price.

APPENDIX B
ENERGY CONSERVATION EXAMPLE

A. ASSUMPTIONS:

OFFICE BUILDING CHICAGO ILLINOIS. Gross area per floor = 100' x 100' = 10,000 sq.ft., 10 stories (total gross floor area = 100,000 sq.ft.). Floor-to-floor height = 10 ft., 33% window/wall area ratio.

CONDITIONS BEFORE OPERATIONAL CHANGES:

Clear single glazing, U=1.1 Negligible interior shading assumed during heating season. Shading by curtains during cooling season, SC=.67. Wall U=0.3 (excluding glazed areas), roof U=0.2. Occupied 40 hours per week. Outdoor ventilation air = 19,800 cfm @ 30 cfm/person x 660 occupants. Average infiltration = 1/2 air change/hour. Interior heat gains: Light 4.0 w/sq.ft., Office equipment = 0.5 w/sq.ft., Fans = 1.0 w/sq.ft. Total = 5.5 w/sq.ft.

No cooling during unoccupied periods.

Indoor temperature = 75° heating season
75° cooling season = 50% RH

Domestic hot water flow rate = 2 gallons/day/person @ 140°F

B. SUMMARY OF ENERGY USED IN CHICAGO OFFICE BUILDING WITHOUT ENERGY-CONSERVING OPTIONS

1.	SITE ENERGY	BTU/sq.ft./yr.
	HEATING (OIL)	106,400
	COOLING (ELEC)	8,200
	LIGHTING	31,400
	POWER	10,600
	DOM. HOT WATER	4,000
	TOTAL	160,600

2.	RAW SOURCE ENERGY	BTU/sq.ft./yr.
	HEATING	106,400
	COOLING*	27,340
	LIGHTING*	104,660
	POWER*	35,330
	DOM. HOT WATER	4,000
	TOTAL	277,730

*The Figures for raw source energy reflect the energy conversion for electricity.

ANALYSIS OF ENERGY SAVINGS FOR CHICAGO OFFICE BUILDING

	ANNUAL SITE ENERGY SAVINGS	BTU SAVINGS PER SQ.FT./YR	% REDUCTION IN THIS SEGMENT OF ENERGY	% REDUCTION TOTAL ENERGY
HEATING				
12 deg. night setback	27,000 gal.#2 oil	38,000	35%	24.0%
7 deg. day setback	1,000 gal.#2 oil	1,400	1%	0.9%
Increase boiler efficiency by 10%	6,600 gal.#2 oil	9,200	9%	6%
Reduce outside air during occupied periods to 8 CFM/PSN	1,800 gal.#2 oil	2,500	2%	1.5%
Caulk windows	12,000 gal.#2 oil	16,700	16%	10.0%
* Add storm windows	26,000 gal.#2 oil	36,400	34%	23.0%
* Add night barrier (U=.1)	29,150 gal.#2 oil	40,000	38%	25.0%
Selected combinations:				
Increase boiler eff. 10% Plus 12° night setback	31,000 gal.#2 oil	43,000	40%	27.0%
Increase boiler eff. 10% Plus 7° day setback	9,000 gal.#2 oil	12,600	12%	8.0%
Increase boiler eff. 10% Plus caulk windows	17,800 gal.#2 oil	25,000	23%	15.5%
COOLING				
Economizer Cycle	47,700 KWH	1,600	20%	1%
Reduce lighting to 2.0 watts/sq. ft.	31,500 KWH	1,100	13%	0.7%
LIGHTING				
Reduce lighting to 3.0 watts/sq. ft.	226,000 KWH	7,700	25%	5.0%
Reduce lighting to 2.0 watts/sq. ft.	450,000 KWH	15,300	49%	9.5%
HOT WATER				
Lower water temperature to 100°F	1,070 gal.#2 oil	1,500	37%	1.0%
Reduce flow rate to 1 gal/PSN/DAY	920 gal.#2 oil	1,250	32%	0.8%
Combined 100°F temperature Plus reduced flow rate	1,990 gal.#2 oil	2,800	70%	2.0%

* Change requires some capital investment - See ECM 2

Note: For multiple changes the savings are not directly additive.

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GLOSSARY

Absorption Chiller	A refrigeration machine using heat as the power input to generate chilled water.
Absorption Coefficient	The fraction of the total radiant energy incident on a surface that is absorbed by the surface.
Absorptivity	The physical characteristic of a substance describing its ability to absorb radiation.
Ambient	Surrounding (i.e. ambient temperature is the temperature in the surrounding space).
Activated Carbon	A form of carbon capable of absorbing odors and vapors.
Air Changes	Expression of ventilation rate in terms of room or building volume. Usually air changes/hour.
Ballast	A device used in starting circuit for fluorescent and other types of lamps.
Blow Down	The discharge of water from a boiler or cooling tower sump that contains a high proportion of total dissolved solids.
British Thermal Unit (Btu)	A heat unit equal to the amount of heat required to raise one pound of of water one degree Farenheit.
Building Envelope	All external surfaces which are subject to climatic impact; for example, walls, windows, roof, floor, etc.

Building Load	Heating load is the rate of heat loss from the building at steady state conditions when the indoor and outdoor temperatures are at their selected design levels (design criteria). The heating load always includes infiltration and may include ventilation loss and heat gain credits for lights and people. Cooling load is the rate of heat gain to the building at a steady state condition when indoor and outdoor temperatures are at their selected design levels, solar gain is at its maximum for the building configuration and orientation, and heat gains due to infiltration, ventilation, lights, and people are present.
Cavity Ratio	Number indicating room cavity proportions, which is calculated using length, width, and height.
Centrifugal Chiller	A refrigeration machine using mechanical energy input to drive a centrifugal compressor to generate chilled water.
Centrifugal Fan	Device for propelling air by centrifugal action. Forward curved fans have blades which are sloped forward relative to direction of rotation. Backward curved fans have blades which are sloped backward relative to direction of rotation. Backward curved fans are generally more efficient at high pressures than forward curved fans.
Coefficient of Utilization	Ratio of lumens on a work plane to lumens emitted by the lamps.
Cold Deck	A cold air chamber forming part of a ventilating unit.
Condensate	Water obtained by changing the state of water vapor (i.e. steam or moisture in air) from a gas to a liquid usually by cooling.

Condenser	A heat exchanger which removes latent heat from a vapor changing it to its liquid state. (In refrigeration chillers the component which rejects heat.)
Conductance, Thermal	A measure of the thermal conducting properties of a single material expressed in units of Btu inch thickness per (sq. ft.) (hour) (degree F temperature difference)
Cooling Tower	Device that cools water directly by evaporation.
Damper	A device used to vary the volume of air passing through an air outlet, inlet, or duct.
Degree Day	The difference between the median temperature of any day and 65°F when the median temperature is less than 65°F.
Degree Hour	The difference between the median temperature for any hour and selected datum.
Demand Factor	The ratio of the maximum demand of a system, or part of a system, to the total connected load of a system or part of the system under consideration.
Desiccant	A substance possessing the ability to absorb moisture.
Direct Expansion	Generic term used to describe refrigeration systems where the cooling effect is obtained directly from the refrigerant (e.g. refrigerant is evaporated directly in a cooling coil in the air stream).
Disability Glare	Spurious light from any source, which impairs a viewer's ability to discern a given object.

Double Bundle Condenser — Condenser (usually in refrigeration machine) that contains two separate tube bundles allowing the option of either rejecting heat to the cooling tower or to another building system requiring heat input.

Dry Bulb Temperature — The measure of the sensible temperature of air.

Economizer Cycle — A method of operating a ventilation system to reduce refrigeration load. Whenever the outdoor air conditions are more favorable (lower heat content) than return air conditions, outdoor air quantity is increased.

Efficacy of Fixtures — Ratio of usable light to energy input for a lighting fixture or system (lumens/watt).

Energy Requirement — The total yearly energy used by a building to maintain the selected inside design conditions under the dynamic impact of a typical year's climate. It includes raw fossil fuel consumed in the building and all electricity used for lighting and power. Efficiencies of utilization are applied, and all energy is expressed in the common unit of Btu's.

Enthalpy — For the purpose of air conditioning enthalpy is the total heat content of air above a datum usually in units of Btu/lb. It is the sum of sensible and latent heat and ignores internal energy changes due to pressure change.

Equivalent Sphere Illumination — That illumination which would fall upon a task covered by an imaginary transparent hemisphere which passes light of the same intensity through each unit area.

Evaporator — A heat exchanger which adds latent heat to a liquid changing it to a gaseous state (In a refrigeration system it is the component which absorbs heat).

Foot-candle — Energy of light at a distance of one foot from a standard (sperm oil) candle.

Heat Gain — As applied to HVAC calculations, it is that amount of heat gained by a space from all sources, including people, lights, machines, sunshine, etc. The total heat gain represents the amount of heat that be removed from a space to main indoor comfort conditions.

Heat Loss — The sum cooling effect of the building structure when the outdoor temperature is lower than the desired indoor temperature. It represents the amount of heat that must be provided to a space to maintain indoor comfort conditions.

Heat, Latent — The quantity of heat required to effect a change in state.

Heat, Sensible — Heat that results in a temperature change but no change in state.

Heat, Specific — Ratio of the amount of heat required to raise a unit mass of material 1 degree to that required to raise a unit mass of water 1 degree.

Heat Pump — A refrigeration machine possessing the capability of reversing the flow so that its output can be either heating or cooling. When used for heating, it extracts heat from a low temperature source to the point where it can be used.

Heat Transmission Coefficient — Any one of a number of coefficients used in the calculation of heat transmission by conduction, convection, and radiation, through various materials and structures.

Hot Deck	A hot air chamber forming part of a ventilating unit.
Humidity, Relative	A measurement indicating moisture content or air.
Infiltration	The process by which outdoor air leaks into a building by natural forces through cracks around doors and windows, etc. (Usually undesirable)
Insolation	The amount of solar radiation on a given plane. Expressed in Langleys or Btu/ft.^{2}
Langley	Measurement of radiation intensity. One Langley = 3.68 Btu/ft.^{2}
Life Cycle Cost	The cost of the equipment over its entire life including operating and maintenance costs.
Load Leveling	Deferrment of certain loads to limit electrical power demand to a predetermined level.
Load Profile	Time distribution of building heating, cooling, and electrical load.
Lumen	Unit of luminous flux.
Luminaire	Light fixture designed to produce a specific effect.
Make-up	Water supplied to a system to replace that lost by blow down, leakage, evaporation, etc.
Manchester, New Hampshire Project	A demonstration building commissioned by GSA (Isaak and Isaak, Architects) and developed by Dubin-Mindell-Bloome Associates to incorporate energy conserving architectural features and mechanical and electrical systems.
Modular	System arrangement whereby the demand for energy (heating, cooling) is met by a series of units sized to meet a portion of the load.

Orifice Plate	Device inserted in a pipe or duct which causes a pressure drop across it. Depending on orifice size it can be used to restrict flow or form part of a measuring device.
Orsat Apparatus	A device for measuring the combustion components of boiler or furnace flue gases.
Piggyback Operation	Arrangement of chilled water generation equipment whereby exhaust steam from a steam turbine driven centrifugal chiller is used as the heat source for an absorption chiller.
Power Factor	Relationship between KVA and KW. When the power factor is unity, KVA equals KW.
R-Value	The resistance to heat flow expressed in units of Sq. Ft. hour Degree F/Btu.
Raw Source Energy	The quantity of energy input at a generating station required to produce electrical energy including all thermal and power conversion losses.
Roof Spray	A system that reduces heat gain through a roof by cooling the outside surface with a water spray.
Seasonal Efficiency	Ratio of useful output to energy input for a piece of equipment over an entire heating and cooling season It can be derived by integrating part load efficiencies against time.
Software	Term used in relation to computers normally describing computer programs and other intangibles.
Sol-air Temperature	The theoretical air temperature that would give a heat flow rate through a building surface equal in magnitude to that obtained by the addition of conduction and radiation effects.

Ton of Refrigeration	A means of expressing cooling capacity - 1 ton = 12,000 Btu/hour cooling.
'U' Value	A coefficient expressing the thermal conductance of a composite structure in Btu per square foot hour degree F temperature difference.
Veiling Reflection	Reflection of light from a task, or work surface, into the viewer's eyes.
Vapor Barrier	A moisture impervious layer designed to prevent moisture migration.
Wet Bulb Temperature	The lowest temperature attainable by evaporating water in the air without the addition or subtraction of energy.

ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
BTU	British Thermal Unit
BTU'S X 10^6	Millions of Btu's
BTU'S X 10^3	Thousands of Btu's
CFM	Cubic ft. per minute
COP	Coefficient of performance
CU	Coefficient of utilization
DB	Dry bulb temperature
DX	Direct Expansion
ESI	Equivalent Sphere Illumination
IES	Illuminating Engineers Society
HID	High intensity discharge (lamps)
HZ	Hertz
HVAC	Heating, Ventilating and Air Conditioning
KVA	Kilovoltampere
KWH	Killowatt hour
O.A.	Outside air
P.F.	Power Factor
PSI	Pounds per square inch
SQ. FT.	Square foot
TD	Temperature difference
TE	Total Energy (system)
WB	Wet bulb temperature

INDEX

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TABLE OF CONTENTS

GPO 904-391