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NBS TECHNICAL NOTE 789

Technical Options For Energy Conservation In Buildings

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[2] Part of the Center for Radiation Research.

[3] Located at Boulder, Colorado 80302.

[4] Part of the Center for Building Technology.

Technical Options For Energy Conservation In Buildings

National Conference of States on
Building Codes and Standards

and

National Bureau of Standards
Joint Emergency Workshop on
Energy Conservation in Buildings

Held at the

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Prepared by

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

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U.S. DEPARTMENT OF COMMERCE, Frederick B. Dent, *Secretary*

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, *Director*

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FOREWORD

In late May 1973, the Office of Building Standards and Codes Services of the Center for Building Technology, National Bureau of Standards was approached by the National Conference of States on Building Codes and Standards with a request that the Bureau assist the States in preparing a workshop in energy conservation in buildings. Specifically, the Bureau was asked to identify measures that State officials could responsibly recommend to their Governors, many of whom had initiated conservation actions in anticipation of an energy crisis they felt to be imminent. The workshop was held on June 19, 1973; the material reproduced in this Technical Note was among the items distributed at the workshop to State, local and Federal Government officials as well as industry representatives and members of the press.

The staff of the Building Environment Division of CBT was called upon to prepare this document under the pressure of this urgent deadline. They drew upon the expertise of Bureau staff members, on the technical literature and on contributions of many colleagues in industry and other agencies of government.

No technical effort undertaken in so short a time can be accomplished without raising some question of technical and economic controversy. This is particularly true in the present case in that scientifically valid answers have yet to be obtained for many of the facets of energy use and conservation in buildings. For example, the concept of human comfort is exceedingly difficult to deal with quantitatively.

Therefore, this document should be read by all with this understanding: the technical options presented herein should be considered as a basis of reference for considered professional judgment.

For those who need technical guidance now, it is hoped that this document will be of practical use.

James R. Wright

James R. Wright, Director
Center for Building Technology
Institute for Applied Technology
National Bureau of Standards

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INTRODUCTION

The purpose of this report is to provide reference material on the technical options for energy conservation in buildings. It has become increasingly evident in recent months that available energy reserves may be inadequate to meet peak energy demands in the United States this summer and possibly over the next few years. Actions relating to energy conservation are needed which will impinge on two important aspects of this "energy crisis." These are a near-term shortage of fossil fuels, and the threat of brown-outs and blackouts resulting from excessive peak demands for electricity.

Principal uses of energy in the U. S. are indicated on Figure A.*[1/] Automobiles account for 68% of the transportation sector or about 17% of total annual energy consumption. Widely publicized efforts are currently underway to reduce this level through reduction of the amount of traffic and maximum speeds of automobiles on the nation's highways. The industrial sector is the dominant user of fuel energy in the U. S., 41.2% of the total. Of this, nearly 40% is used for process steam and 28% is used as direct heat. It is not clear how much energy use could be reduced in this sector. However, if substantial savings in energy use can be achieved in the residential and commercial sector these actions could significantly reduce the impending shortages.

To determine how much impact energy conservation actions in buildings could have it is essential to understand patterns of energy use in buildings. Figure B[1/] shows the principal uses of energy in buildings. Note the dominant

*Numbers refer to references listed at end of text.

role of space heating, which occurs, of course, mostly in the winter months. Summer loads of residential and commercial buildings consist primarily of air conditioning -- an estimated 56% of the summer load for commercial buildings and 30% for homes and apartments. Therefore, these are the most logical targets for concerted energy saving efforts. Also, it is important to note the interdependence of these various types of load. As will be shown in some detail in subsequent sections of this report, actions in any one of these areas are likely to influence energy use in others and often beneficially.

An estimate of the potential energy savings achievable through actions in the residential and commercial sector is presented on Figure C. These potential savings are expressed as percentages of U. S. total annual energy use. For this estimate for existing buildings it is assumed that summer cooling and winter heating loads could be reduced 30% and 40%, respectively. In the absence of any other basis for estimating the extent to which such measures would be adopted and when, it has been assumed that just 10% of these savings would actually be achieved.

For new buildings a wider range of energy saving options is available. Again in the absence of data on public and industry response to such measures, it has been assumed for this estimate that just 10% of new buildings each year would be impacted to this extent.

In summary, it would appear that these potential savings in the residential and commercial sector may have the same order of magnitude as potential energy savings in the transportation sector.

The balance of this report presents the details of the technical options which give rise to these estimates.

Actions pertinent to existing and new buildings are considered separately. In each of the three major portions of the chapter dealing with existing buildings -- i.e., summer cooling, winter heating, and other energy conservation features -- actions which can be accomplished voluntarily or without expense are considered separately from actions which require some modest effort or expense on the part of the building occupant or owner. Throughout this report, emphasis has been placed on technical options. Economic implications of such options have not been detailed.

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BASIC PATTERN OF ENERGY USE

TRANSPORTATION	25.2%
INDUSTRIAL	41.2%
RESIDENTIAL & COMMERCIAL	33.6%
	100%

Figure A.

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OF THE 33.6% RESIDENTIAL & COMMERCIAL

by type of use . . . . .

SPACE HEATING	53
WATER HEATING	12
AIR CONDITIONING	8
REFRIGERATION	7
LIGHTING	5
OTHER ELECTRICAL	5
COOKING	4
CLOTHES DRYING	1
MISC.	5
	100%

Figure B.

Center for Building Technology

POTENTIAL ENERGY SAVINGS AS % OF TOTAL ANNUAL ENERGY USE through action in RESIDENTIAL & COMMERCIAL SECTORS

- EXISTING BUILDINGS (SHORT TERM) — 1% OF ANNUAL TOTAL

  ASSUMING .... SUMMER COOLING (30%)
  WINTER HEATING (40%)

  10% OF BUILDINGS AFFECTED

- NEW BUILDING (AT END OF 10 YEARS) — 3% OF ANNUAL TOTAL

  ASSUMING .... ON ORDER OF 40% SAVINGS IN NEW BUILDINGS

  10% OF NEW BUILDINGS AFFECTED /YEAR

Figure C.

Summer Cooling
Existing Buildings
With and Without Extra Cost

Opening Statement

Use of summer cooling systems provides a worthwhile investment both in dollars and in energy for improvement in working conditions and quality of life which is not subject to debate because of the current recognition of energy utilization concern. The need, however, is evident to reduce the energy consumption to provide summer cooling, by improving the energy performance of cooling systems, by reducing the loads imposed on cooling systems, and by conscientiously reassessing the levels of cooling needs. The total use of energy for cooling will continue to increase - our objective is to reduce the relative requirement for each essential cooling system, existing or new, in order that the service rendered by such systems will continue to serve people. Even though the energy used for residential and commercial summer cooling is less than 3 percent of the national annual total it is 42 percent of the summer total for these types of buildings, and it does represent an annual national energy expenditure of more than 1.5×10^{15} Btu* (in 1968 and increasing at 10 percent per year)[1/]. If it is assumed that wasteful cooling system practices can be improved by implementation of the techniques to the extent presented here, then it is reasonable to expect that the energy requirement can be reduced as much as 30 percent over present rates,

*Patterns of Energy Consumption in the United States.

in many cases without sacrificial reduction of needed performance. In many cases the actual performance of systems can be improved at the same time that both dollar cost and energy cost is lowered.

Some of the suggestions to be made in our presentation today can be implemented with little or no cost. Others would require investment of materials or equipment and labor. Not all of these modifications have had broad experience because traditionally buildings have been constructed with primary concern for first cost, and some of the devices may not have an early payback in dollars although they can be expected to accomplish the energy reduction tasks. It is our hope that the necessary field and laboratory work will be done to evaluate these suggestions and determine other means to conserve our valuable energy resources.

Many of the suggestions for reworking existing systems and designing new systems can best be utilized by considering the investigation of all elements. This integrated design can best be done by professional engineers, architects and designers.

Summer Cooling
Existing Buildings
No Extra Cost

o Reduce use of cooling systems

Turn off cooling systems not actually needed for people or essential processes. Many cooling systems either in total or in part provide cooling in spaces which do not need cooling. These could be eliminated with little or no sacrifice. Examples of these areas are entrances, halls, storerooms and other such spaces which people use either infrequently or for only short periods.

Turn off cooling systems at all times when spaces are unoccupied. Many spaces are unnecessarily cooled continuously throughout periods of non-occupancy, for example homes and apartments unoccupied all day, meeting rooms, auditoriums, etc. which are used only occasionally. If cooling cannot be turned off completely during periods of non-occupancy, set thermostats (and humidistats) at the highest setting on the controls.

Turn off cooling systems in parts of buildings not in use. To facilitate this many buildings could have the occupancy schedules arranged to group light load uses in one wing, or on one floor rather than scattered throughout the entire building.

The energy reduction to be obtained by turning off systems will, of course, be determined by the extent to which these steps apply to a particular building. It is estimated that, on the average, this could reduce energy usage by 5 to 10 percent.

o Raise thermostat and humidistat settings

Thermostat settings of 75°F or lower are not uncommon, in fact, may be prevalent, for summer cooling operation. In systems with humidity control space humidity of 50% is a customary design. Recent studies show that, with suitable clothing, temperatures approaching 80°F and humidities approaching 60% R.H. may be acceptable.

Raising thermostat settings to 80°F and humidistat settings to 60% R.H. could reduce energy demand by an estimated 15% compared with operation at 75°F and 50% R.H. (Note: In some reheat systems internal operating temperatures must also be raised, along with thermostat settings, to effect the desired energy savings.)

Many systems because of poor zoning, poor distribution, improper location of controls, or improper control function, may actually operate at temperatures below desired levels. Adjusting and balancing such systems will reduce the energy requirement to the extent that overcooling is eliminated.

Humidity controlling systems, particularly those which use reheat, present opportunity to reduce energy usage by raising the humidistat to the highest acceptable setting. These systems operate to control humidity by cooling the air to remove moisture, then reheating as necessary to maintain the desired room temperature. Most of these systems use "new" energy such as electricity, steam or hot water for the reheating operation.

Even systems which use "recovered" heat (normally discarded) will use less energy if the humidistat setting is set at the highest acceptable level.

o Reduce cooling loads

Turn off or reduce to the lowest acceptable level all lights and heat-releasing appliances. Lighting, particularly contributes heavily to the cooling load of offices and commercial buildings. Encourage use of high - efficiency lighting at the point of actual work and minimize excessive general lighting. Reducing internal lighting saves energy in two ways: (1) reduction of the energy to operate the light, and (2) reduction of the load on the cooling system because the light energy is no longer released into the space. In some of the commercial buildings, lighting loads may be 50% of the total load. In homes, lights and appliances (TV sets, fans) increase the cooling load and should be turned off when not actually needed. Optimize use of natural light.

Minimize use of major heat producing devices or appliances whenever possible during periods of operation of the cooling system, or at least during periods of peak load operation of the cooling system. Peak load power plant operation is usually much less efficient than normal load application.

Use stove and oven ventilation hoods - the cooling load of the makeup air required by the hoods will probably be less than the heat release of the cooking operation. Avoid excessive cooking during the hottest weather.

To accomodate the higher temperature settings, encourage use of informal lightweight clothing.

In homes, turn off furnace pilots during the cooling season when practical. It is recognized that the service system for turning on pilot lights for winter may be taxed after the first cold night.

Reduce excessive ventilation. Cut back forced ventilation to minimum acceptable levels and operate ventilation systems only when necessary. Minimize infiltration by keeping all doors and windows closed during operation of the cooling system. Leave storm doors and windows in place during the cooling season. Seal off or close all unused chimneys and other unneeded vents.

Minimize solar loads. Shade all windows exposed to direct sunlight. Use light colored or reflective shades. Close venetian blinds.

Utilize outdoor air for cooling whenever possible. In homes opening doors and windows and placing fans in selected locations to draw air through the building can provide interior comfort when the outdoor air is just a few degrees cooler than the desired indoor temperature. In apartments, office and commercial buildings use of outdoor air for successful comfort cooling is more difficult to accomplish because of the lack of through paths for the air, lack of screens, non-openable windows, etc. Normal air ducts generally do not move sufficient air for cooling unless the supply air is at least 15 degrees below desired indoor temperature.

o Maintain cooling systems and components in clean condition and in good working order

Keep cooling system components such as coils, blowers, and especially filters, clean. Maintain entire system in good condition. It is difficult to quantify the energy cost for allowing cooling systems to operate in poor mechanical conditions. It is reasonable to estimate that a general energy reduction of 10 percent could be realized if a cooling system is kept clean and in good operating condition compared to operating that same system with dirty heat transfer surfaces, dirty filters and improper mechanical conditions.

Summer Cooling
Existing Buildings
With Extra Cost

Suggestions in this section are those which can be implemented with investments of money, equipment and labor. Suggestions in the previous section which required little or no investment should also be considered in support of the suggestions in this section.

Implementation of some of these procedures can result in lower overall dollar costs and energy requirements for providing normal cooling services than many existing systems designed prior to recognition of the urgent need to conserve energy and those designed with only first costs in mind. It is also possible that implementation of some effective energy-saving systems may not provide early dollar payback. Detailed long-term or "life-cycle" energy and dollar cost analysis should be made for all major new or modified cooling systems.

o Reduce the cooling load.

Reduce heat transmission through the building exterior

(1) by adding or installing effective insulation [criteria for determining adequate insulation effectiveness will be discussed by others later in this presentation as will other features relating to basic design.] Many buildings have inadequate insulation and the various techniques for adding insulation should be investigated.

(2) by reducing glass area and by installing insulating glass (or storm) windows and doors. Replace high conductive window frames with those of lower conduction values.

(3) by installing exterior solar shading devices, such as awnings, wings, balconies, trees, etc, to shield windows and walls from direct solar heating. Paint exterior surfaces in light colors and install light colored roofing.

(4) by insulating and ventilating attics and roof crawl spaces to reduce top floor cooling load. Hot ceilings on top floors of buildings not only require more cooling because of the heat flow downward, they actually require lower air temperatures to compensate for the radiant heat emanating from the ceiling surface. In homes, even those with ceiling insulation, thermostat controlled attic ventilating fans will reduce the interior cooling load sufficiently to more than offset the energy required for fan operation. Such fans can also be used to provide cooling by outside air through the house at night if proper air flow dampers or other devices are installed.

Install additional zone controls to permit selective use of cooling systems in only those areas of a building actually in use at a given time. Such additional zoning control should provide means for turning off cooling in unused areas in addition to providing selected levels of control during occupancy periods.

Reduce lighting loads by installing more efficient lighting fixtures sized to meet task plane needs. Avoid excessive general lighting by deactivating certain fixtures, or installing lower wattage elements. Install ventilated or water cooled light fixtures to remove a major part of the cooling load from the lights by cooling means other than the space cooling system. Keep light fixtures clean to avoid need for extra fixtures.

Establish schedules and provide automatic means for turning off lights, ventilating fans and cooling systems to match actual demand needs. Scheduling of activities in buildings to use one wing or one floor during light occupancy can facilitate establishing an optimum building use pattern.

Install automatic pilots in all heat operated devices in the conditioned spaces, particularly furnaces, gas clothes dryers and even stoves in homes.

Reduce unnecessary ventilation by installing suitable interior air filtering (odor and particulate) devices to lower the need for outside air. Ventilation air loads are a major portion of most cooling systems. If ventilation cannot be reduced install heat recovery devices (such as thermal wheels, heat pipes, "run-around circuits," etc.) to salvage the cooling effect in the exhaust air.

Reduce infiltration by repairs to the building such as caulking windows, weatherstripping doors, sealing penetrations and points, installing revolving doors and automatic door closures, etc.

o Improve cooling system efficiency

Eliminate reheat systems (for humidity control) which require "new" heat for the reheat function - convert to heat recovery systems (commonly referred to as "run-around" or bootstrap systems) which utilize the heat rejected from the cooling system for reheat.

Install equipment when needed for replacement or new uses, which has optimum energy-use characteristics. For example cooling units can be obtained with a wide range of effectiveness. In selecting new equipment conduct "life-cycle" energy-use analysis to determine which system will require the least total energy use. Consider all possible combinations of equipment/ building characteristics, particularly those with heat recovery features.

Install short-term (one- or two-days) heat storage equipment where applicable. For example, some buildings require cooling during part of a day, and heating part of a day - a heat storage system will permit storing some of the heat normally rejected during cooling and make it available for heating use during the night.

In all buildings which have separate heating/cooling systems, install control means to assure that simultaneous operation is either eliminated or minimized. In many buildings overlap or duplication of heating/cooling system operation occurs without being detected. A detailed analysis of the building systems characteristics will identify the possible areas for improvement in this regard. In homes. an interlock which prevents operation of one system when the other is operating can be installed, if not already provided.

Install heat recovery devices for all elements of the cooling system where opportunity for essential energy reduction exists. For example, use rejected heat from electric generating engines or turbines, waste heat boilers, or incinerators to power heat operated cooling systems. Consider on-site generation of power to provide this source of energy for cooling. Burn solid waste as a source of low cost energy. Consider powering cooling systems by prime movers other than electric motors when such applications are feasible, such as areas where electric power supply is marginal for the summer demand. Modify mechanical cooling systems to operate at condensing temperatures which drop as a function of outdoor temperature rather than hold a constant pressure.

Insulate and seal all ducts in non-conditioned spaces. In homes, particularly, this accounts for large losses in both cooling and heating.

In building with central cooling systems consider the use of separate spot or zone cooling units for spaces which are used for occupancy when the majority of the building is unoccupied. For example, in homes with central cooling installing a small room cooler in the bedroom would permit turning off the large system during sleeping hours. Similarly, in commercial buildings those office or other spaces which operate around the clock can use unit cooling systems during those periods when the majority of the building is unoccupied and the main system can be turned off. Some hospitals have found it practical to furnish individual cooling units in patient rooms which are used only when and if the occupants wish to pay for the service.

Central cooling/heating systems in multi-family apartments and in some multi-occupancy office buildings in which the cost of providing these services is included in the rent do not offer the incentive or, in some cases, the physical means to the occupant to minimize the use of the services. The use of individual metered systems, billed to the occupant, offers the advantage of allowing the occupant to have heating or cooling as desired and inherently includes the cost incentive to minimize the use to actual needs. Installation of such metering should be considered in modification of existing buildings or in designs of new buildings.

Modify the building cooling system to use cool outside air in lieu of the powered cooling system whenever the conditions permit. Many cooling systems operate at low outdoor temperatures and could make use of the outdoor air if the system were so designed.

Implement effective maintenance/preventive maintenance schedules to keep all cooling system components and in optimum operating conditions. Such scheduled maintenance may not always represent an optimum cost feature but should assure optimum energy utilization.

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SUMMER COOLING

RESIDENTIAL AND COMMERCIAL COOLING ENERGY USAGE IS

- 1.5×10^{15} Btu ANNUALLY* (EQUIVALENT TO $.44 \times 10^{12}$ kwh)
- 3% OF ANNUAL NATIONAL TOTAL
- 42% OF SUMMER TOTAL

*1968, INCREASING 10% PER YEAR

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SUMMER COOLING

REDUCTION OF ENERGY USAGE FOR SUMMER COOLING OF EXISTING BUILDINGS

- WITH LITTLE OR NO EXTRA COST
- WITH MODERATE COST

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SUMMER COOLING

REDUCTION OF COOLING ENERGY USAGE WITHOUT EXTRA COST

- REDUCE USE OF COOLING SYSTEMS
- RAISE THERMOSTAT AND HUMIDISTAT SETTINGS
- REDUCE COOLING LOADS
- MAINTAIN COOLING SYSTEMS

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SUMMER COOLING

REDUCE USE OF COOLING SYSTEMS

- TURN OFF UNNEEDED SYSTEMS
- TURN OFF IN UNUSED SPACES

Center for Building Technology

SUMMER COOLING

RAISE THERMOSTAT AND HUMIDISTAT SETTINGS

- SET AT UPPER COMFORT LEVELS

  80°F, 60% RH vs 75°F, 50% RH COULD LOWER ENERGY BY 15%

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SUMMER COOLING

REDUCE COOLING LOADS

- TURN OFF UNNEEDED LIGHTS
- USE IMPROVED LIGHTING PRACTICES
- MINIMIZE USE OF HEAT PRODUCING DEVICES
- USE STOVE/OVEN VENTILATION HOODS
- WEAR LIGHTWEIGHT CLOTHING
- REDUCE EXCESSIVE VENTILATION
- MINIMIZE SOLAR LOADS
- USE COOL OUTSIDE AIR FOR COOLING

Center for Building Technology

SUMMER COOLING

MAINTAIN COOLING SYSTEMS

- KEEP HEAT TRANSFER SURFACES CLEAN
- CLEAN OR REPLACE AIR FILTERS REGULARLY
- LUBRICATE AND SERVICE UNIT REGULARLY

Center for Building Technology

SUMMER COOLING

REDUCTION OF ENERGY USAGE WITH EXTRA COST

- REDUCE THE COOLING LOAD
- IMPROVE COOLING SYSTEM EFFICIENCY

Center for Building Technology

SUMMER COOLING

REDUCE THE COOLING LOAD

- INSULATE OR ADD INSULATION
- USE INSULATING GLASS
- INSTALL SOLAR SHADING
- INSULATE AND VENTILATE ATTICS
- INSTALL ZONE CONTROLS
- REDUCE LIGHTING LOADS
- INSTALL AUTOMATIC PILOTS
- REDUCE UNNEEDED VENTILATION
- REDUCE INFILTRATION

Center for Building Technology

SUMMER COOLING

IMPROVE COOLING SYSTEM EFFICIENCY

- ELIMINATE 'NEW ENERGY' REHEAT SYSTEMS
- INSTALL HIGH-EFFICIENCY REPLACEMENTS
- INSTALL SHORT-TERM HEAT STORAGE
- INSTALL INTERLOCKS BETWEEN HEATING AND COOLING
- INSTALL HEAT RECOVERING DEVICES
- INSULATE AND SEAL DUCTS
- USE 'SPOT' COOLING
- USE INDIVIDUAL METERED SYSTEMS
- USE COOL OUTSIDE AIR FOR COOLING
- ESTABLISH EFFECTIVE MAINTENANCE

WINTER HEATING
- Existing Buildings

Opening Statement

Winter heating systems are a necessity for human health and comfort. The current effort to reduce and conserve energy for heating does not and should not impact severely on this basic human need.

The need to reduce energy consumption for heating by eliminating waste of heating energy is evident and can be accomplished by reassessing our levels of heating needs. The total use of energy for heating will continue to increase so that our conservation objective is to reduce the relative requirements for essential heating systems that exist or are newly installed.

Energy used for heating buildings, residential and commercial, is about 18 percent of the national energy consumption and represents a expenditure of 10.9×10^{15} Btu annually (in 1968 and increasing at 4 percent per year).[1/] If wasteful heating practices can be improved as much as anticipated then it is reasonable to assume that the energy requirement can be reduced as much as 40 percent over present rates, in many cases without sacrificing a reduction of needed performance. Further, the heating system performance may be improved at the same time that both dollar cost and energy cost is lowered.

Some of the suggestions presented here can be implemented at little or no cost. Others would require application of materials, equipment and labor. Not all of these suggestions have been applied on a broad scale because buildings in the past have been designed and constructed with first cost as the primary ground rule. Some suggestions have an early payback and others may take longer but all are expected to save energy. We hope that necessary data will be gathered in the laboratory and in the field to evaluate suggestions made here and by others.

Many of the suggestions made for existing buildings could also apply to new buildings. When considering reworking of existing heating systems or installation of new systems the suggestions for both should be investigated. Such an integrated approach can be done by professional engineers, architects and designers.

Winter Heating

Existing Buildings

No Extra Cost

- Set your thermostat lower

If you are now setting your thermostat at 76 or 80°F consider lowering the setting to 72 or 70 or 68°F and wearing more clothing. Roughly, for each degree above 70°F it will cost about 3% more for heating in a typical U. S. climate. This is true because the heating load is directly dependent upon the temperature difference between indoors and outdoors. The smaller you can make that difference the higher the percentage of savings.

Obviously, lowering the thermostat for long periods of time such as week-ends and vacations saves considerable heating energy.

Setting your thermostat lower overnight can save energy. It has been said that this is not worthwhile because the drop in temperature of the building and its furnishings overnight requires as much or more heating energy in the morning to restore comfortable conditions as can be saved. If energy is saved then how far back should the thermostat be set and for how long? As an example here are some results of an NBS-conducted laboratory test on a fully furnished 4-bedroom townhouse.

Figure 1 shows what happened to the temperature in this 60,000 pound insulated wood-frame house when the outdoor temperature was rapidly decreased to about 34°F and then held constant with no heating or lighting energy being supplied to the indoors. Note that in 8 hours the indoor temperature decreased from about 78°F to 69°F and it took about 24 hours to decrease to 58°F. These results are predictable by computer. Other tests, Figure 2, show that when the thermostat was lowered from about 75°F to 65°F for 8 hours at night a savings of 9% heating energy per day was observed for a night time temperature of about 3°F and about 12% for a night temperature of 21°F. Table 1 is computer calculated and shows the 24-hour percent fuel savings per day for 25 cities when the thermostat is lowered 5, 7 1/2 and 10°F at night for eight hours between 10 pm and 6 am. The table indicates that even though the percentage of fuel savings is higher in warmer climates the total savings will be greater in colder regions where more fuel is used.

In larger buildings energy can be saved by discontinuing humidity control at the end of the workday. It must be recognized that energy is required to produce water vapor to satisfy the humidity demand.

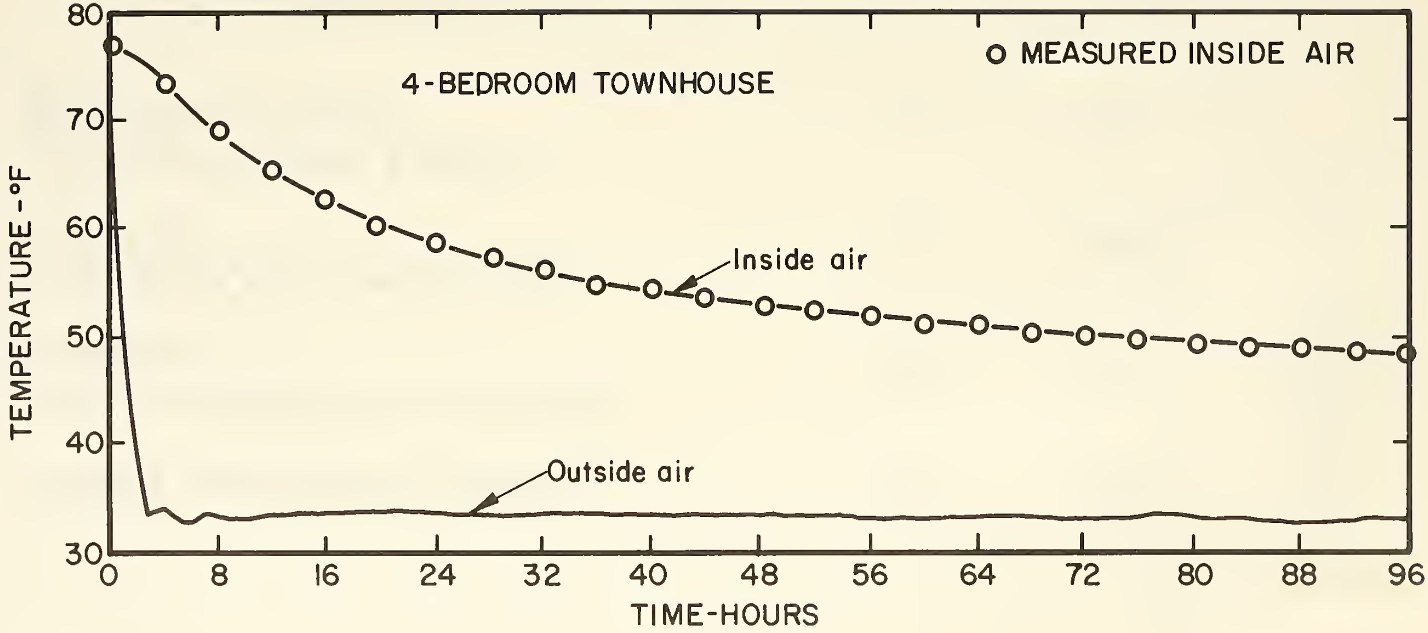
80
70
60
50
40
30
TEMPERATURE -°F
0
8
16
24
32
40
48
56
64
72
80
88
96
TIME-HOURS
4-BEDROOM TOWNHOUSE
O MEASURED INSIDE AIR
Inside air
Outside air

Figure 1

Center for Building Technology

4-BEDROOM TOWNHOUSE*

8-HOUR THERMOSTAT SETBACK	9°F	9°F
NIGHT OUTDOOR TEMPERATURE, MINIMUM	3°F	21°F
DAY OUTDOOR TEMPERATURE, MAXIMUM	35°F	65°F
24-HOUR HEATING ENERGY REDUCTION, PERCENT	9.0	11.5

* NBS MEASURED DATA

Figure 2

Table 1

Percent Fuel Savings* with
Night Thermostat Setback
From 75°F

Setback 8 hours; 10 pm to 6 am

City	5° Setback	7 1/2° Setback	10° Setback
Atlanta	11	13	15
Boston	7	9	11
Buffalo	6	8	10
Chicago	7	9	11
Cincinnati	8	10	12
Cleveland	8	10	12
Dallas	11	13	15
Denver	7	9	11
Des Moines	7	9	11
Detroit	7	9	11
Kansas City	8	10	12
Los Angeles	12	14	16
Louisville	9	11	13
Milwaukee	6	8	10
Minneapolis	8	10	12
New York City	8	10	12
Omaha	7	9	11
Philadelphia	8	10	12
Pittsburgh	7	9	11
Portland	9	11	13
Salt Lake City	7	9	11

Percent Fuel Savings* with
Night Thermostat Setback
From 75°F (cont'd)

City	5° Setback	7 1/2° Setback	10° Setback
San Francisco	10	12	14
St. Louis	8	10	12
Seattle	8	10	12
Washington, D.C.	9	11	13

*Minneapolis-Honeywell Data, 1973.

o Close off rooms not used and turn off heat

Closing off rooms and turning off the heat saves energy simply because the heating system need not supply that room. The amount saved would depend on the room size, weather and the time. Care should be used in cold climates to drain water from pipes or other containers that may freeze in the room or alternatively do not close off the room so tightly as to allow temperatures to go below 32°F.

o On winter days let the sunshine in but pull the shades and drapes at night

Solar heat can be used to help maintain room temperature. Any "green house effect" translates into energy savings because less heat is required from the heating plant.

At night when the window glass is chilled a closed blind or drapery reduces radiation heat loss from people near the window and may prevent them from feeling colder and turning up the thermostat. Closed blinds are usually not fitted tightly allowing room air to circulate through the space behind the blind and for this reason only a minor savings of fuel energy can be realized from blinds and drapes.

o Reduce air leakage (drafts) and ventilation

Warm air leaking from a building is replaced by cold air which must be heated. For many houses about 35% of the heating energy is used to warm the cold air which enters because of leakage. Therefore it is important for energy conservation to close and seal tightly openings from the indoors to the outdoors. Examples of air leakage openings include cracks around windows and doors, attic stairway doors, fireplace dampers when not in use, electric light ceiling fixtures, around plumbing vents or pipes, air ducts penetrating ceilings or walls, etc. A 1/4 inch crack 3 feet wide under an attic door could cost $5.00 a winter in energy waste. Simply placing a scrap piece of carpeting over the crack could stop this leak.

For larger buildings that have power ventilation systems reducing the amount of ventilation and size of fan motors, and operating by scheduling operations to use ventilation only where and when it is actually needed can save a considerable amount of energy, as much as 50% over inefficient operations. As an example see Figure 3.

o Be careful about open windows and doors

Open windows and doors represent a huge heating load. Cold air passing through a building will by-pass the insulating effect of walls, windows, doors, ceilings and floors causing the thermostat to start the heating plant which in turn tries

HEAT PUMP - VENTILATING AIR

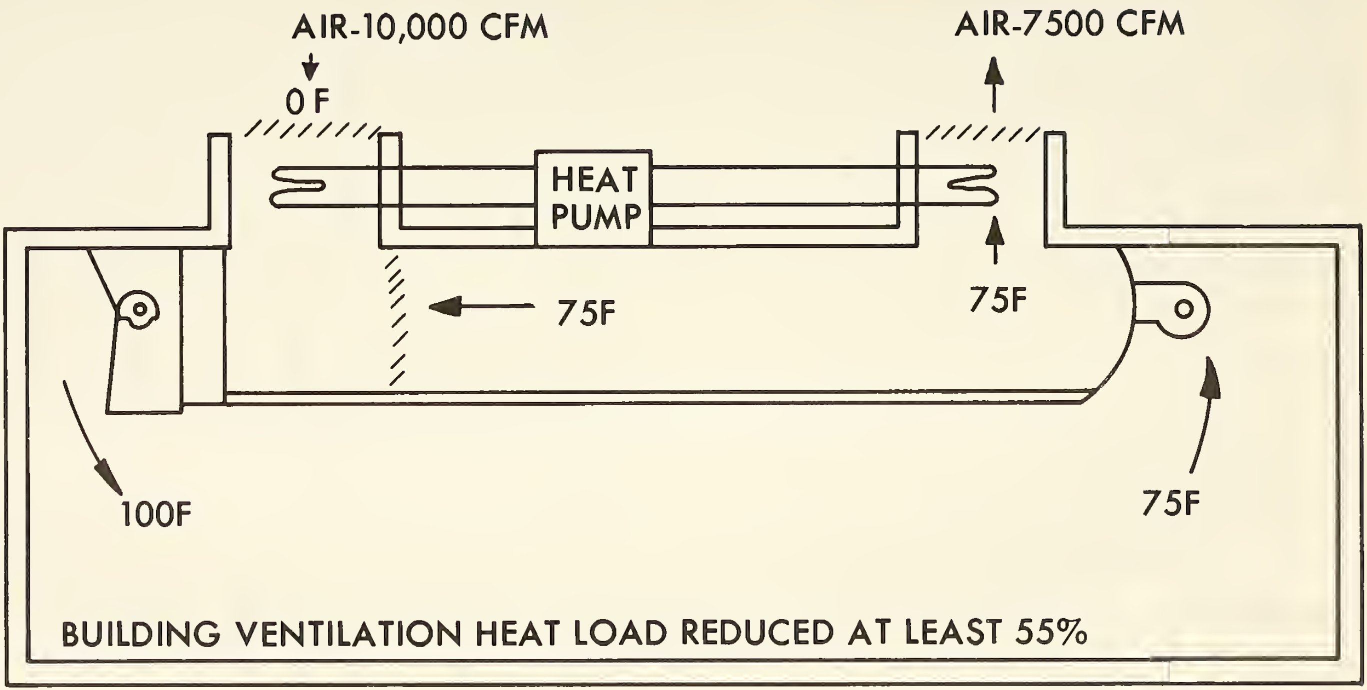

Figure 3

to heat a building that is being flushed with cold outdoor air. A simplified example of this is to open the bedroom window before retiring and not closing the bedroom door. The cold outdoor air finds it way to the thermostat while you are sleeping and the heating plant operates, sometimes fruitlessly, all night long wasting heating energy. For most situations a common sense approach should prevail. For example, standing in an open doorway talking with callers for long periods of time doesnt make energy conservation sense. Keep the conversation brief, send the caller on his way, or if prudent invite him in and close the door to keep the heat in. Also, as mothers know, children need to be constantly reminded to close the door behind them until it becomes an ingrained habit. Windows not normally opened should be latched to prevent or reduce constant air leakage through the cracks.

In large buildings where there is an almost constant stream of people entering and leaving the building use of such techniques as revolving doors, double sets of doors, and especially engineered heating and air systems can make a substantial impact on energy consumption for the building and should be encouraged.

o <u>Reduce the temperature in public spaces, corridors, hallways, lobbies, etc.</u>

Public spaces such as lobbies are not occupied by a given individual for a very long period of time. People usually move through these spaces, stand and talk for short periods of time but seldom sit for hours at a time. Reducing the controlled temperature even a few degress could save considerable energy in a given large building over a heating season. For employees that must spend their workday in these spaces selective heating of the actual work space could be provided and these employees could be encouraged to wear heavier clothing.

o <u>Institute rigorous schedules for planned operation of ventilation</u>

Ventilation systems in existing buildings are sometimes operated continuously and often without conscious planning to respond to the actual need. Operating ventilation systems only as needed in response to known building occupancy schedules could save energy. The ventilation required in modern buildings is variable with time of day and level of building occupancy. It is only partially predictable but the important point here is to first examine present scheduling with a view for changes that can be made to save energy without seriously influencing occupant comfort. Most ventilation systems can be adjusted.

Generally, the rate of ventilation to satisfy odor requirements changes in a ratio of 8 or 10 to 1 depending on whether the occupants are heavy smokers or non-smokers. Normal occupancy in an office building, for example, may occur for only about 10 hours per day and the use of toilets and cafeterias, where high levels of exhaust are needed, may be correspondingly less than 50 percent of this time as indicated in Figure 4. Some heating and ventilating systems are designed or can be operated for a high rate of ventilation with outdoor air during mild weather to control indoor conditions and a much lower level during the heating and cooling seasons.

A prominent mechanical engineering consultant from Chicago has estimated that 30 to 50% of the energy required for heating and 15 to 20% of the energy required for electrically powered air conditioning could be saved by variable exhaust of air and by utilizing heat recovery devices between exhaust and intake air. The design parameters are shown in Figure 5.

o <u>Wear heavier clothing</u>

Six key variables have been identified as having a major influence on human comfort in occupied building spaces. These are the temperature, relative humidity, air velocity, mean radiant temperature, the degree of physical activity and the amount of clothing worn. The occupant has a great deal of

Center for Building Technology

PLANNED VENTILATION OF OFFICE BUILDINGS

VENTILATION REQUIREMENTS

- 3 CFM/PERSON, OXYGEN SUPPLY
- 5 CFM/PERSON, ODOR CONTROL (NO SMOKING)
- 10-12 CFM/PERSON, CAFETERIAS
- 25-40 CFM/PERSON, SMOKERS

- 2 AIR CHANGES/HR, MIN., CORRIDORS
- 10-15 AIR CHANGES/HR, TOILET EXHAUST

OCCUPANCY AND USE

- 10-12 HR/DAY, OFFICES AND TOILETS
- 6-8 HR/DAY, CAFETERIAS

Figure 4

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DESIGN JUDGMENTS

- OCCUPANCY LEVEL
- AREAS OF HEAVY SMOKING
- DURATION OF DAILY USE
- USE OF MILD-WEATHER VENTILATION
- CONSTANT VS VARIABLE EXHAUST
- USE OF INLET-EXHAUST HEAT EXCHANGE

Figure 5

control over his own physical activity and clothing. Generally, bare arms and ankles tend to make a person feel cooler in heated spaces and simple compensation by wearing long sleeves, coats, sweaters and heavier and longer socks permit lowered room temperatures thus saving energy.

o Maintain an efficient heating plant

The operating efficiency of a heating plant is a very important factor in influencing the amount of fuel energy used for heating. For example, two prime sources of energy waste are the amount of air supplied for combustion and the conditions of the furnace or boiler. Heat transfer surfaces should be clean to minimize any reduction of heat transfer that may be caused from soot that results from products of combustion. The quantity of air received by the burner influences the efficiency of combustion. Too much air increases heat losses to the chimney and too little air does not allow complete combustion. Heating contractors or utility company personnel can check and adjust your furnace. Other things can be done effectively by building personnel. For example, air filters should be cleaned or changed and electric motors, pumps or other devices should be oiled or lubricated. A potential energy savings of 10% or more can be realized by maintaining the heating plant in good operating condition.

o Turn off - turn down lights and electric appliances except when needed

It is true that heat released from lighting fixtures and appliances in the winter contribute to maintaining indoor temperatures. The suggestion to turn off lights and appliances unless actually needed is made in the context of energy conservation. The rationale is that the thermal efficiency of electric energy supplied from the power plant is of the order of 30-35% and savings of electric energy at the point of consumption contribute directly and considerable to savings of fuel energy at the power plant. It has become customary to perform janitorial services in commercial and office buildings after the majority of the occupants leave in the evening. For operational and security reasons the lighting systems of these buildings remain on into the night while the work is being done. Frequently entire buildings remain lighted even though the work at a given moment is limited to one area. Using lighting only in areas of work and scheduling all work in one area at a time would permit significant reductions in the lighting energy. Consideration should be given to scheduling during daytime hours those janitorial tasks which will cause minimal interruption or interference to normal activity. This suggestion applies to all types of buildings year around.

o <u>Concentrate evening work or meetings in a single heating zone</u>

In large buildings instead of heating the whole building to accomodate a few people who must work in the evening consider asking the people to move for the evening to a heated zone in the building and then reduce the heating on the remainder of the building to save energy.

Winter Heating
Existing Buildings
With Extra Cost

o Add a clock thermostat

Night-time thermostat set-back can be done manually but in practice because of the necessity of actually turning it back it may not be done consistently. Automatic clock controlled devices to accomplish night set - back of the thermostat are available. Also, many buildings are presently equipped with clock-type thermostats that are not being used.

o Add insulation

The addition of thermal insulation to save energy has been verified many times. In existing housing, for example, adding insulation to the attic floor, about 6 inches deep, will contribute to comfort in both winter and summer and will pay for itself from savings from heating and cooling bills. Adding insulation to side-walls should be done with technical advice because of the possibility of moisture condensation within the walls.

Adding insulation to large existing buildings that are not insulated or contain minimum amounts of insulation may present practical and expensive difficulties because of such variables as the ratio of glass to insulated area, access to add insulation, interruption of personnel or vital services, and other considerations. Usually masonry buildings are difficult to retrofit with insulation. Therefore, professional advice should be sought before undertaking massive modifications because insulation is only one element which should be taken in context with other energy conservation techniques in large buildings.

The potential for energy conservation by using thermal insulation is large for all types of new buildings.

o Add insulating glass or storm windows and doors

Storm doors and windows and insulating glass save energy because they cut in half the heat that would be lost through the glass area of single pane windows. Generally, considering air leakage and conduction of heat through walls the net effect of heating bills could be a reduction of 10-15 percent. Further benefits in terms of comfort and a reduction of cold floor drafts are inherent. Also, storm windows and doors are effective in reducing heat gain in summer and thereby reducing the load on air conditioning equipment.

o Caulk and seal around windows and doors, and other openings

Caulking, sealing, and use of weatherstrip is very effective in sealing out the entry of cold air into a building and the exit of warm air from the building. Because of the necessity to heat cold air leakage about one-third of the output of the furnace is used for this purpose and any reduction air leakage will save energy.

o <u>Insulate heating ducts and seal against air leakage into non-heated spaces (attics, crawl spaces)</u>

Ducts that convey warm air from the furnace to the occupied spaces sometimes pass through unheated spaces such as attics and crawl spaces that are cold. Within these areas the ducts should be heavily insulated and sealed against leaking warm air to the cold space through cracks in the ductwork. When the furnace blower is working the duct work is operating under positive pressure. The air lost from these sections is a direct waste of energy.

In some buildings piping containing fluids such as water or steam will pass through cold spaces. These should also be heavily insulated to prevent gross heat energy loss.

o <u>Maintain heating equipment - clean heat transfer surfaces, change filters, set flames and combustion air</u>

This subject was mentioned under the heading of no cost suggestions. It is estimated that ten percent energy savings can be realized when comparing a well maintained heating system with a system that is not in good operating condition.

It is suggested that this work be done by service professionals.

o <u>Install heat recovery and conservation devices</u>

In buildings, especially large buildings, two prime areas of heating system loss are stack losses and ventilation air losses.

Recovery of some of the heat that normally would go up the stack and channeling it back into the heating system represents a means to conserve energy. Also, when warm air is exhausted from a building by a mechanical ventilation system and at the same time cool air is drawn in as fresh air, energy can be saved by removing heat from the exhausted air and using it to warm the cool air which otherwise must be heated by the normal heating system. Several techniques are available for accomplishing this energy savings. For example, to recover heat from stacks heat pipes, runaround circuts, automatic stack dampers, etc. and for ventilation systems runaround circuts, thermal wheels, heat pipes, heat pumps and other heat exchange circuts. The potential for ventilation heat load reduction is illustrated in Figure 6.

o Install automatic pilots

Energy can be saved if pilot lights on heating devices are replaced by substituting an automatic ignition device to light the burner. Gas pilot lights usually operate continuously 24 hours a day and typically consume 1 to 2 cubic feet of gas per hour. The fuel energy savings could amount to the pilot consumption when the burner is not operating. Replacing pilots could in some cases allow corrosion in furnaces or boilers and each system should be evaluated before extensive changes are made.

o Adjust ventilation systems

It may be possible to adjust ventilation systems in a way to cut down on the amount of air flow and maintain comfort conditions. Use of heat recovery devices and additions of odor removal filters could be studied as a means for maintaining comfort with less net energy consumption.

o Avoid use of portable electric heaters by improving main heating system

Electric energy could be conserved, with its attendent savings in fuel energy for power generation, if the use of portable electric heaters is avoided by improving the main heating system of the building.

Fuel fired heating plants in a building operate at thermal efficiencies of about 60-75 percent while the thermal efficiency of electric power generation is about 30 percent. The difference in efficiencies is indicative of the amount of energy saved.

o Replace defective or inefficient heating systems with systems of higher efficiency

Over the years improvements in heating systems have been made to make them more efficient. If present systems are defective and are known to be inefficient the difference in efficiency between an old and new system is a savings in fuel energy when both systems must accomodate the same load.

o Modify systems for zone control using systems of higher efficiency

In some larger buildings the heating requirements of different zones or areas in the building vary but the original heating system is designed to respond to a single control or thermostat. Those types of systems could be modified by the addition of control valves and the addition of thermostats that prevent overheating with its attendant waste of energy.

o Provide means to transfer heat from the core of a large building to the cool periphery needing heat

Heat generated by people and activities in the central core area of large buildings is often in excess of what is needed to provide heating needs. If this excess heat is ventilated to the outdoors or is absorbed by refrigeration systems at a time heat is supplied to the colder periphery changes could be considered to transfer this heat to where it is needed and when it is needed by modifying existing systems or their controls. The energy savings would amount to the equivalent of that energy that would have been rejected to the outdoors.

o Install automatic door closers

Open doors represent a major heat leak. People tend to leave doors open even in winter. Automatic door closers would save the energy that would normally be lost. The savings are difficult to quantify but it is estimated that it is worthwhile. Some data are available in the handbooks of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), New York, N. Y.

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WINTER HEATING

RESIDENTIAL AND COMMERCIAL SPACE HEATING ENERGY CONSUMPTION* IS

- 10.9×10^{15} BTU ANNUALLY
- 18 PERCENT OF ANNUAL NATIONAL TOTAL
- 1968, INCREASING 4 PERCENT PER YEAR
- WASTE IS 40 PERCENT

* 1968, PATTERNS OF ENERGY CONSUMPTION IN THE U.S.

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WINTER HEATING

REDUCTION OF ENERGY CONSUMPTION FOR WINTER HEATING OF EXISTING BUILDINGS

- WITH LITTLE OR NO EXTRA COST
- WITH MODERATE COST

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WINTER HEATING

REDUCTION OF HEATING ENERGY CONSUMPTION
— WITHOUT EXTRA COST

- SET YOUR THERMOSTAT LOWER
- CLOSE OFF ROOMS NOT USED AND TURN OFF HEAT
- ON WINTER DAYS LET THE SUNSHINE IN - PULL SHADES AT NIGHT
- REDUCE AIR LEAKAGE AND VENTILATION
- BE CAREFUL ABOUT OPEN WINDOWS AND DOORS
- REDUCE TEMPERATURE IN PUBLIC SPACES, LOBBIES, ETC.
- INSTITUTE RIGOROUS SCHEDULES FOR PLANNED OPERATION OF VENTILATION
- WEAR HEAVIER CLOTHING
- MAINTAIN AN EFFICIENT HEATING PLANT
- TURN OFF - TURN DOWN LIGHTS AND ELECTRIC APPLIANCES EXCEPT WHEN NEEDED
- CONCENTRATE EVENING WORK OR MEETINGS IN A SINGLE HEATING ZONE

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WINTER HEATING

SET YOUR THERMOSTAT LOWER

- 68 TO 72°F, COSTS 3% MORE FOR EVERY DEGREE ABOVE 70°F
- WEAR HEAVIER CLOTHING
- DURING VACATIONS AND WEEK-ENDS
- DISCONTINUE HUMIDITY AT END OF WORK DAY
- SET THERMOSTAT BACK EACH NIGHT

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WINTER HEATING

CLOSE OFF ROOMS NOT USED AND TURN OFF HEAT

- SAVINGS DEPEND UPON ROOM SIZE, WEATHER AND TIME
- BE CAREFUL NOT TO FREEZE PIPES

ON WINTER DAYS LET THE SUNSHINE IN BUT PULL SHADES AND DRAPES AT NIGHT

- SOLAR HEAT HELPS HEAT ROOM
- SHADES AND DRAPES REDUCE HEAT LOSS AT NIGHT

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WINTER HEATING

REDUCE AIR LEAKAGE (DRAFTS) AND VENTILATION

- AROUND DOORS AND WINDOWS
- ATTIC STAIRWAY DOORS
- FIREPLACE DAMPERS WHEN NOT IN USE
- AROUND CEILING LIGHTING FIXTURES
- AROUND PLUMBING VENTS AND PIPES
- AROUND AIR DUCTS PENETRATING TO COLD SPACES
- CAN SAVE 50% OF HEATING AIR LEAKAGE

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WINTER HEATING

BE CAREFUL ABOUT OPEN WINDOWS AND DOORS

- CLOSE BEDROOM DOORS
- DON'T TALK IN OPEN DOORWAYS
- KEEP AFTER CHILDREN
- USE REVOLVING DOORS OR AIR LOCKS

REDUCE TEMPERATURE IN PUBLIC SPACES, CORRIDORS, HALLWAYS, LOBBIES, ETC.

- EVEN A FEW DEGREES HELPS
- PROVIDE SPOT HEATING FOR EMPLOYEES
- WEAR HEAVIER CLOTHING

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WINTER HEATING

INSTITUTE RIGOROUS SCHEDULES FOR PLANNED OPERATION OF VENTILATION

- REDUCE VENTILATION
- SLACK-OFF WHEN BUILDING IS NOT OCCUPIED
- SAVING 30 TO 50% HEATING ENERGY

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WINTER HEATING

WEAR HEAVIER CLOTHING

- COVER ARMS AND ANKLES

MAINTAIN AN EFFICIENT HEATING PLANT

- CLEAN HEAT TRANSFER SURFACES
- ADJUST BURNER AND COMBUSTION AIR
- CLEAN OR CHANGE AIR FILTERS
- OIL MOTORS AND LUBRICATE BEARINGS
- SAVING 10 PERCENT

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WINTER HEATING

TURN OFF, TURN DOWN LIGHTS AND ELECTRIC APPLIANCES EXCEPT WHEN NEEDED

- SAVES FUEL AT THE POWER PLANT
- SCHEDULE SOME JANITORIAL SERVICES DURING WORKING HOURS

CONCENTRATE EVENING WORK OR MEETINGS IN A SINGLE HEATING ZONE

- ENERGY SAVED IN MOST OF THE BUILDING

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WINTER HEATING

REDUCTION OF ENERGY CONSUMPTION - WITH EXTRA COST

- ADD A CLOCK THERMOSTAT
- ADD INSULATION, AS MUCH AS FEASIBLE
- ADD INSULATING GLASS OR STORM WINDOWS AND DOORS
- CAULK AND SEAL AROUND WINDOWS, DOORS AND OTHER OPENINGS
- INSULATE HEATING DUCTS AND SEAL AGAINST AIR LEAKAGE INTO NON-HEATED SPACES (ATTICS, CRAWL SPACES)
- MAINTAIN HEATING EQUIPMENT - CLEAN HEAT TRANSFER SURFACES, SET FLAME AND COMBUSTION AIR
- INSTALL HEAT RECOVERY AND CONSERVATION DEVICES
- INSTALL AUTOMATIC PILOT LIGHT
- ADJUST VENTILATION SYSTEM
- AVOID USE OF PORTABLE ELECTRIC HEATERS BY IMPROVING MAIN HEATING SYSTEM
- REPLACE DEFECTIVE OR INEFFICIENT HEATING SYSTEMS WITH SYSTEMS OF HIGHER EFFICIENCY
- MODIFY SYSTEMS FOR ZONE CONTROL USING SYSTEMS OF HIGHER EFFICIENCY
- PROVIDE MEANS TO TRANSFER HEAT FROM THE CORE OF A LARGE BUILDING TO THE COOL PERIPHERY NEEDING HEAT
- INSTALL AUTOMATIC DOOR CLOSERS

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WINTER HEATING

ADD A CLOCK THERMOSTAT

- AUTOMATIC NIGHT SET-BACK

ADD INSULATION

- 6 INCHES CEILINGS
- 3 INCHES SIDEWALLS
- GET PROFESSIONAL ADVICE ON LARGE BUILDINGS
- PAYS FOR ITSELF

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WINTER HEATING

ADD INSULATING GLASS OR STORM WINDOWS AND DOORS

- SAVES 10-15 PERCENT ENERGY
- CUTS AIR LEAKAGE
- INCREASED COMFORT

CAULK AND SEAL AROUND WINDOWS AND DOORS AND OTHER OPENINGS

- KEEPS OUT COLD AIR
- SAVES ENERGY

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WINTER HEATING

INSULATE HEATING DUCTS AND PIPES AND SEAL AGAINST AIR LEAKAGE IN NON-HEATED SPACES (ATTICS, CRAWL SPACES)

- GROSS LOSS OF ENERGY
- MOISTURE DAMAGE

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WINTER HEATING

MAINTAIN HEATING EQUIPMENT - CLEAN HEAT TRANSFER SURFACES, CHANGE FILTERS, SET FLAME AND COMBUSTION AIR

- 10 PERCENT SAVINGS
- USE PROFESSIONAL HELP

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WINTER HEATING

INSTALL HEAT RECOVERY AND CONSERVATION DEVICES

- RECOVER STACK HEAT
- RECOVER VENTILATION EXHAUST HEAT
- HEAT PIPES
- RUNAROUND CIRCUITS
- THERMAL WALLS
- HEAT PUMPS

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WINTER HEATING

INSTALL AUTOMATIC PILOTS

- FUEL SAVED IS EQUAL TO PILOT CONSUMPTION WHEN BURNER IS NOT OPERATING

ADJUST VENTILATION SYSTEMS

- CUT DOWN AIR FLOW - MAINTAIN COMFORT
- USE HEAT RECOVERY DEVICES
- INSTALL ODOR CONTROL

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WINTER HEATING

AVOID USE OF PORTABLE ELECTRIC HEATERS BY IMPROVING MAIN HEATING SYSTEM

- ENERGY TRADE-OFF IS DIFFERENCE IN THERMAL EFFICIENCY OF 60 - 75 PERCENT VS ABOUT 30 PERCENT

REPLACE DEFECTIVE OR INEFFICIENT HEATING SYSTEMS WITH SYSTEMS OF HIGHER EFFICIENCY

- NEW SYSTEMS ARE MORE EFFICIENT THAN OLDER SYSTEMS

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WINTER HEATING

MODIFY SYSTEMS FOR ZONE CONTROL WITH SYSTEMS OF HIGHER EFFICIENCY

- USE SEVERAL CONTROLS INSTEAD OF ONE
- ADD CONTROL VALVES AND THERMOSTATS
- PREVENTS OVERHEATING WASTE

PROVIDE MEANS TO TRANSFER HEAT FROM THE HOT CORE OF A BUILDING TO THE COOL PERIPHERY

- USE HEAT TRANSFER DEVICES INSTEAD OF REFRIGERATION IN THE WINTER
- MODIFY EXISTING SYSTEMS

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WINTER HEATING

INSTALL AUTOMATIC DOOR CLOSERS

- CUT DOWN COLD AIR ENTRY

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PERCENT FUEL SAVINGS* WITH NIGHT THERMOSTAT SETBACK FROM 75°F

SETBACK 8 HRS.; 10 P.M. TO 6 A.M.

CITY	5° SETBACK	7½° SETBACK	10° SETBACK
ATLANTA	11	13	15
BOSTON	7	9	11
BUFFALO	6	8	10
CHICAGO	7	9	11
CINCINNATI	8	10	12
CLEVELAND	8	10	12
DALLAS	11	13	15
DENVER	7	9	11
DES MOINES	7	9	11
DETROIT	7	9	11
KANSAS CITY	8	10	12
LOS ANGELES	12	14	16
LOUISVILLE	9	11	13
MILWAUKEE	6	8	10
MINNEAPOLIS	8	10	12
NEW YORK CITY	8	10	12
OMAHA	7	9	11
PHILADELPHIA	8	10	12
PITTSBURGH	7	9	11
PORTLAND	9	11	13
SALT LAKE CITY	7	9	11
SAN FRANCISCO	10	12	14
ST. LOUIS	8	10	12
SEATTLE	8	10	12
WASHINGTON, D.C.	9	11	13

* MINNEAPOLIS-HONEYWELL DATA, 1973

ENERGY CONSERVATION FEATURES

INSULATION

Of all energy conservation methods for building heat losses and gains, none can be considered as important as thermal insulation. President Nixon recognized this in his energy messages (June 1971 and February 1972) by directing HUD-FHA to upgrade insulation standards for single and multi-family dwellings.

As an example of the impact possible in residences, NBS in 1970 prepared a 25-year projection of energy and cost savings from thermally improved buildings. Figure 6 shows the projected national stock of residential units for 25 years from about 60 million to 100 million units. The annual energy consumption for heating and cooling these residences is projected in figure 7 on the assumptions that a building would not be thermally improved and present (1970) insulation levels would prevail and on the assumption that insulation levels would be improved to the extent of 10 percent for existing buildings and 50 percent for new buildings. Annual and accumulated savings are shown as energy requirements in Q units (1Q unit = 10^{15} Btu). The accumulated savings show 50 Q units over 20 years. Figure 8 shows the fuel cost in billions of dollars of the accumulated energy savings to be about $100 billion over 25 years assuming energy prices remain at 1970 levels. Figure 9 shows the effect if prices of energy should

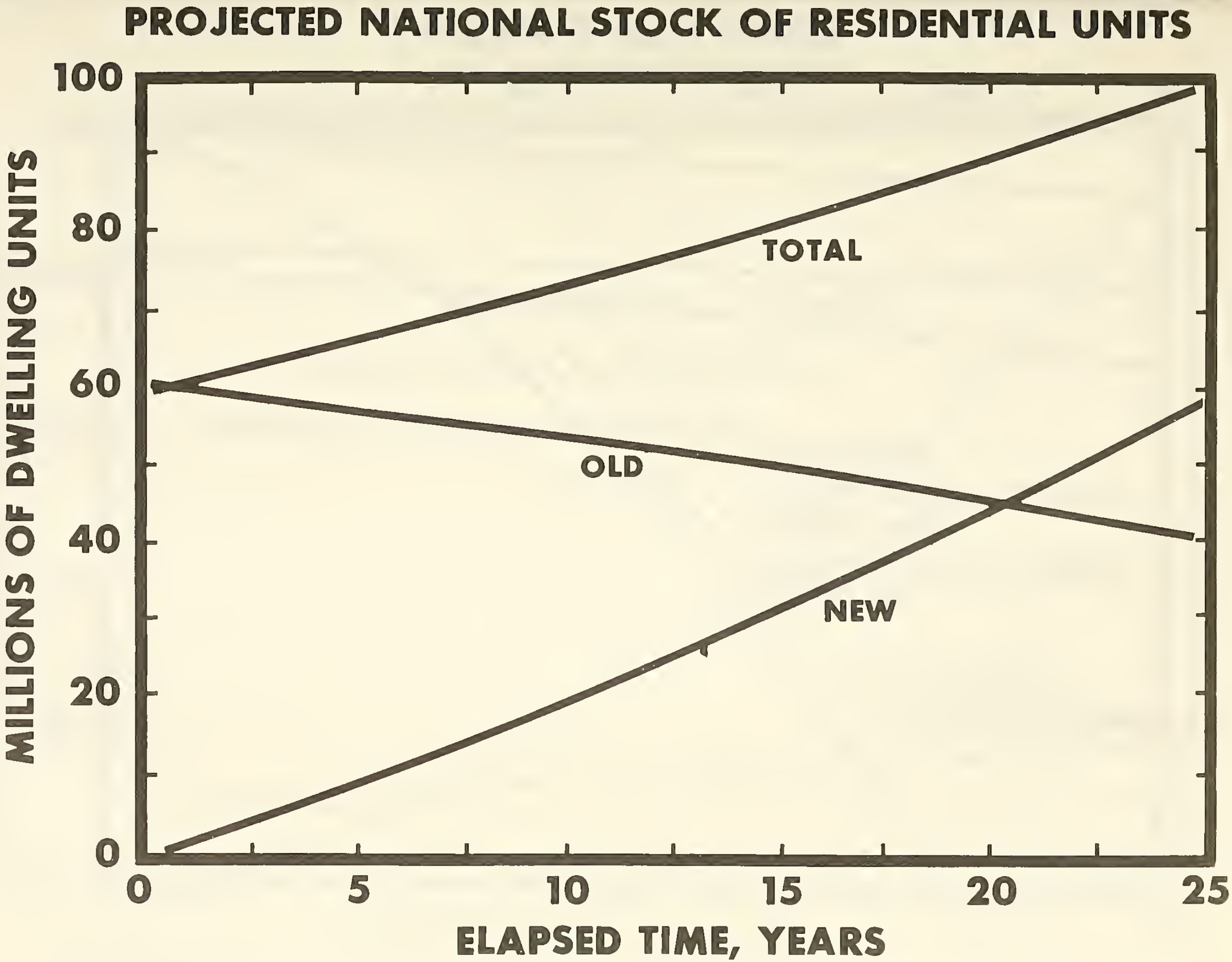

PROJECTED NATIONAL STOCK OF RESIDENTIAL UNITS
MILLIONS OF DWELLING UNITS
100
80
60
40
20
0
TOTAL
OLD
NEW
0
5
10
15
20
25
ELAPSED TIME, YEARS

Figure 6

FUEL ENERGY USAGE FOR HEATING AND COOLING
(1 Q UNIT = 10^{15} BTU)

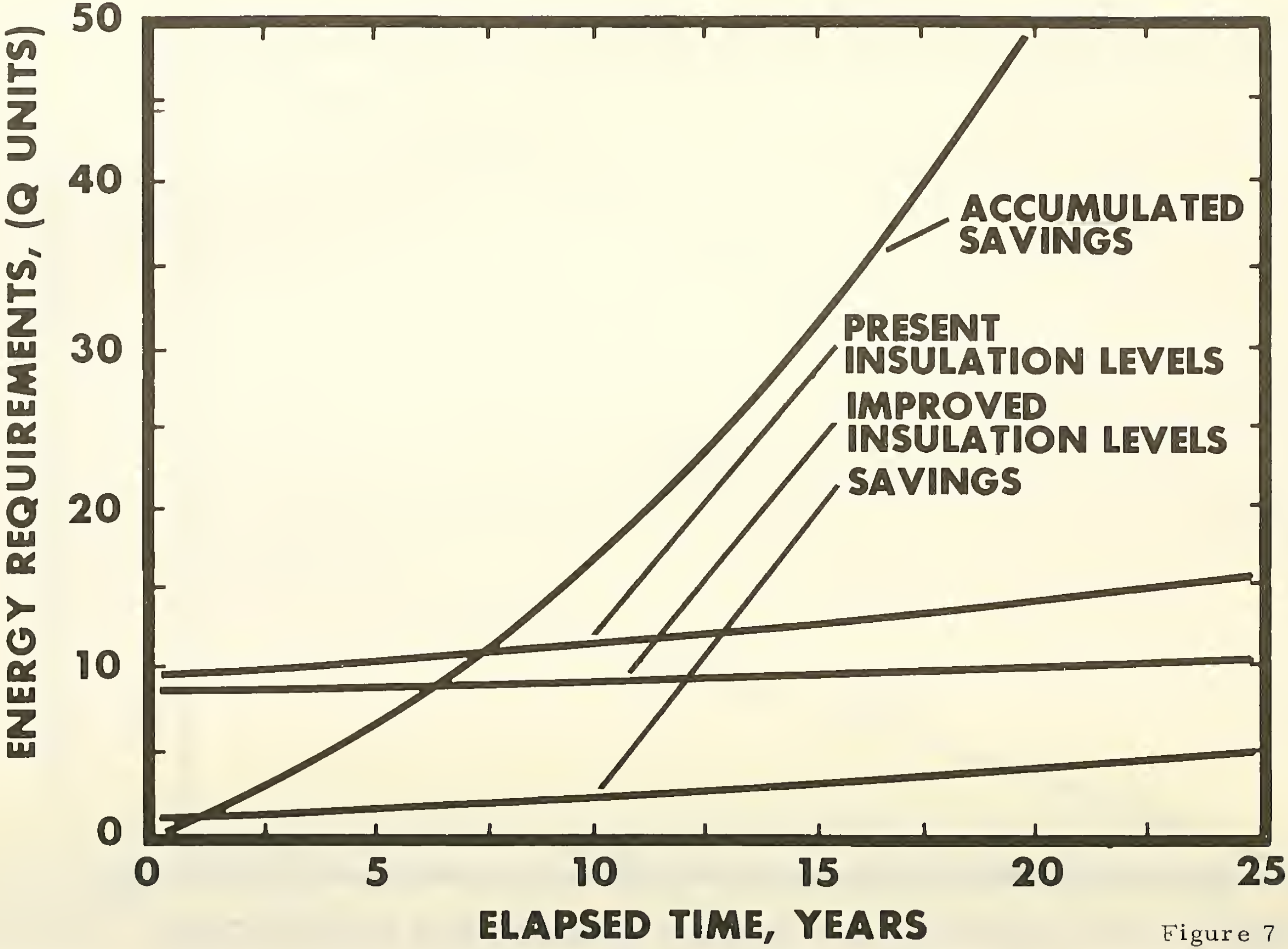


Figure 7

COST OF FUEL FOR HEATING AND COOLING AT CURRENT PRICES

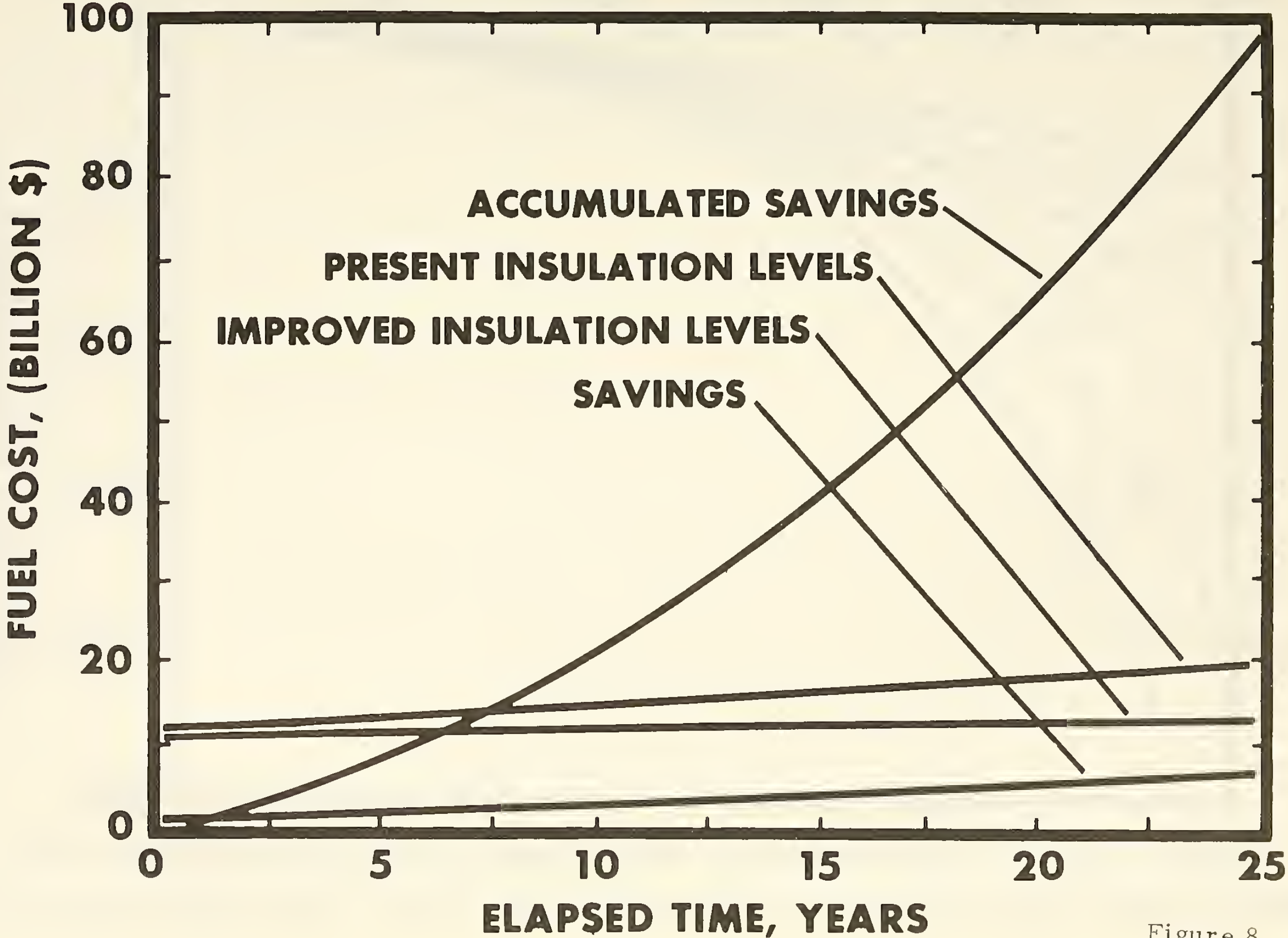


Figure 8

ACCUMULATED FUEL COST SAVINGS DUE TO IMPROVED INSULATION FOR VARIOUS ANNUAL PERCENTAGE INCREASES OF FUEL PRICES

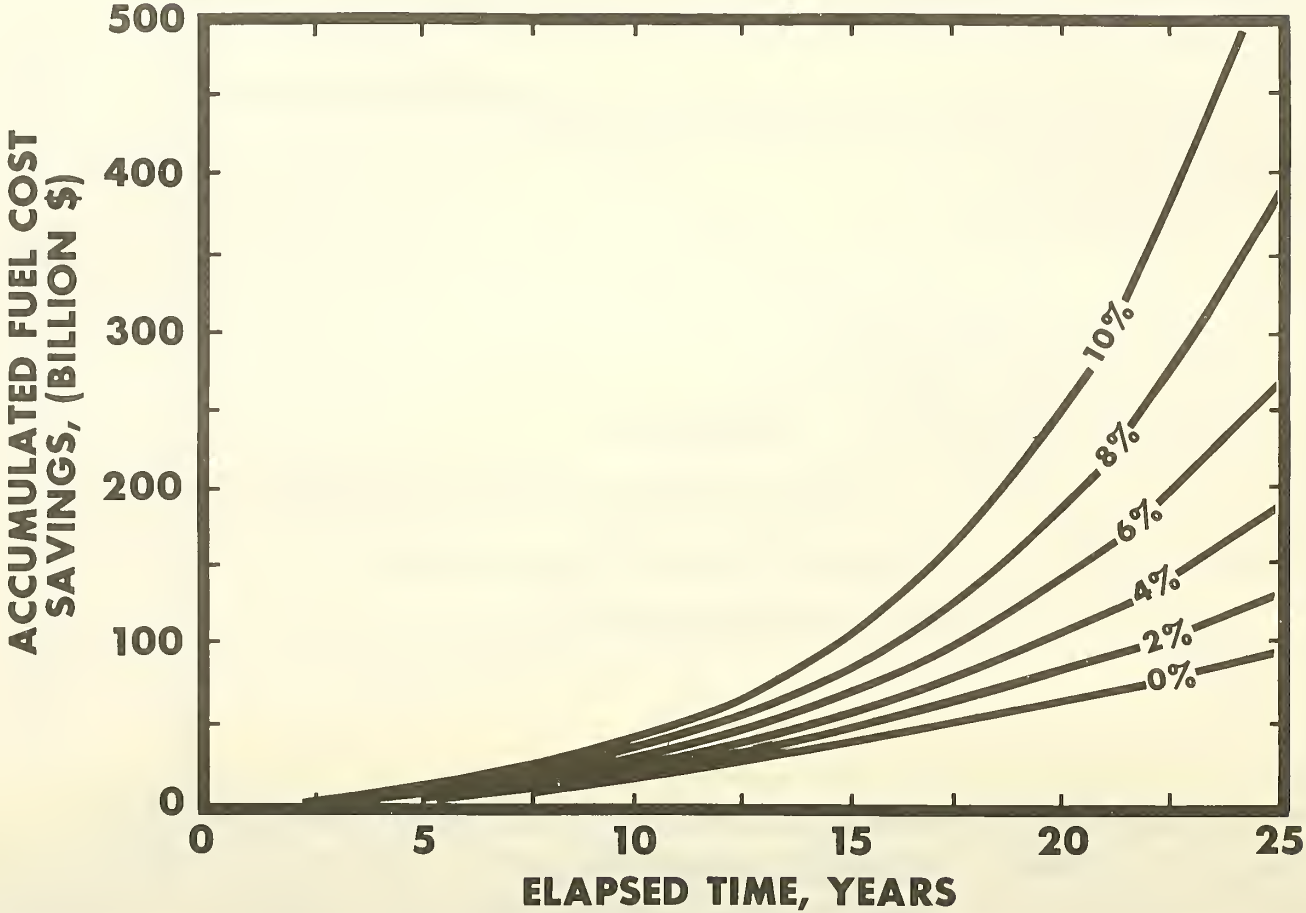


Figure 9

increase annually at rates of 2, 4, 6, 8, and 10 percent, e.g., at 7% about $200 billion over 20 years. These projections for housing are also indicitive of the scope of similar energy and cost savings potential that might be attained in other types of building such as office buildings.

It is possible to reduce the heat loss or gain in residences by 50 percent through the use of thermal insulation in the ceilings, (6 inches) walls (3 inches) and floors (3 inches). As an example, Figure 10 was prepared to illustrate the application of four insulation requirements in terms of a heat load factor defined as Btu/(1000 ft^3 of heated volume) (degree-day) for a hypothetical residence of 1200 ft^2.

In addition to conserving energy, increased insulation can save on heating furnaces (about 20 percent smaller), cooling machinery (about 10-15 percent smaller), and also smaller flues, smaller electrical wire sizes to equipment and smaller duct sizes.

RESIDENTIAL INSULATION REQUIREMENTS

REQUIREMENT	HEAT LOAD FACTOR
OLD MPS	>2,000
BREAKTHROUGH GUIDE CRITERIA	1,500 - 2,000
NEW MPS/CRITERIA	<1,000
ATTAINABLE GOAL WITH REASONABLE COST	700

Figure 10

ENERGY CONSERVATION FEATURES

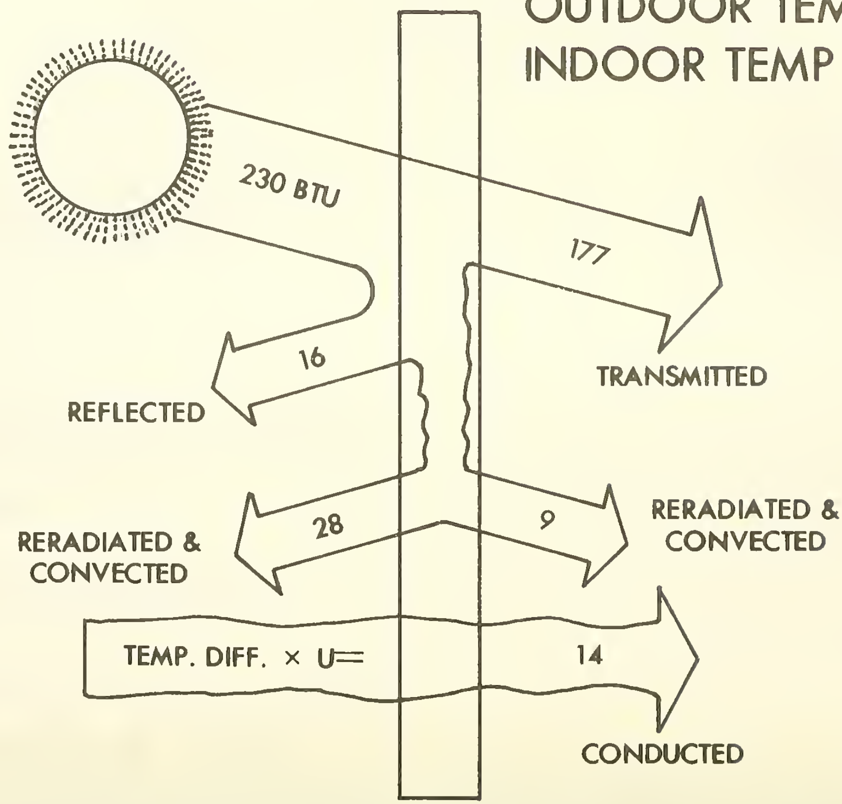
FENESTRATION

General building design practice over the past decade has called for large expanses of glass with most commercial building having between 50 and 60 percent of the exterior surface area occupied by these transparent surfaces. Historically it was for the purpose of making proper use of natural light; however, most often today it is to provide a view of the outside, which in most instances is to cater to a real or assumed psychological need.

In contrast to the favorable characteristics of windows, they can have a significant impact on the heating and cooling loads imposed on the building. For example, figure 11 depicts a typical process occuring during the summer with solar radiation impinging on a 1/4" clear plate window and also energy being conducted across it as a result of hot outdoor air.[3/] As can been seen over 80 percent of the incident solar energy enters the space and the total energy entering is probably ten times larger than through a comparable amount of conventional wall. In the winter time, a different kind of problem exists. The ability to conduct heat of ordinary plate glass is five to ten times more than typical well insulated walls. Consequently they become a source of "heat leaks" in cold weather, being only partly compensated for by the solar energy. In addition, their high conductance results in a cool

1/4" CLEAR PLATE

OUTDOOR TEMP - 89°F
INDOOR TEMP - 75°F



RELATIVE HEAT GAIN 200 BTU

Figure 11

interior surface which is detrimental to thermal comfort and can cause condensation problems under certain circumstances.

It is possible to enjoy the benefits of windows and yet compensate for their negative characteristics through proper design initially as well as proper use.

1. Shading: It is possible to reduce solar transmission through windows significantly by proper use of shading. The most effective way is by use of external shading devices. These can be in the form of trees, shrubs, overhangs, awnings, building fins or eyebrow reveals. Figure 12 is a schematic representation of how overhangs and side fins are placed to shade windows. Figure 13 shows one way in which the building design and shading devices can be integrated together.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) specify in their 1972 Handbook of Fundamentals,[4/] the percent reduction of solar heat gain that can be expected for a single plate glass window as a result of internal shading devices as follows:

Venetian Blinds		Roller Shade		
		Opaque		Translucent
Medium	Light	Dark	White	Light
36%	45%	41%	75%	61%

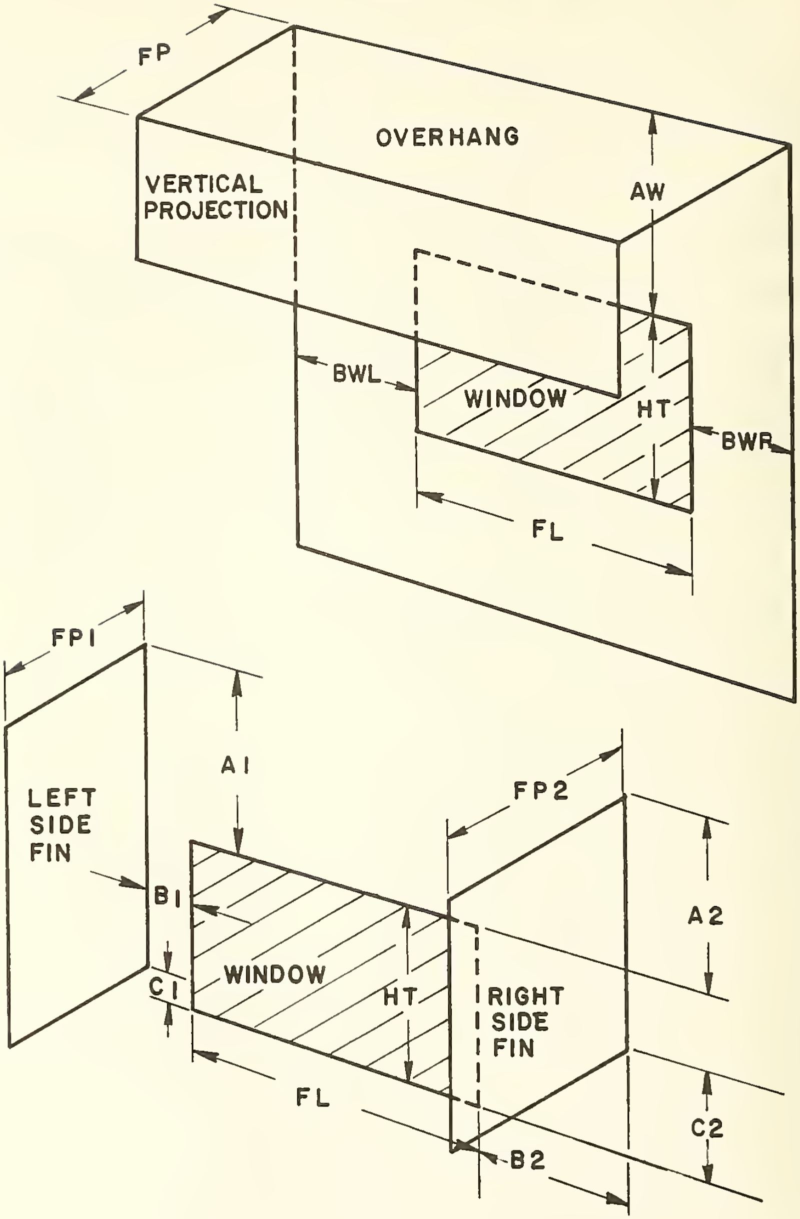
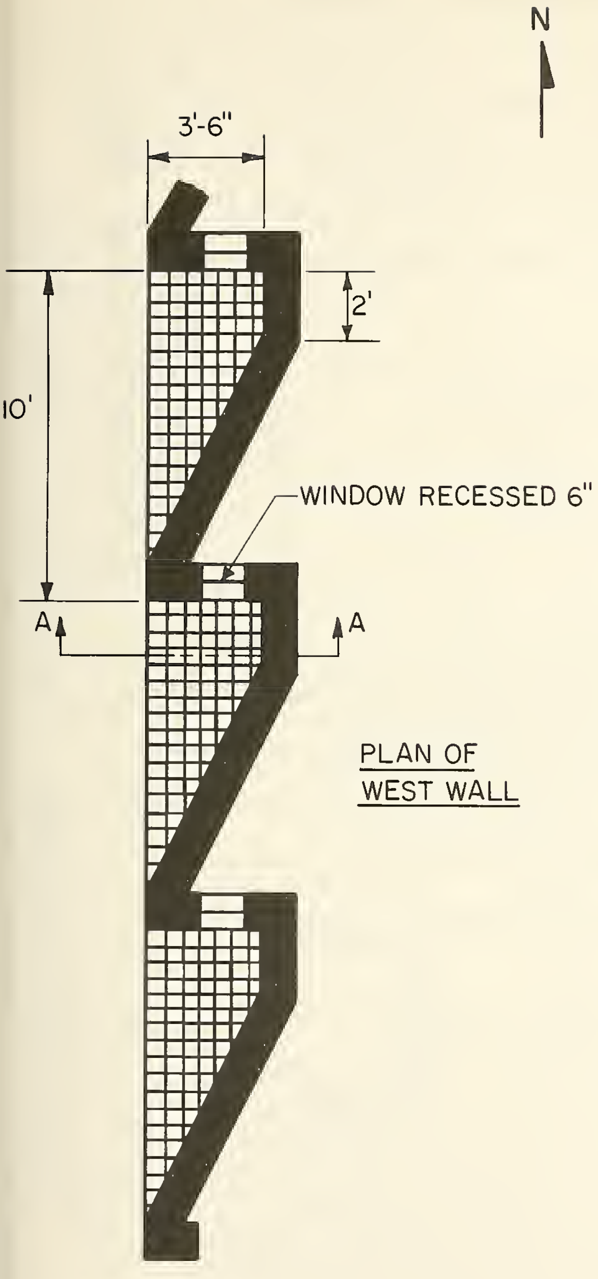

FP
OVERHANG
VERTICAL
PROJECTION
AW
BWL
WINDOW
HT
BWR
FL
FP1
A1
LEFT
SIDE
FIN
B1
C1
WINDOW
HT
FL
FP2
A2
RIGHT
SIDE
FIN
C2
B2

Figure 12


N
3'-6"
2'
10'
WINDOW RECESSED 6"
A
A
PLAN OF
WEST WALL

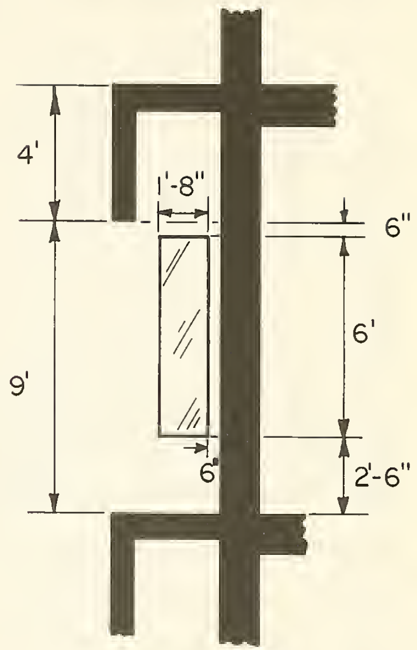

4'
1'-8"
6"
6'
9'
6"
2'-6"
SECTION A-A

Figure 13

Similar results are given by ASHRAE for closed draperies showing that they can reduce solar gain by as much as 65%. These internal shading devices are relatively inexpensive and yet can be very effective. Of course they must be used properly, that is, shades and drapes should be closed during the cooling season on sunlit surfaces and yet opened when needed during the heating season.

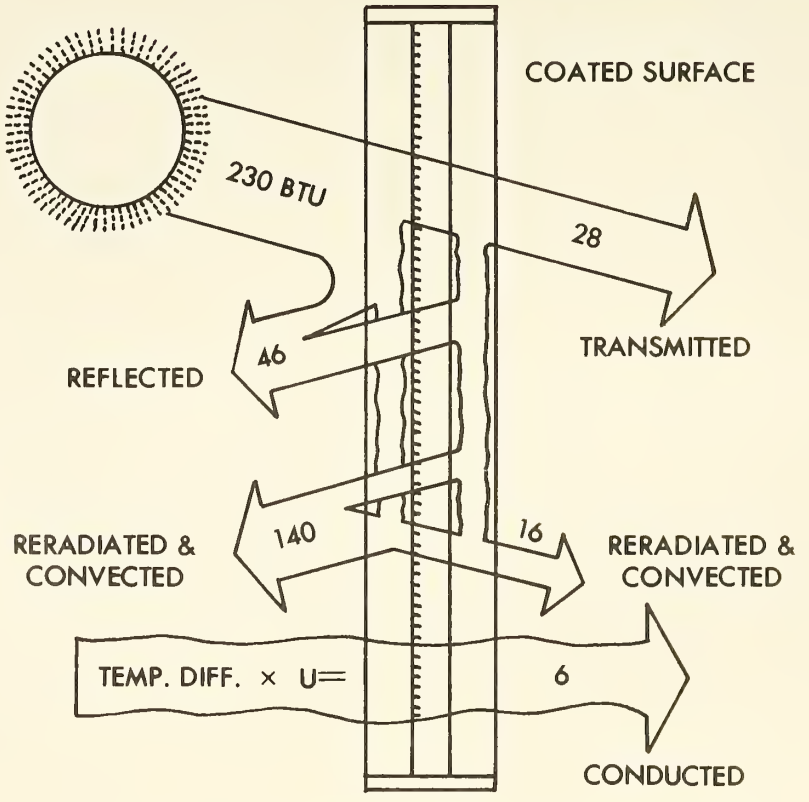
2. Use of other than ordinary glass: Where the opportunities arise in the design of commercial buildings, consideration can be given to the use of other than single plate glass. Most glass manufacturers have available a wide variety of glasses that are more efficient from a thermal standpoint and yet allow visual communication with the outside.

As an example of comparison with figure 11, figure 14 depicts what happens under the same environmental conditions where a commercially available double glass is used having one pane coated.[3/] The use of such glass is no doubt more expensive but might be justified as is demonstrated by the following example:

Consider the design of the Toledo Edison Building by the firm of Samborn, Steketee, Otis, and Evans. The Architects, along with Libby-Owens Ford, did a detailed computer study of the effects of a variety of glasses on the buildings' construction and operating costs. They selected a chromium coated dual wall insulating glass that made an added expense initially of $122,000 compared with the conventional 1/4" plate glass.

DOUBLE PANE - COATED SURFACE

OUTDOOR TEMP - 89°F
INDOOR TEMP - 75°F



RELATIVE HEAT GAIN 50 BTU

Figure 14

However, offsetting this initial expense was a savings of $123,000 in initial costs for the heating and cooling equipment, ductwork and the like. (A 64.7 percent reduction in the capacity of the central refrigeration system, a 53.2 percent reduction in the capacity of the central heating equipment and a 67.9 percent reduction in the capacity of the distribution system). The pay-off is the fact that the design chosen results in an energy consumption savings of 729.4 kilowatts per hour (translates to a savings in yearly operating cost of approximately $40,000).

The architect today has a wide choice of transparent surfaces to install. Heat absorbing glass hit the market in the late 50's and early 60's and can absorb as much as 45 percent of the solar energy striking it. Combining it with external shading such as sunscreen can be very effective, blocking up to 75 percent of the available solar energy. The effect of air movement between the screen and window offers further reductions. The big change in glass, however, has come in the past three or four years with the advent of reflective metallic coatings. They can block any desired amount of solar light and heat, with the standard transmittance ratings being 8, 14, and 26 percent; combined with dual insulating glass, the result is glass that keeps heat where it is wanted -- outside or inside -- depending on the weather conditions.

The individual homeowner would generally not consider the kind of glass mentioned above but indeed might be interested in double pane or storm windows. They offer a reduction in solar transmission for the cooling season of 10 to 15 percent (excluding the use of internal shading devices) but more importantly the glass area becomes at least twice as resistant to normal conduction transmission losses in the winter time. These losses can be significant as shown in figure 15 for a typical one story concrete slab house located in the center of the United States.[5/]

It should be noted that the window framing itself is important from a thermal standpoint. In a recent study by the Hittman Associates of Columbia, Maryland on the energy consumption of typical residences in the Baltimore-Washington area,[6/] they found that aluminum windows lose approximately 25 percent of the total window loss through the frame assembly. In contrast, wood assemblies lose only approximately 13 percent of the total window loss. The accompanying two figures, 16 and 17, show a comparison of total loss (winter) and gain (summer) for the two kinds of window frames.

3. <u>Use of smaller amounts of glass</u>

It appears feasible that in both commercial and residential dwellings it is possible to reverse the trend of large expanses of glass to minimize their poor thermal efficiency and yet allow for a sufficient amount of visual communication.

In a recent study completed at NBS on a federal government building in Manchester, New Hampshire (this will be described more fully in a later section), the effect of amount of glass

Center for Building Technology

DIVISION OF HEAT LOSSES BASEMENTLESS HOUSE ON CONCRETE SLAB

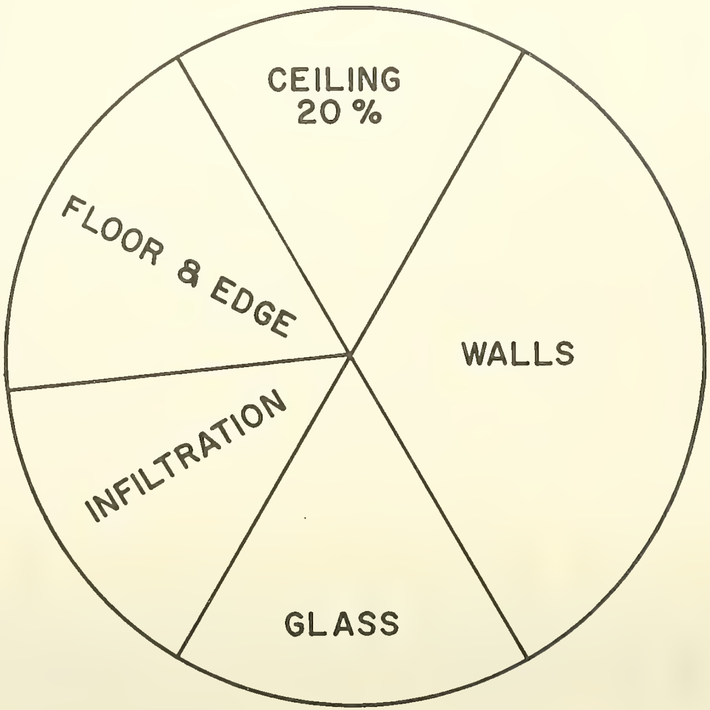


Figure 15

WINTER DAILY HEAT LOSS FOR WINDOW COMPONENTS

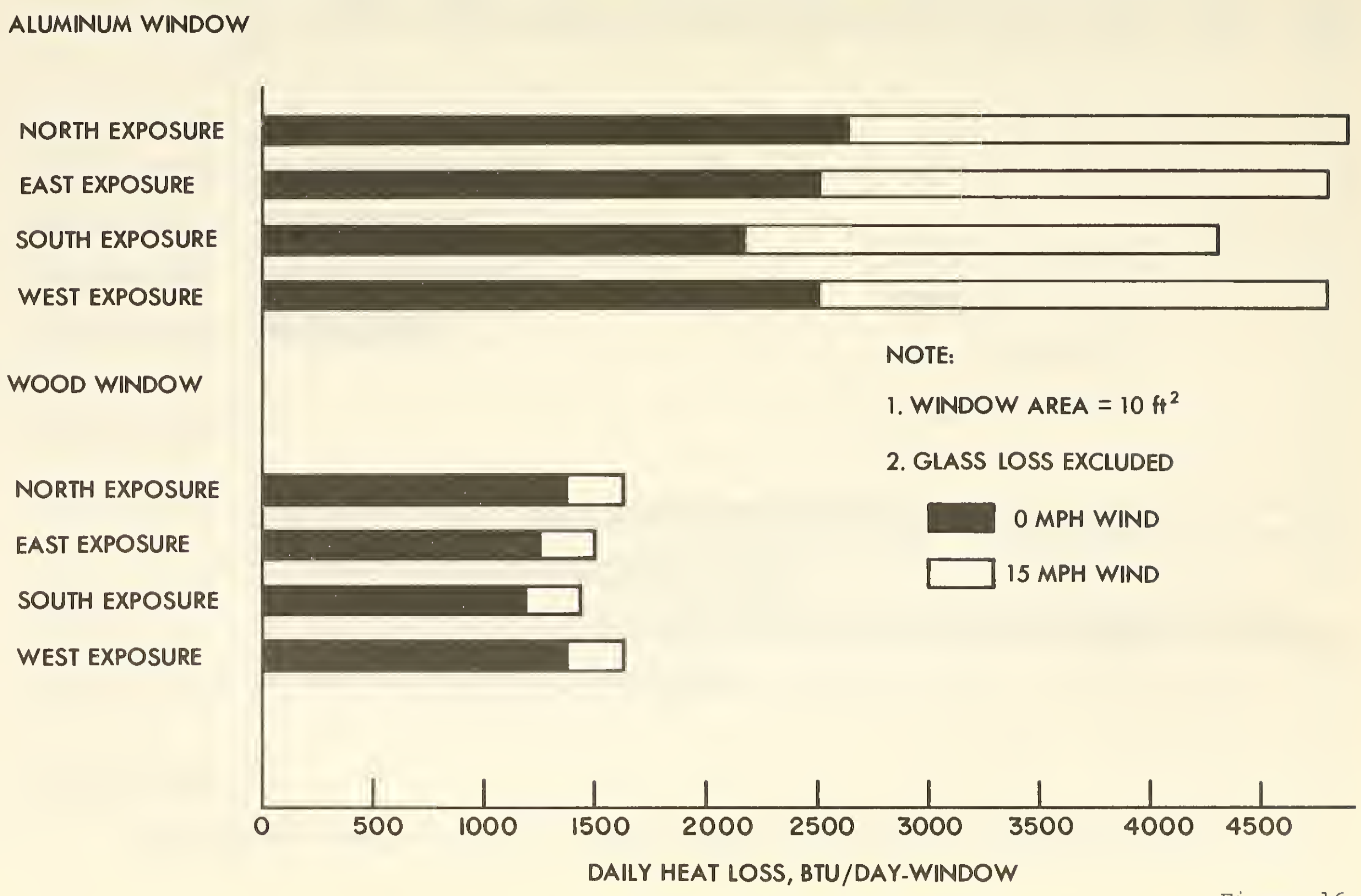


Figure 16

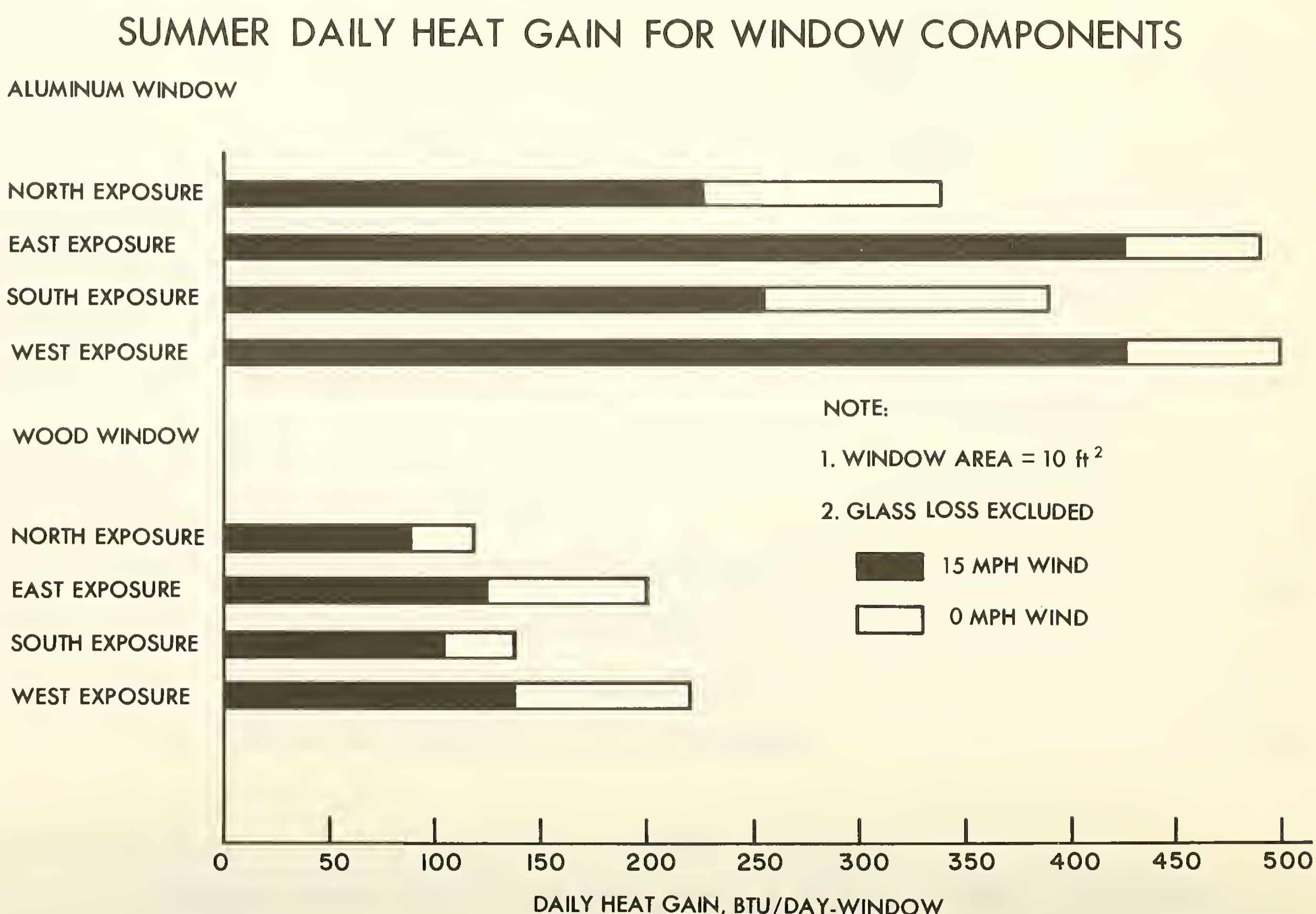
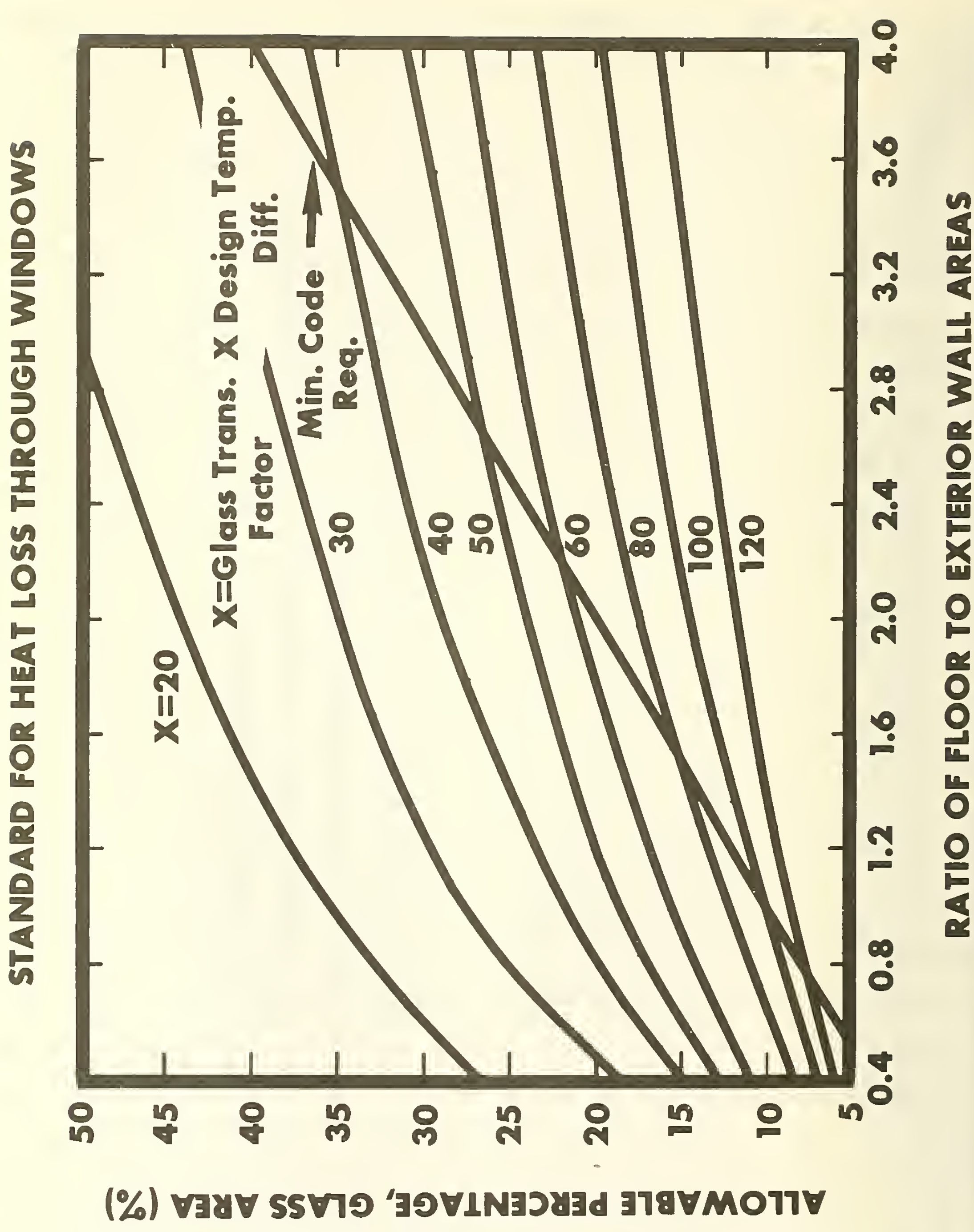

SUMMER DAILY HEAT GAIN FOR WINDOW COMPONENTS
ALUMINUM WINDOW
NORTH EXPOSURE
EAST EXPOSURE
SOUTH EXPOSURE
WEST EXPOSURE
WOOD WINDOW
NORTH EXPOSURE
EAST EXPOSURE
SOUTH EXPOSURE
WEST EXPOSURE
NOTE:
1. WINDOW AREA = 10 ft²
2. GLASS LOSS EXCLUDED
15 MPH WIND
0 MPH WIND
0
50
100
150
200
250
300
350
400
450
500
DAILY HEAT GAIN, BTU/DAY-WINDOW

Figure 17

on yearly energy requirements was determined. Reducing the window to exterior wall ratio (based on floor to ceiling height) from 50% to 10% resulted in a savings of yearly energy demand for all services by over 10%. Perhaps the ratio of 10% is too small; however, the architect should strive for a pleasing design giving proper fenestration due consideration.

Consideration should definitely be given to effective amounts of glass in residences. In making recommendations to FHA for inclusion into their Minimum Property Standards, NBS in 1972 devised figure 18 for determining allowable percentages of glass for any individual room. Under winter design conditions with the indoor air temperature at 75°F, the glass area of a living room/unit expressed as a percentage of its total exterior wall area should not exceed the value along the ordinate of the figure. The abscissca is the ratio of the floor area of the room/unit to the total exterior wall area including glass areas and doors and the third parameter "X" is as shown, the U value of the glass times the temperature difference at winter design conditions. This rationally derived chart thus accounts for the geographic location as well as the kind of glass used i.e., larger amounts of glass could be used for a given location provided one went from single pane to storm windows or insulating glass.



STANDARD FOR HEAT LOSS THROUGH WINDOWS
X=20
X=Glass Trans. X Design Temp. Diff. Factor
Min. Code Req.
30
40
50
60
80
100
120
ALLOWABLE PERCENTAGE, GLASS AREA (%)
50
45
40
35
30
25
20
15
10
5
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
RATIO OF FLOOR TO EXTERIOR WALL AREAS

Figure 18

ENERGY CONSERVATION FEATURES

LIGHTING

In office buildings, lighting consists of from 25 to 60 percent of the cooling load of air conditioning equipment and contributes from 20 to 30 percent of the total annual demand for electrical energy. Clearly, the reduction in lighting or the better utilization of energy expended for lighting will have a pronounced effect on not only the power demands for lighting, but also the power demands for operating air conditioning equipment. Without altering life styles or increasing total costs, energy required to light new buildings could be reasonably reduced by 25 percent. Demand for lighting could be cut by at least 15 percent in most existing buildings. Suggestions for the reduction in or better utilization of energy expended for lighting is summarized as follows:[7/]

1. Turn off lights when not needed. When the working or living space is empty, secure and not used for display or observation there is no need for lighting. The power energy savings realized are direct in winter and could be one and one half times the energy output of the lighting fixtures that have been turned off in summer due to the additional savings in cooling.

2. Control window brightness and utilize daylighting as practicable. The levels of illumination required for working and living spaces can be made adequate by the control of window

brightness and proper utilization of daylighting. Control systems could be utilized to turn off or reduce the amount of electric lighting when daylighting provides adequate illumination.

3. Provide planned operation and maintenance procedures. Operation and maintenance of lighting (electric and daylight) should be considered for both the utilization of power and economic considerations. Maintenance involves keeping lighting equipment clean and in good working condition so that illumination levels remain adequate for prolonged periods of time.

4. Use lighter colors on surface finishes of ceilings, walls, floor and furnishings. Light finishes increase the utilization of available light. By repainting ceilings, walls and floors and using lighter colors of furniture, the average illumination level of the room using the same light sources could be increased by as much as 30 footcandles (amount of light received by a surface). Reflectances of the surfaces should be in the following range*

Ceiling finishes	80-90%
Walls	40-60%
Furniture	26-44%
Office machines and equipment	26-44%
Floors	21-39%

---

* American Standard Practice for Office Lighting, ANSI A132.1-1966.

The upper reflectance limits have been selected to avoid excessively bright surfaces which could be uncomfortable.

5. Use efficient light sources and luminaires. For overall design, consideration should be given to the use of the more efficient light sources such as fluorescent and high pressure sodium and metal halide (HID) lamps. Incandescent lamps are about 30 percent as efficient in terms of the light output per electric power used (lumens/watt) as fluorescent lamps.

Incandescent Lamps

40-watt general service lamps produce 11 lumens/watt

60-watt general service lamps produce 14.3 lumens/watt

100-watt general service lamps produce 17.4 lumens/watt

100-watt extended service lamps produce 14.8 lumens/watt

1000-watt general service produces 22 lumens/watt

As can be seen higher wattage incandescent lamps are more efficient than lower wattage ones and in the same way general service lamps are more efficient than extended service (longer life) lamps.

Fluorescent Lamps

2 24-inch cool white lamps produce 50 lumens/watt

2 48-inch cool white lamps produce 67 lumens/watt

2 96-inch cool white lamps produce 73 lumens/watt

HID Lamps

400-watt phosphor coated mercury lamps produce 46 lumens/watt

400-watt metal halide lamps produce 74 lumens/watt

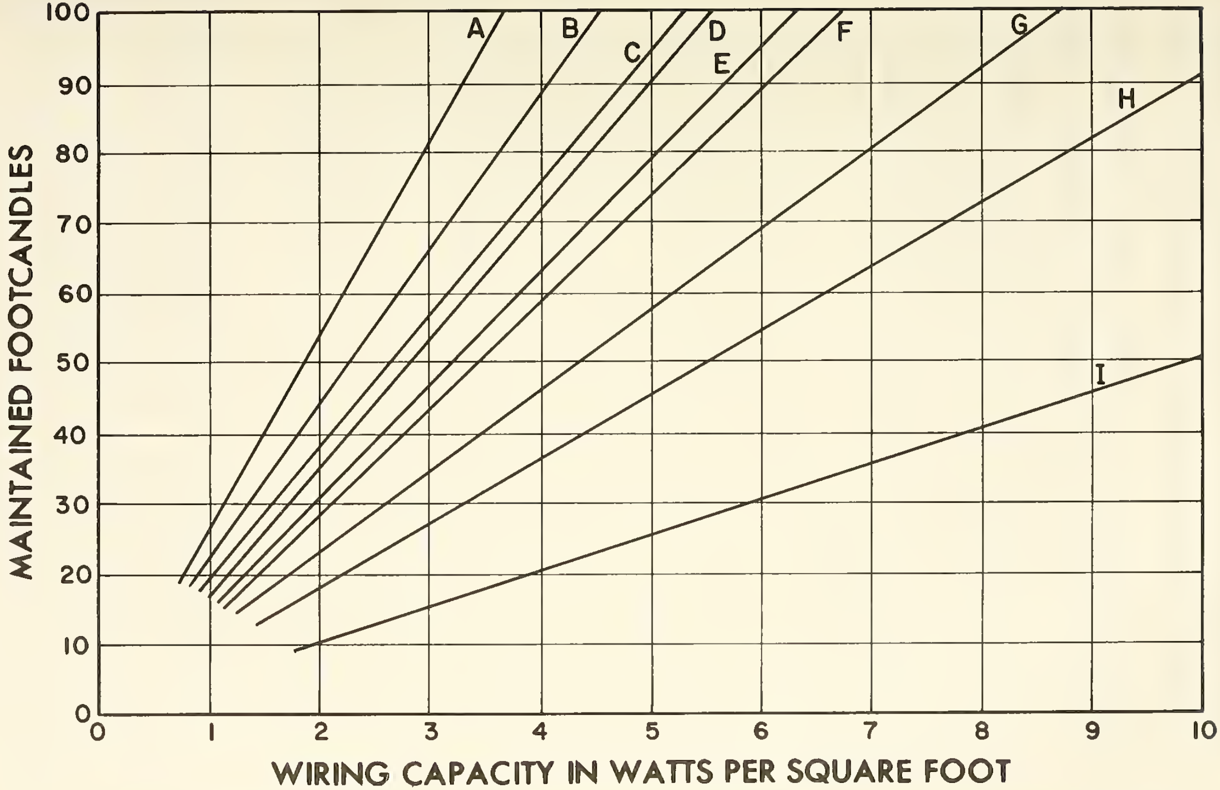
400-watt high pressure sodium lamps produce 100 lumens/watt

1000-watt metal halide produce 85 lumens/watt

Again higher wattage lamps are more efficient. HID lamps are usually used outdoors. More efficient luminaires produce a greater amount of light on the task surface with less wattage, as shown in figure 19. Where direct or semi-direct incandescent luminaires may require a load of 5.5 watts per square foot of floor area to produce a 50 foot candle level, general diffuse fluorescent luminaires require only 2.2 watts per square foot (*IES Lighting Handbook).

6. Design lighting for expected activities. Where task positions are fixed and known, the lighting should be designed accordingly where less lighting should be provided in surrounding non-working areas. The Illuminating Engineering Society recommends in the IES Lighting Handbook, values of illumination for visual tasks on a group of tasks in an area. The following statement is made: "Supplementary luminaires may be used in combination with general lighting to achieve these (task) levels. The general lighting should not be less than 20 footcandles and should contribute at least one-tenth the total illumination." Task oriented lighting by supplementary luminaires or suitable means can reduce electrical demand in many existing buildings as much as 20 to 50 percent.

Corridor and room lighting should be reduced to the maximum extent consistant with safety and security. The above mentioned reductions in light level can be accomplished by turning off lights or substituting lamps of lower wattage.



APPROXIMATE WIRING CAPACITY TO PROVIDE A GIVEN MAINTAINED LEVEL OF ILLUMINATION IN A ROOM OF 2.5 ROOM CAVITY RATIO BY MEANS OF THE FOLLOWING: A - DIRECT OR SEMI-DIRECT INDUSTRIAL FLUORESCENT B - GENERAL DIFFUSE FLUORESCENT C - DIRECT FLUORESCENT TROFFER D - DIRECT OR SEMI-DIRECT MERCURY INDUSTRIAL E - SEMI-INDIRECT FLUORESCENT F - DIRECT FLUORESCENT LUMINOUS OR LOUVERED CEILING G - INDIRECT FLUORESCENT H - DIRECT OR SEMI-DIRECT INCANDESCENT I - INDIRECT INCANDESCENT

IES LIGHTING HANDBOOK, 4th EDITION, 1966, PAGE 10-12

Figure 19

7. <u>Design with effective luminaires and fenestration</u>. Luminaire and fenestration lighting effectiveness depends on how well the light provided enhances the visibility of visual tasks. Light from either source, if not controlled can reduce visibility by producing veiling reflections and glare.

8. <u>Use heat transfer luminaires</u>. By using luminaires with air and water heat transfer capabilities, heat from luminaires can be removed before entering an occupied space in warm weather or conversely the heat can be utilized in occupied spaces in cold weather. By this means 30 to 80 percent of the total heat output of the lights can be withdrawn.

ENERGY CONSERVATION FEATURES

APPLIANCES

The several electrical appliances currently being used within a modern home consume approximately 12,000 KW-hr of electricity per year. The probabilistic distribution of annual energy consumption within a residence for appliances as given by Hittman Associates[6/] are shown below:

Appliances	Annual KW-hr
Central Air Conditioning	3600
Lights	2000
Range	1175
Refrigerator-Freezer	1830
Clothes Dryer	993
Color TV	500
Furnace Fan	394
Dishwasher	363
Clothes Washer	103
Iron	144
Coffee Maker	106
Miscellaneous	1200
	12408

Other appliances are listed as miscellaneous. These values are exclusive of the energy consumption of the heating system and the domestic hot water heater. It is obvious that the decreased use of any one of the above appliances will give reductions in energy consumption. Suggestions for reducing energy consumption are given as follows:

1. Cooking equipment could be made considerably more efficient in the following ways:
   a) Use cooking pots for better surface burner contact by using a pot of the same size as the burner and a flat bottom pot.
   b) Improve oven insulation in new appliances.
   c) Reduce heat transmission and air leakage of oven doors.
   d) Provide an outdoor vent for the oven for summer use.
   e) Use lids on pots and pans.
   f) Use thermostatically controlled stove surface units to reduce energy usage.
   g) When possible, use the oven in place of surface stove units and cook several items at once
2. Refrigerator-Freezer
   a) Frostless units consume approximately 1 2/3 times the energy of manual defrost units. Use manual defrost units where practical.
   b) Door gaskets on refrigerators and freezers should be checked for air leakage. If you can easily slide a dollar bill past the gasket it leaks air.
   c) Clean condenser coils of units to provide more efficient operation
   d) Open doors of units only when necessary to reduce heat and moisture gains.

3. Clothes washer-dryer

   a) Use maximum size loads for washer to reduce frequency of use

   b) Use cold and warm water settings with appropriate detergents to reduce hot water demands

   c) clean lint filters for more efficient operation

   d) Vent the dryer to the outside particularly for summer conditions

   e) Use automatic drying cycle because overdrying wastes energy

4. Other Appliances

   a) Discourage use of instant-on television sets. Without picture tube on, these sets continuously consume energy, e.g. about 50 watts for black and white and 100 watts for color.

   b) Load dishwasher completely to reduce frequency of operation

   c) Use heat producing appliances when demands on the cooling system are less - early mornings, evenings and cool days.

ENERGY CONSERVATION FEATURES

DOMESTIC HOT WATER

Ways to Reduce Energy Consumed in Domestic Hot Water Heating

At the present time the energy used for domestic hot water heating constitutes 4% of the total annual energy consumption - 2.9% for residential and 1.1% for commercial.[1/] This is equivalent to 1/4 of the energy used for residential space heating and about 1/6 of the energy used for commercial space heating. Suggestions for reducing energy consumption for hot water heating are given below:

1. Reduce Hot Water Temperature to 120°F

Most domestic hot water systems presently maintain water temperatures of 140-150°F or more. Average hot water utilization temperatures are in the range of 105-115°F with the exception of dishwashing and laundry operations (140°F for residential and 180°F for commercial and institutional). Since some dishwashers have built-in booster heaters and there are detergents available for use at low water temperatures, it is not necessary to maintain hot water at 140-150°F. The savings by maintaining water at a temperature of 120°F are:

a. Reduction heat losses from storage tanks and piping by 20-45%. Since the heat loss is about 1/4 of the energy input to a water heater, this amounts to 6-12% reduction in energy usage. For systems with long circulating pipe-lines (high-rise and large buildings), the reduction will be greater.

b. Reduction of energy input to hot water used for laundry and other residential uses (30% of the overall daily hot water usage) where no mixing with cold water is required. A 12-15% reduction in daily energy consumption for water heating is possible.

2. Reduce waste of hot water in taking showers and baths.

The typical daily hot water usage for bathing is about 42% of the total daily usage of hot water in a residence. If this amount can be reduced by 1/3, an energy savings of 14% in daily hot water heating is possible. The percentage saving will be higher for motels, hotels, dormitories and high schools since the major hot water usage is for washing.

3. Operate dishwashers and clothes washers only at full loads to reduce the number of washings needed.

4. Operate dishwasher and clothes washer in the morning or at night to reduce peak period power demand on electricity.

5. Shut-off the circulating line pump during non-occupancy period:

Most large office and commercial buildings have a well defined occupied period and a long hot water circulating pipe-line. Shutting off the circulating pump at night and during weekends, holidays, will eliminate pump power and the heat loss from the long run of pipe-line. (The line loss for insulated pipe is about 30 Btu/hr-ft, and for un-insulated pipe is 60 Btu/hr-ft of pipe).

6. Use detergents designed for cold or warm water washing:

This will eliminate the need for high water temperature laundry operation.

7. Insulate hot water storage tank if presently not insulated to reduce heat loss.

8. Insulate long run of circulating line - A bare pipe losses twice the heat from a pipe with 1/2" of insulation.

9. Repare leaky faucets.

One drop per second of hot water from a leaky faucet will amount to about 650 gallons of wasted hot water and energy over a year.

10. Check hot water temperature control device. Replace if not regulating properly.

11. Replace shower heads with smaller ones to reduce flow rate.

12. <u>For new buildings, avoid over-capacity in sizing hot water system</u>. Locate storage tanks as close to point of usage as possible to avoid long run of pipe-line. Consider the installation of separate water heaters or booster heaters for special purpose high temperature operation.

ENERGY CONSERVATION FEATURES

HUMAN COMFORT

In various other parts of this document, reference has been made to saving energy by the use of more clothing, less clothing, higher or lower levels of temperature and/or relative humidity. Justification for these changes can be made on the basis of research done over the past fifty years.

There are approximately twenty prominent indices or groups of experimental data that have been presented to indicate man's response or feeling when subjected to a certain environment. The majority are experimental in nature (i.e., human subjects have been exposed to a specified and controlled environment and asked to describe their feeling or at least have physiological measurements taken on them during the exposure). However, during the last several years there has been a great deal of interest in describing mathematically the thermal interaction between man and his environment, thus enabling one to predict what occurs or how one might feel in given surroundings.

Undoubtedly the most familiar of all comfort indices is the American Society of Heating, Refrigerating and Air Conditioning (ASHRAE) Effective Temperature. The scale was first established in the 1920's by Houghten and Yaglou.[8/] Subjects wearing clothing having an unspecified insulation value were passed between test chambers in which the temperature, air velocity, and humidity were maintained at specified levels and were asked to describe their feeling immediately upon entering the new environment. The results are shown in figure 20 where lines of constant thermal sensation are shown plotted on a temperature-relative humidity chart. The experiments were conducted for a large range of air velocities; however, the data shown here is for an air velocity of less than 20 fpm. The lines of constant thermal sensation were arbitrarily given numerical values corresponding to the temperature at which the line intersected the 100% relative humidity curve. One should note the large dependence of thermal sensation on relative humidity. This dependence continues to be accepted as valid in the very hot region but has been abandoned as inaccurate in the comfort region or the region of most interest in analysis for energy conservation.

Perhaps the most definitive experimental study on thermal comfort is one conducted on over 1600 college students at Kansas State University over the past several years.[9/] The students were exposed (over a 3 hour period) to a uniformly heated or cooled environment (wall temperatures identical to the air temperature) with moderate air velocities and asked to vote on a scale from 1 to 7 which ranged from cold to hot:

1. cold
2. cool
3. slightly cool
4. comfortable
5. slightly warm
6. warm
7. hot

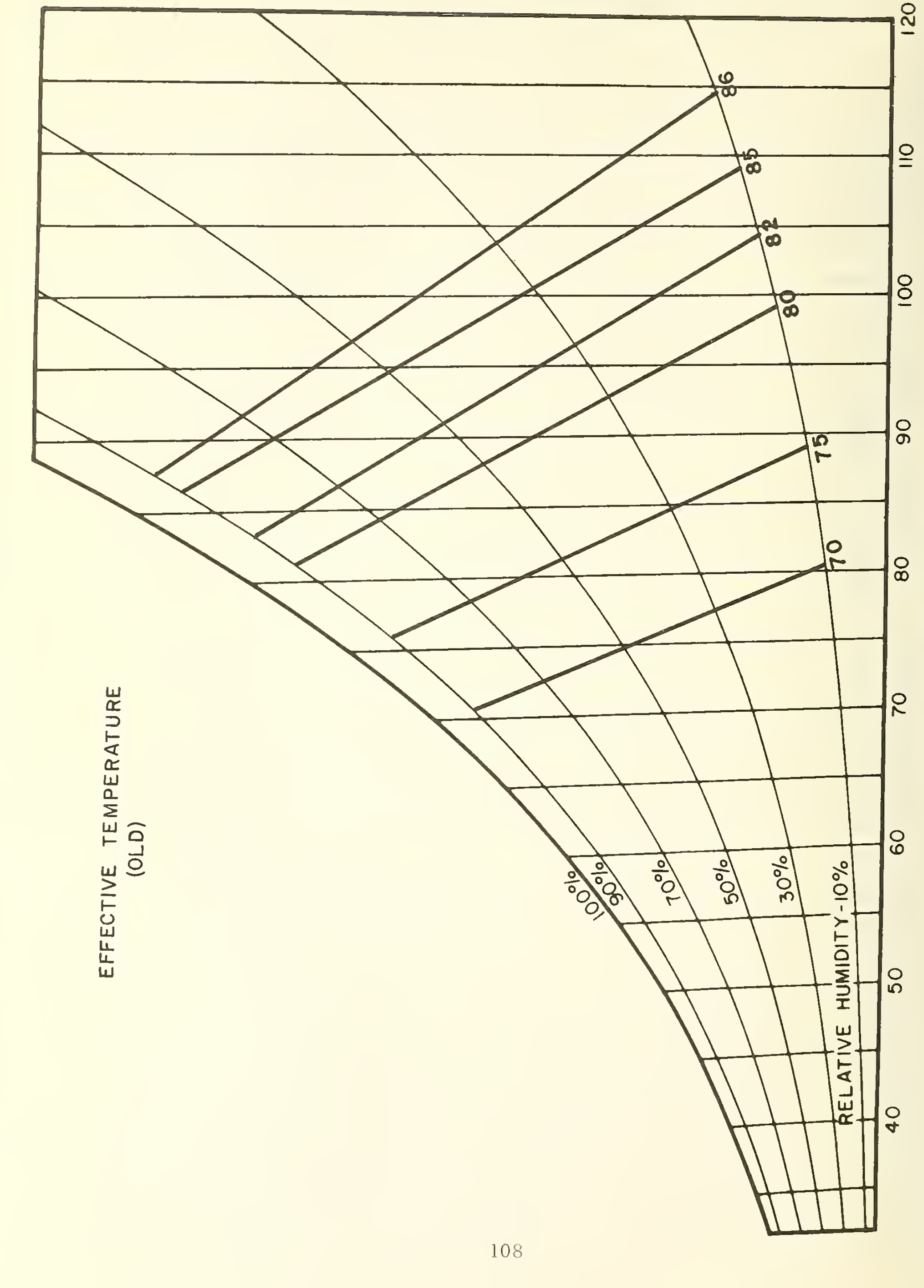

EFFECTIVE TEMPERATURE
(OLD)
100%
90%
70%
50%
30%
RELATIVE HUMIDITY-10%
70
75
80
82
85
86
40
50
60
70
80
90
100
110
120
DRY BULB TEMPERATURE, °F

Figure 20

All subjects, males and females alike, were clothed in cotton twill shirts and trousers (shirts worn outside of the trousers), and cotton sweat socks without shoes. The net insulating value for the clothing ensemble, as computed by means of an electrically heated copper manikin has been determined to be 0.6 clo* which has been generally accepted as the standard clothing for thermal comfort studies.

Even though the results are available for men and women separately and also for the votes taken at each half an hour for the entire 3 hours of exposure, the data shown in Figure 21 is an average for the votes of men and women taken together at the end of the 3 hours. One should note the very slight dependence of comfort on relative humidity. Studies such as these have led to the conclusion that temperature is far more important than relative humidity at comfort conditions.

One of the most significant attempts to predict analytically the thermal interaction between man and his environment is presented by P. O. Fanger of the Technical University of Denmark in his recent book Thermal Comfort.[10/] He begins by pointing out the most important variables which influence the condition of thermal comfort:

1. activity level (heat production in the body)
2. thermal resistance of the clothing (clo-value)

*1 clo represents a measured resistance to heat transfer of the clothing ensemble of 0.18 sq. m hr °C/Kcal. (0.88 sq. ft hr °F/Btu or equivalent of an overall heat transfer coefficient - 1.13 Btu per (hr)(sq. ft)(F)).

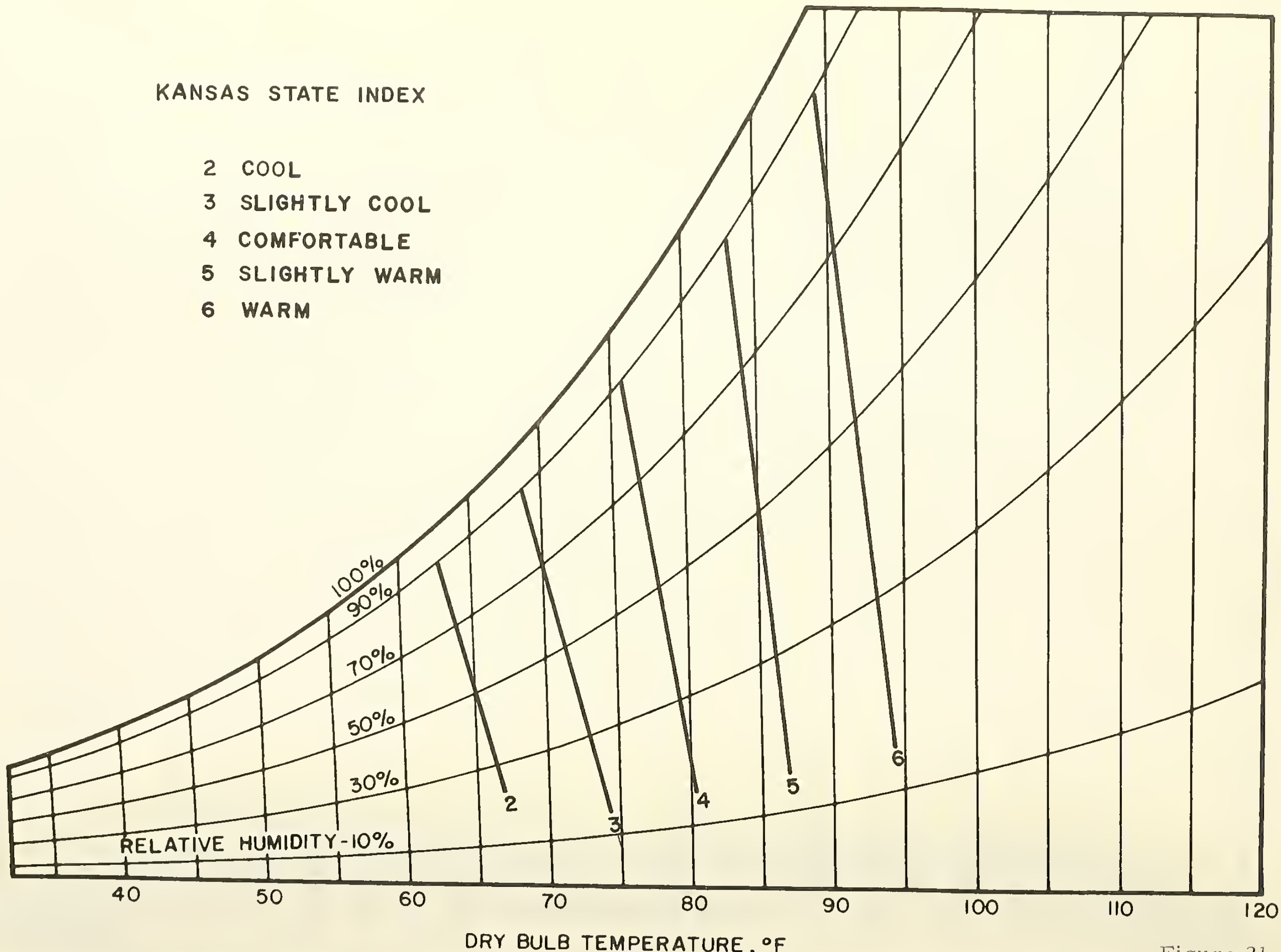

KANSAS STATE INDEX
2 COOL
3 SLIGHTLY COOL
4 COMFORTABLE
5 SLIGHTLY WARM
6 WARM
100%
90%
70%
50%
30%
RELATIVE HUMIDITY-10%
2
3
4
5
6
40
50
60
70
80
90
100
110
120
DRY BULB TEMPERATURE, °F

Figure 21

3. air temperature (dry-bulb)

4. mean radiant temperature

5. relative air velocity

6. water vapor pressure in ambient air

The basis of his analysis is the so-called general comfort equation which defines all combinations of the variables which will create thermal comfort. The importance of such equations lies in the fact that once proven valid, they can be used very quickly to determine the effect of changing any one of the six variables, something considerably more difficult by experimentation. His comfort equation was modified to define a variable predicted mean vote (PMV) and a scale similar to the one used in the Kansas State Studies was chosen:

-3 cold

-2 cool

-1 slightly cool

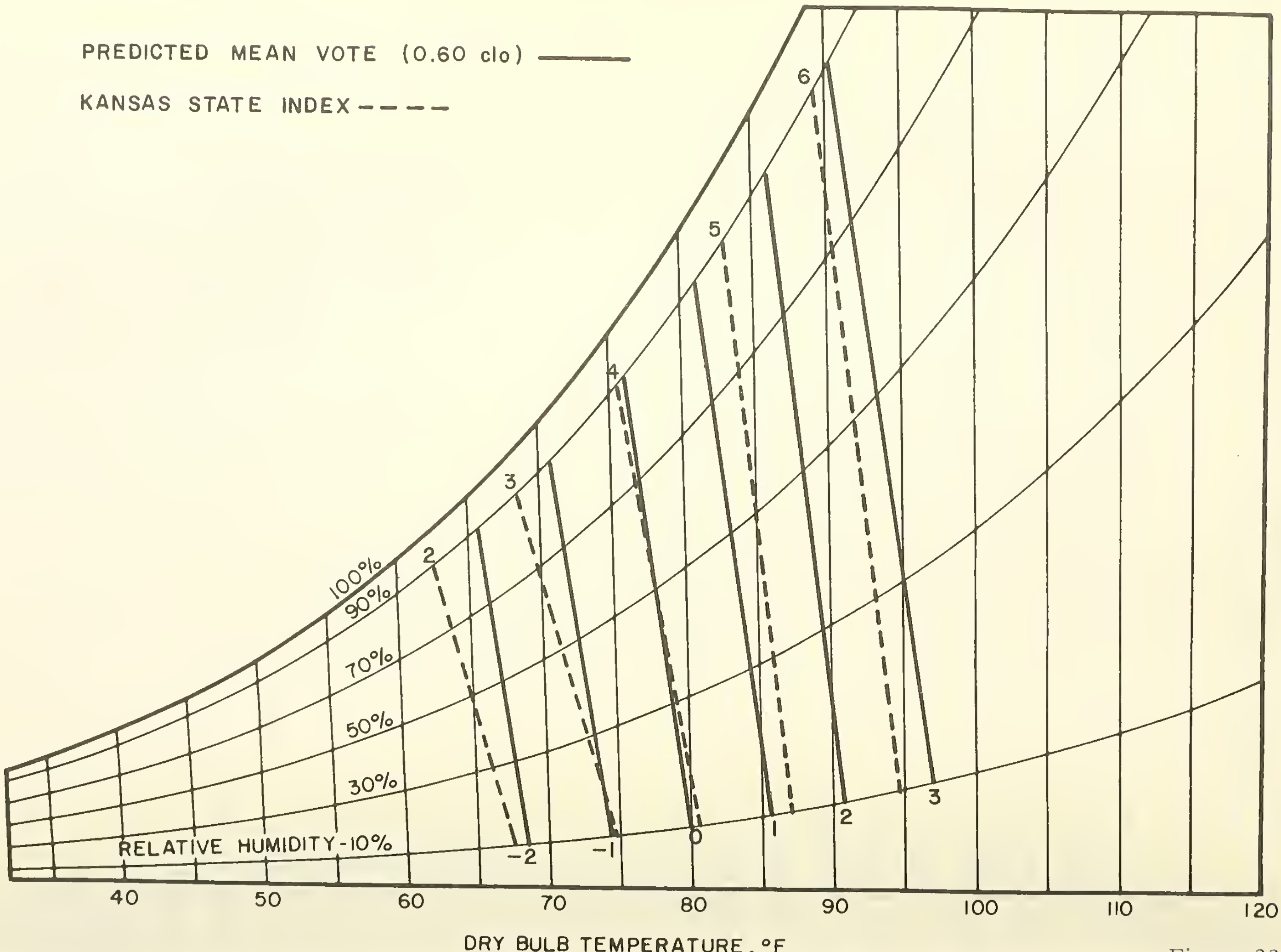
0 neutral

+1 slightly warm

+2 warm

+3 hot

The numerical values, however, are lower by 4. A scale is thus obtained which is easier to remember, as it is symmetrical around the zero point, so that a positive value corresponds to the warm side and a negative value to the cold side of neutral. In figure 22 the results are compared with the experimentally determined KSU comfort vote. As can be seen the agreement is



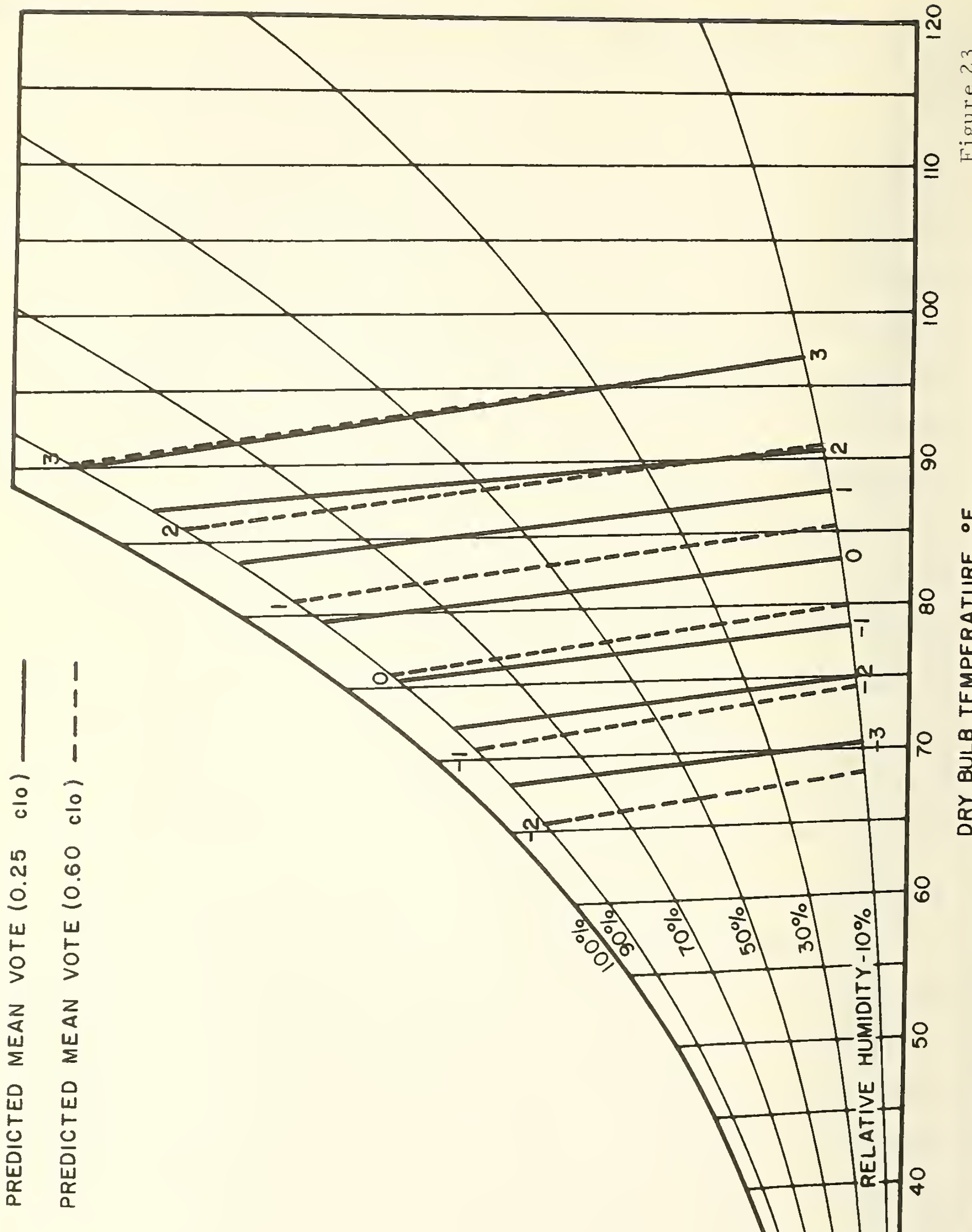
PREDICTED MEAN VOTE (0.60 clo)
KANSAS STATE INDEX
100%
90%
70%
50%
30%
RELATIVE HUMIDITY-10%
2
3
4
5
6
−2
−1
0
1
2
3
40
50
60
70
80
90
100
110
120
DRY BULB TEMPERATURE, °F

Figure 22

excellent for the comfort line (KSU = 0, PMV = 4) but not so good for environmental conditions outside of the comfort range.

As mentioned previously, an advantage of an analytical model such as this is the capability of observing the effect of one of the six controllable parameters without having to conduct extensive experiments. For example, it may be unrealistic to assume that during the summer subjects will wear the standard 0.6 clo clothing ensemble. Certainly in hot weather people would be more inclined to wear lighter clothing such as shorts and an open neck shirt with short sleeves. Data for this type of clothing ensemble (clo = 0.25) is compared with the standard Kansas State clothing ensemble in figure 23. The comparison shows what one might intuitively expect. For lighter clothing, subjects would report comfort at 4 or 5°F warmer temperature. It would be expected that they would vote cool at a somewhat higher temperature also (approximately 6°F). However, both subjects would vote hot at approximately the same temperature and relative humidity.

Consequently for the sake of energy conservation, one can justify higher temperature limits in the summer if lighter clothing is worn and lower temperature limits in the winter if more than the standard amount of clothing is worn. Figure 24 has been included here to show precisely by use of Fanger's analysis, how the "acceptable room temperature" can be varied by changing the clothing.



PREDICTED MEAN VOTE (0.25 clo)
PREDICTED MEAN VOTE (0.60 clo)
100%
90%
70%
50%
30%
RELATIVE HUMIDITY-10%
-3
-2
-1
0
1
2
3
40
50
60
70
80
90
100
110
120
DRY BULB TEMPERATURE, °F

Figure 23

ACTIVITY LEVEL - SEDENTARY ADULT

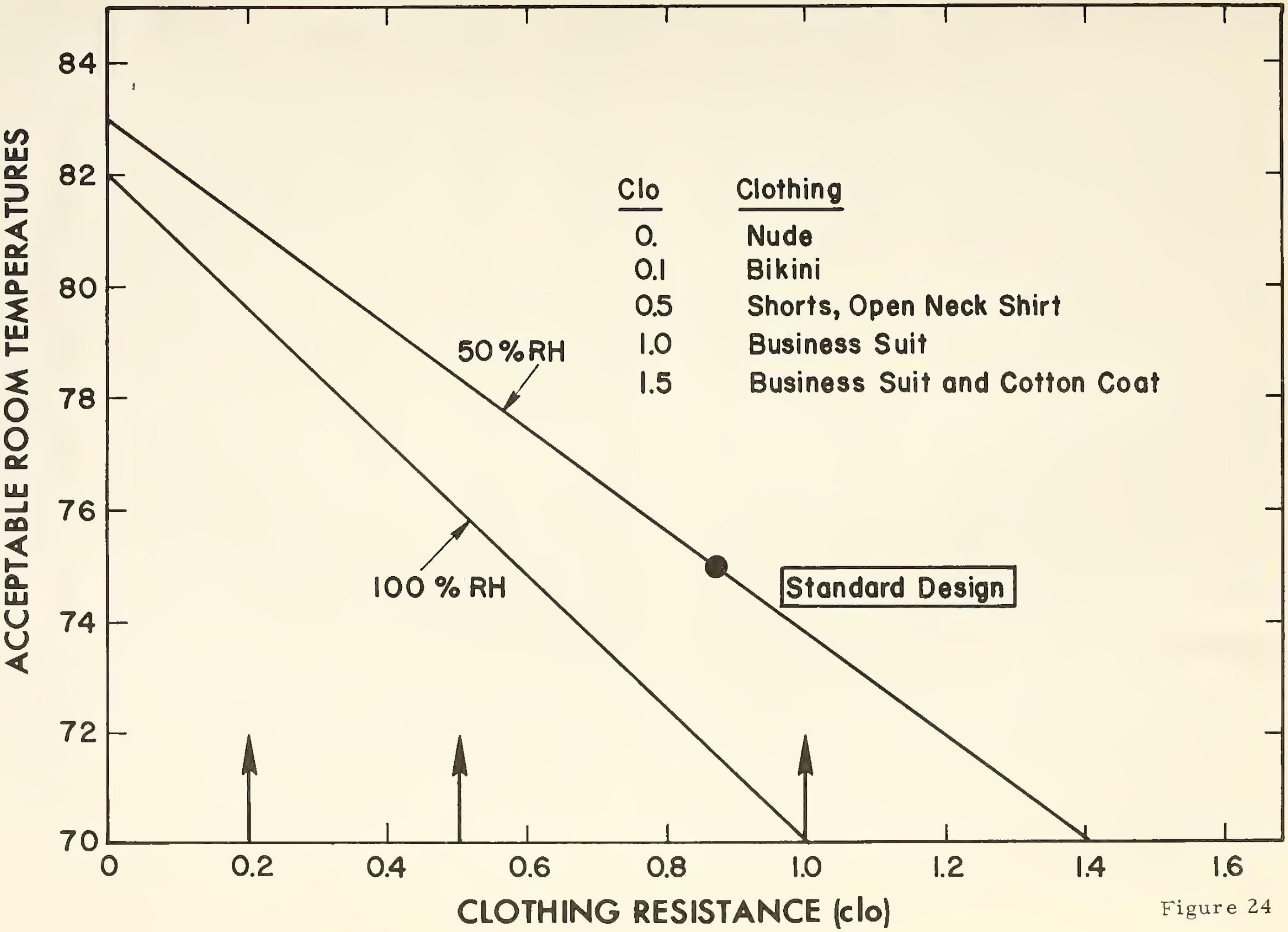


Figure 24

In setting upper and lower limits for the control of temperature and/or relative humidity for the sake of saving energy, the ASHRAE Standard 55-66 can be referenced. This standard was established in 1966 and based on a careful analysis of all existing analytical and experimental studies on human thermal comfort. Its contents are presently being reevaluated in light of the massive amount of work that has been done over the last several years.

The Standard is very specific in its stipulation of thermal comfort conditions. It states in part that in a region between 3 inches above the floor and 72 inches above the floor and at least 2 feet from any wall, the following should be met at all times:

1. The dry bulb temperature shall be between 73 and 77°F.
2. The relative humidity shall not exceed 60 percent and be greater than 20 percent.
3. The air motion shall not exceed 45 fpm and be greater than 10 fpm.

Of course most space conditions are not completely uniform and are also time dependent. To cover these more realistic occurrences, the Standard also includes the following:

4. The rate of change of dry bulb temperature at any point in the occupied zone shall not exceed 4 deg/hr if the peak-to-peak variation in the temperature cycle is two degrees or greater within the limits stated in 1.

5. The rate of change of relative humidity at any point in the occupied zone shall not exceed 20 percent/hr if the peak-to-peak variation of the humidity cycle is 10 percent or more, within the limits stated in 2.

6. When the mean radiant temperature* in the occupied zone differs from the dry bulb temperature, the dry bulb temperature shall be reduced 1.4°F for each 1.0°F mean radiant temperature elevation above air temperature and vice versa.

7. The rate of change of mean radiant temperature at any point in the occupied zone shall not exceed 3 deg/hr if the peak-to-peak variation of the MRT cycle is 1.5°F or more, within the limits stated in 6.

Consequently based on the Standard, one could justify 77°F and 60% RH in the summer and 73°F and 20% RH in the winter. It is felt by proper clothing the upper temperature limit can be extended to 80°F and the lower one can drop to 68°F.

*Mean radiant temperature is defined as the uniform surface temperature of an imaginary black enclosure with which man (also assumed a black body) exchanges the same heat by radiation as in the actual environment.

NEW BUILDINGS

The opportunity for energy savings in new buildings falls into one of the following categories:

1. Building structure and/or fabric design
2. Building system design, and
3. Building operation.

The areas unique to new buildings by and large fall mainly into the first two categories. Consequently those will be discussed here since many of the operation controls have been mentioned previously.

Building Design:

Since there presently exists few controls or regulations on the use of energy in buildings, many of the steps that can and should be taken to conserve energy have to be economically effective to be accepted on a wide scale. It is therefore imperative to have life cycle costing as an integral part of the decision making process and design process for new buildings. That is, decisions on design and selection of equipment should be based on the lowest initial cost plus owning and operating costs (including energy costs) for a reasonable life expectancy of the building rather than lowest first cost alone. The impact of this statement can be demonstrated by use of the following example:

Consider how the increased first cost associated with extra insulation can be justified on the basis of savings in operating costs.

Source: NAHB Insulation Manual 1971.*

Small house, one-story, in Columbus, Ohio.
Floor area 1370 ft^2; total wall area 1480 ft^2;
Window plus door area 260 ft^2; double glass windows.

Ceiling	R-7**	R-11**	R-19**
Wall	R-7**	R-11**	R-11**
Heating Cost/yr	$87	$72	$66
Cooling Cost/yr	37	33	30
Operating Cost Savings		$19	$28/yr
Cost of added insulation		$85	$181
Reduction in first cost:			
Furnace		$10	$30
Flue		5	10
Elec. System		5	8
Ducts		5	5
Inside wall ducts		10	10
Air conditioner		75	200
		$110	$263
Net first cost		$-25	$-82

In any detailed analysis of a building design, one can make the following general statements:

1. For residences, the most significant features include the use of insulation, control of infiltration, and to some degree consideration for proper fenestration.

*The calculations were performed by NBS based on data presented in this reference.

**Indicates the level of thermal resistance or degree of insulation. The larger the R value, the more the resistance or amount of insulation.

2. For commercial buildings, the most significant features that should be addressed include the use of insulation, proper fenestration, control of ventilation amounts, levels of illumination, orientation of the building, and to some degree, the amount of exposed surface area.

Since the importance of all the factors mentioned above has been discussed in some detail previously, they will not be further discussed; however the type of analysis generally necessary for the design of a building for the sake of conservation will be illustrated here by way of an example.

NBS is participating in a study of the design and construction of a federal office building to be built in Manchester, New Hampshire. The study was done in order to determine what could be done in the design of the building to ultimately conserve energy. The study will be outlined here giving numerical results and it can be assumed that the results are typical of what one would expect for the analysis of most commercial buildings of a comparable size.

The building is to be seven or eight stories high having a gross office floor area of approximately 125,000 ft^2. A sophisticated mathematical[11/] model for the thermal response of buildings was used in conjunction with New England weather data for the year 1962 to determine the thermal requirements of a building constructed according to "typical design practice" for that area. The defined building parameters were as follows:

1. U-value of the roof = 0.20 $\frac{Btu}{hr\ ft^2\ °F}$

2. U-value of the walls = 0.30 $\frac{Btu}{hr\ ft^2\ °F}$

3. U-value of the floor above the garage = 0.25 $\frac{Btu}{hr\ ft^2\ °F}$

4. Windows - single pane with no external shading but internal shading so that the solar transmission would be reduced by 50%.

5. Windows area equal to 50% of the exposed floor to ceiling height on each floor.

6. The length to width ratio was 2:1 with the long axis running north to south.

Additional assumptions were made including

1. natural infiltration of outdoor air continuously at a rate of 1/4 volume of the building per hour

2. Indoor conditions of

Summer	Winter
75°F, 50% RH - day	70°F, 30% RH - day
85°F - night	60°F - night

3. For 10 hours a day (Monday thru Friday)

   indoor lighting of 2.9 watts per ft^2 of gross floor area

   occupancy of 600 people,

ventilation air introduced from the outside at a rate of 15,000 cubic feet minute, and

heat output of office equipment at a rate of 1/2 watt per ft^2 of gross floor area.

To determine the effect that possible design changes had on total building energy consumption and not just on heating and cooling loads, additional assumptions were made that included

1. assumed seasonal efficiency for heating of 60%,
2. assumed seasonal coefficient of performance for cooling of 2.5, and
3. various other "rules of thumb" for electrical requirements of fans, pumps, cooling tower, elevators, etc.

Once this "basic building" was defined, its yearly energy consumption was predicted for the year 1962 as shown in figure 25. One should note the relatively large percentage of the total energy consumed that goes for lighting as well as driving the pumps and fans for the heating and cooling systems. Figure 26 shows the percentage of the heating load that can be attributed to the various building components with figure 27 showing a similar plot for the cooling load. Note that over 70 percent of the cooling load during the months of December and January can be assigned to the lights; however the load is low during these months.

Following this initial determination, individual design changes were made and the calculation repeated to determine

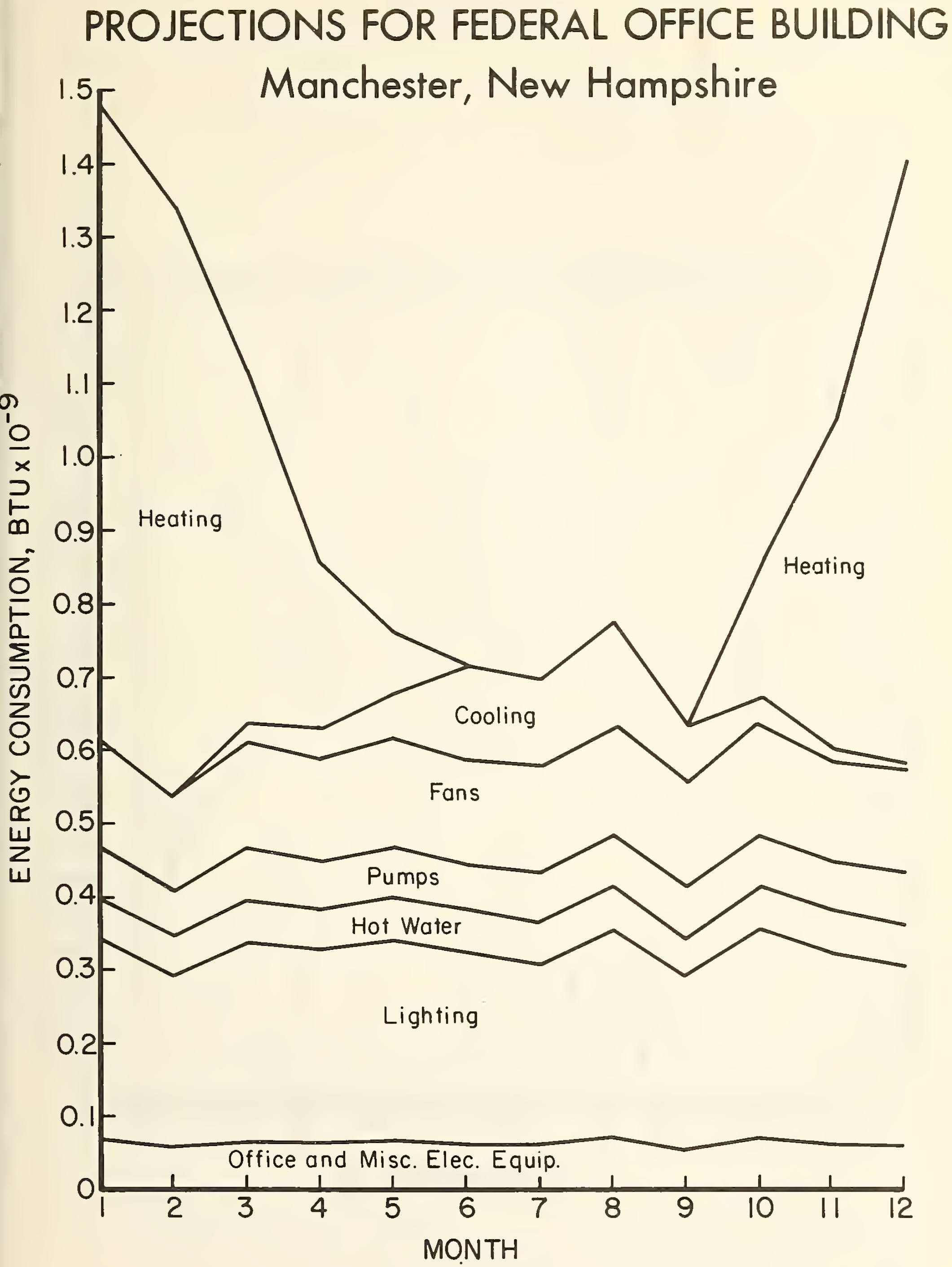

PROJECTIONS FOR FEDERAL OFFICE BUILDING
Manchester, New Hampshire
ENERGY CONSUMPTION, BTU x 10^-9
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Heating
Heating
Cooling
Fans
Pumps
Hot Water
Lighting
Office and Misc. Elec. Equip.
1
2
3
4
5
6
7
8
9
10
11
12
MONTH

Figure 25

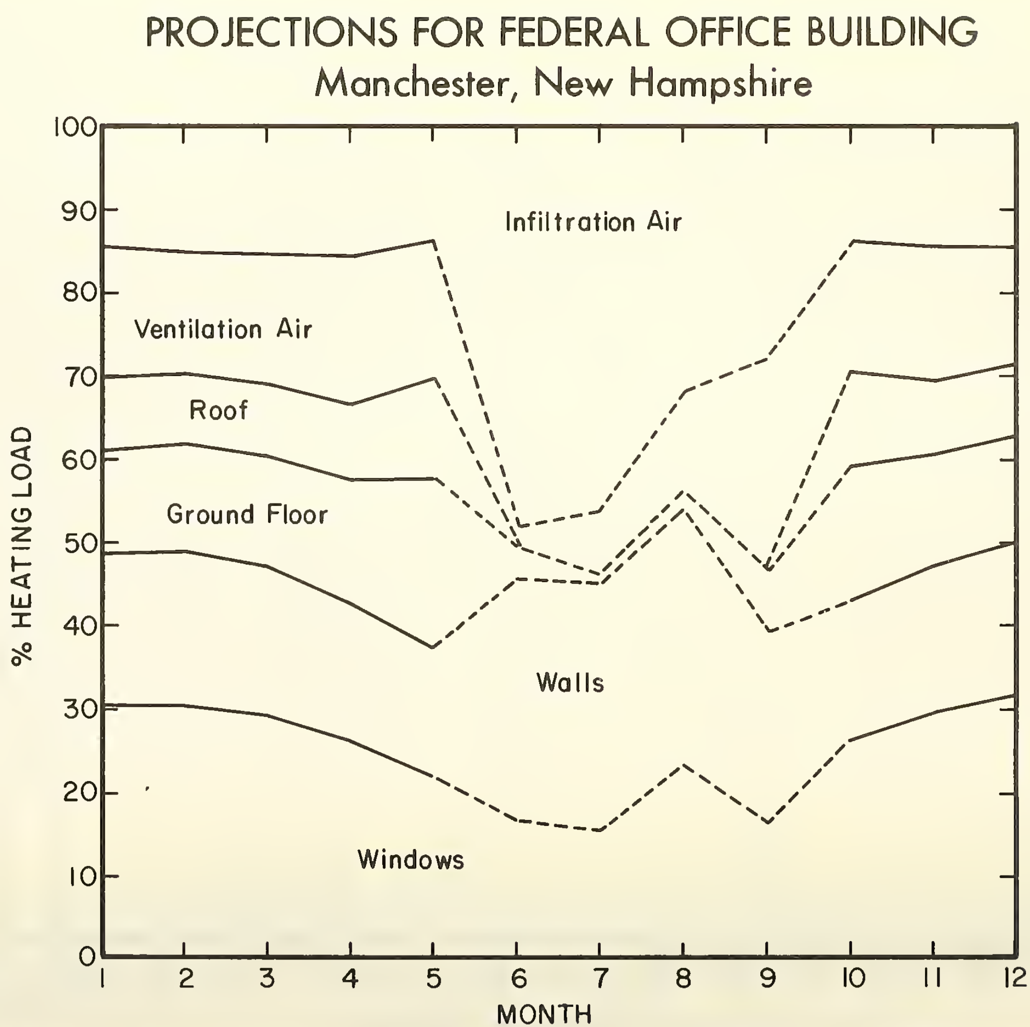

PROJECTIONS FOR FEDERAL OFFICE BUILDING
Manchester, New Hampshire
% HEATING LOAD
MONTH
Infiltration Air
Ventilation Air
Roof
Ground Floor
Walls
Windows
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12

Figure 26

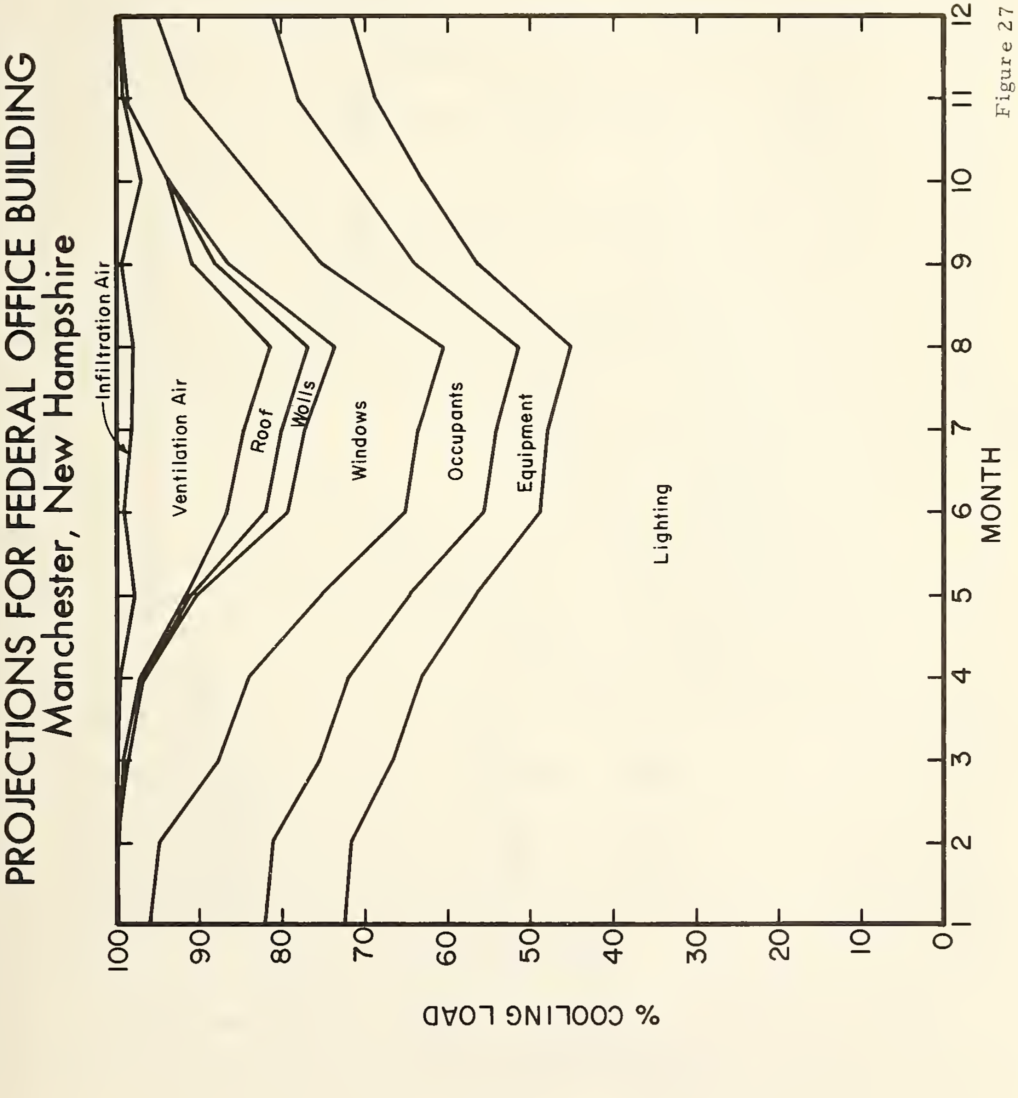

PROJECTIONS FOR FEDERAL OFFICE BUILDING
Manchester, New Hampshire
% COOLING LOAD
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
MONTH
Infiltration Air
Ventilation Air
Roof
Walls
Windows
Occupants
Equipment
Lighting

Figure 27

the percent reduction in annual energy consumption. The results are as follows:

1. Roof U-value from 0.20 to 0.06 3.5%
2. Wall U-value from 0.30 to 0.06 8.5%
3. Floor U-value from 0.25 to 0.06 6.0%
4. Window from single pane to triple pane 13.5%
5. Window internal shading removed * 2.5%
6. Window area from 50% of exposed wall area to 10% 10.5%
7. Building height increased 4 stories** 2.5%
8. Building changed to a square shape** 2.0%

Since these reductions in energy consumption could not be assumed to be directly additive, one final calculation was made using the following conditions

1. all U-values = 0.06
2. double pane windows with internal shading
3. window area only 10% of exposed floor to ceiling height
4. original height and shape

The result of this calculation was a 33 percent reduction in yearly energy requirements compared to the initial building.

One should be cautioned that a constant and optimistic efficiency was assumed for the heating and cooling equipment throughout this study. Depending upon the type of system and

*The increased cooling load was negated by the reduction in in heating load during winter months.
**These changes were made in such a way that the gross floor area remained the same.

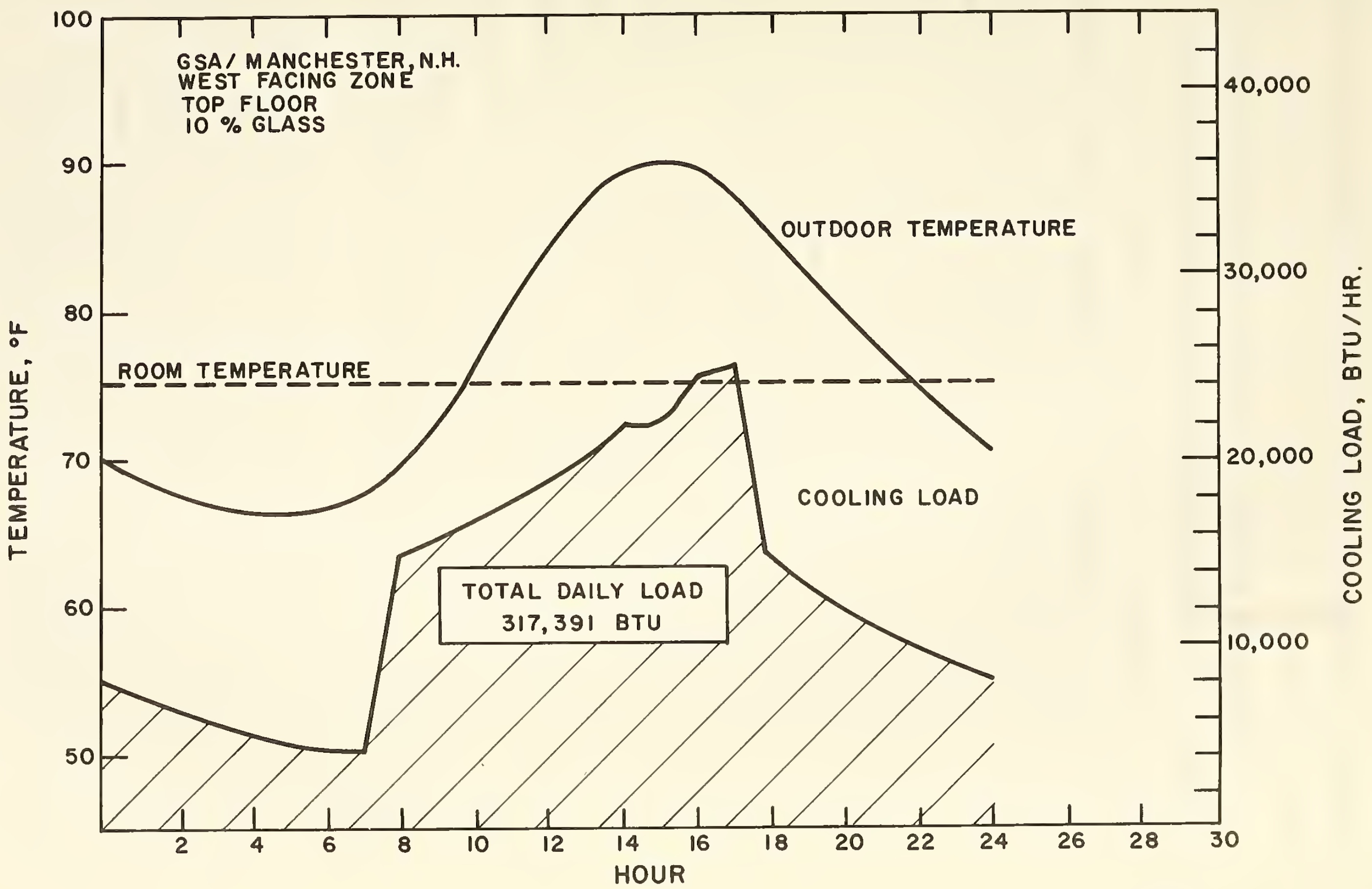

GSA/ MANCHESTER, N.H.
WEST FACING ZONE
TOP FLOOR
10 % GLASS
OUTDOOR TEMPERATURE
ROOM TEMPERATURE
COOLING LOAD
TOTAL DAILY LOAD
317,391 BTU
TEMPERATURE, °F
100
90
80
70
60
50
COOLING LOAD, BTU/HR.
40,000
30,000
20,000
10,000
HOUR
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

Figure 28

degree of control installed, the 33 percent figure could be altered significantly.

In order to show what could be done in the sizing of equipment allowing for realistic fluctuation of space conditions an exterior zone on the top floor and west side of the building was isolated for analysis. A completely cloudless summer day was chosen and a conventional design calculation was done as shown in figure 28. In order to maintain the indoor temperature precisely at 75°F and constant, a peak capacity of 25,000 Btu/hr is needed and the accumulated load is 317,000 Btu for the day. Figure 29 shows that by setting the temperature up 5°F at night, the accumulated load decreases approximately 8 percent; however the peak capacity had to be increased by 20% as a result of the need to bring the temperature back down suddenly at the start of the occupied hours. The result of flushing the zone out with cool outdoor air at night is indicated in figure 20. The result was a decrease in the peak capacity back to within 12% of the value of figure 28 but in addition, the accumulated load has now dropped further so that it is 24% below the initial value.

Figure 31 depicts what happens if one goes an additional step and limits the peak capacity to 18,000 Btu/hr in the zone. The zone indoor temperature stays within reasonable limits and the accumulated load has been decreased a total of 32%. Figure 32 shows that if the 18,000 Btu/hr unit is limited further to operation only during the occupied hours, the indoor temperature exceeds the acceptable limits. Figure 33 shows the disastrous effect of applying no cooling.

In conclusion one can say that considerable energy savings can be effected by proper consideration for insulation and fenestration during the design phase. Additional savings are possible by use of outdoor air for natural cooling, relaxation of rigid temperature limits, and proper sizing of equipment.

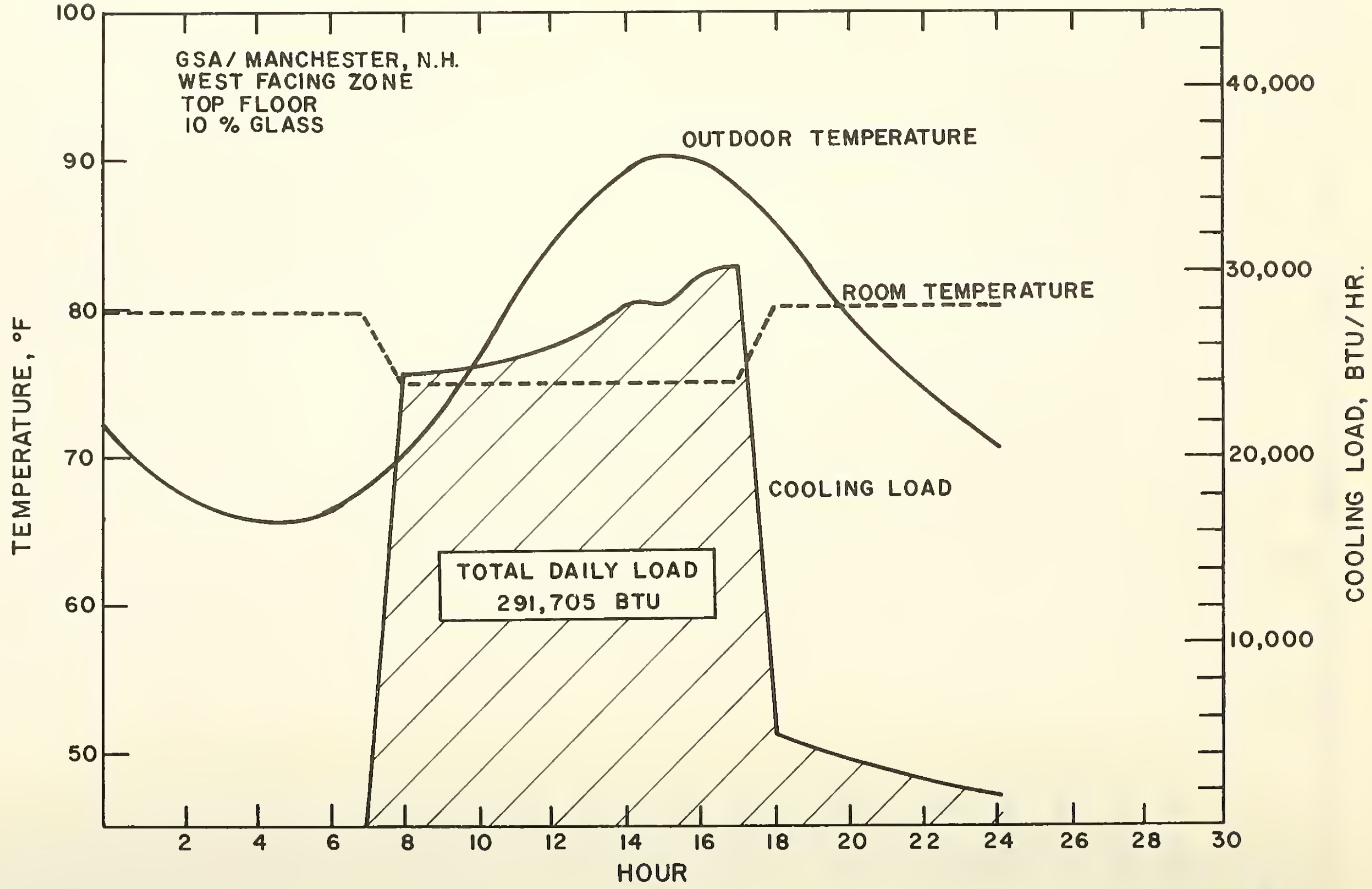

GSA/ MANCHESTER, N.H.
WEST FACING ZONE
TOP FLOOR
10 % GLASS
OUTDOOR TEMPERATURE
ROOM TEMPERATURE
COOLING LOAD
TOTAL DAILY LOAD
291,705 BTU
TEMPERATURE, °F
100
90
80
70
60
50
COOLING LOAD, BTU/HR.
40,000
30,000
20,000
10,000
HOUR
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

Figure 29

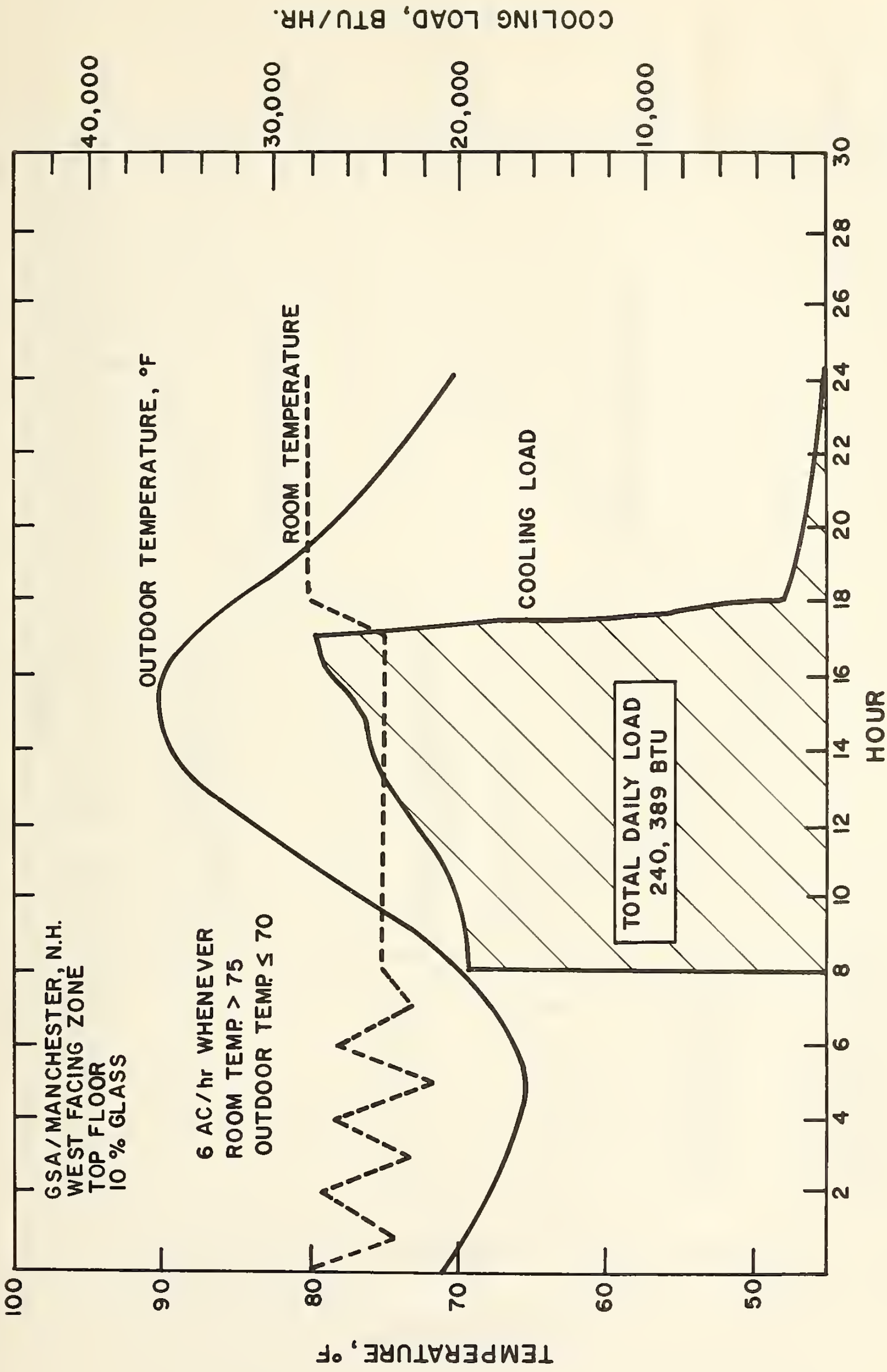

COOLING LOAD, BTU/HR.
40,000
30,000
20,000
10,000
GSA/MANCHESTER, N.H.
WEST FACING ZONE
TOP FLOOR
10 % GLASS
6 AC/hr WHENEVER
ROOM TEMP. > 75
OUTDOOR TEMP. ≤ 70
OUTDOOR TEMPERATURE, °F
ROOM TEMPERATURE
COOLING LOAD
TOTAL DAILY LOAD
240, 389 BTU
100
90
80
70
60
50
TEMPERATURE, °F
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
HOUR

Figure 30

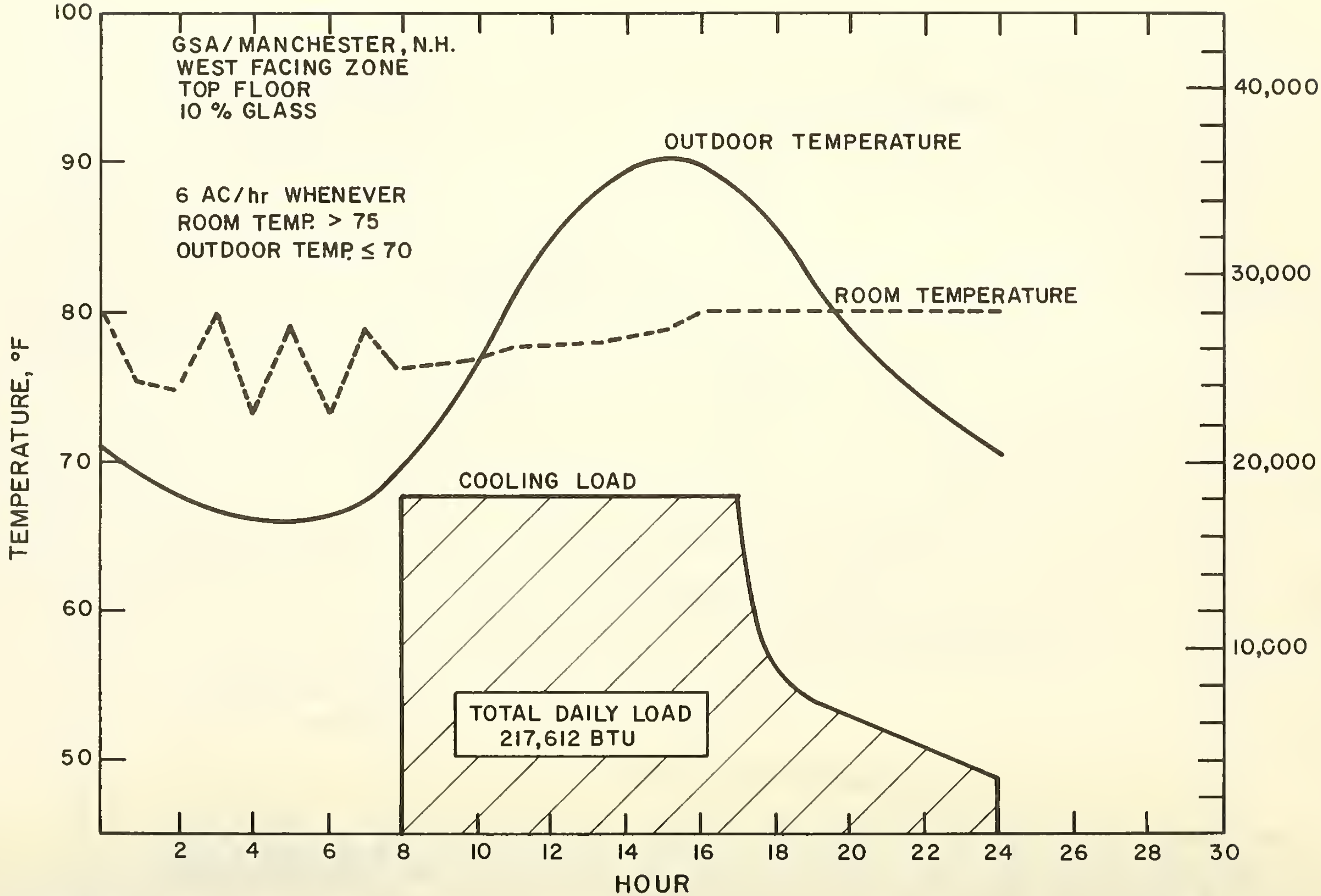

GSA/MANCHESTER, N.H.
WEST FACING ZONE
TOP FLOOR
10 % GLASS
6 AC/hr WHENEVER
ROOM TEMP. > 75
OUTDOOR TEMP. ≤ 70
OUTDOOR TEMPERATURE
ROOM TEMPERATURE
COOLING LOAD
TOTAL DAILY LOAD
217,612 BTU
TEMPERATURE, °F
COOLING LOAD
HOUR
100
90
80
70
60
50
40,000
30,000
20,000
10,000
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

Figure 31

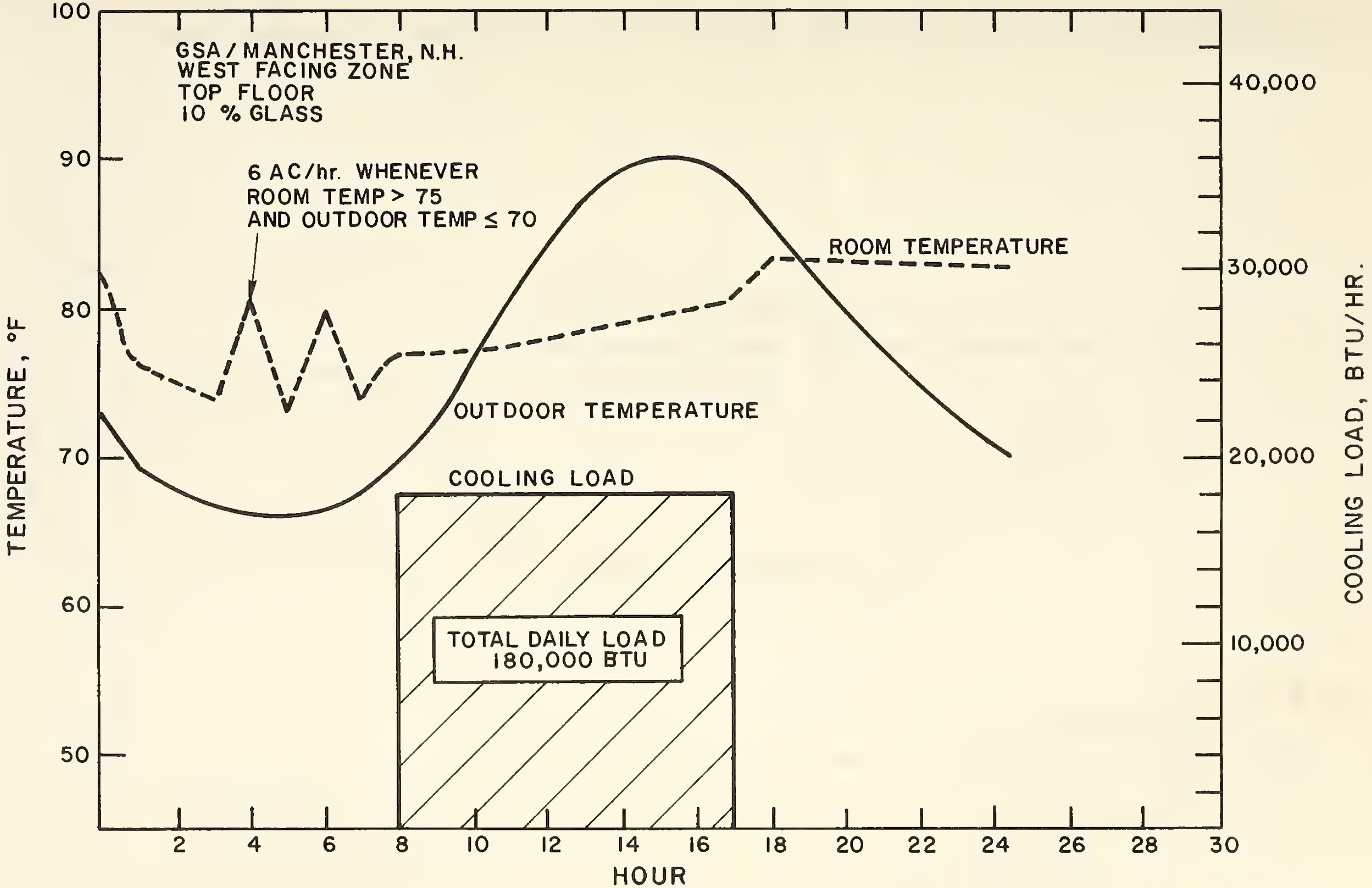

GSA / MANCHESTER, N.H.
WEST FACING ZONE
TOP FLOOR
10 % GLASS
6 AC/hr. WHENEVER
ROOM TEMP > 75
AND OUTDOOR TEMP ≤ 70
ROOM TEMPERATURE
OUTDOOR TEMPERATURE
COOLING LOAD
TOTAL DAILY LOAD
180,000 BTU
TEMPERATURE, °F
COOLING LOAD, BTU/HR.
HOUR
100
90
80
70
60
50
40,000
30,000
20,000
10,000
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

Figure 32

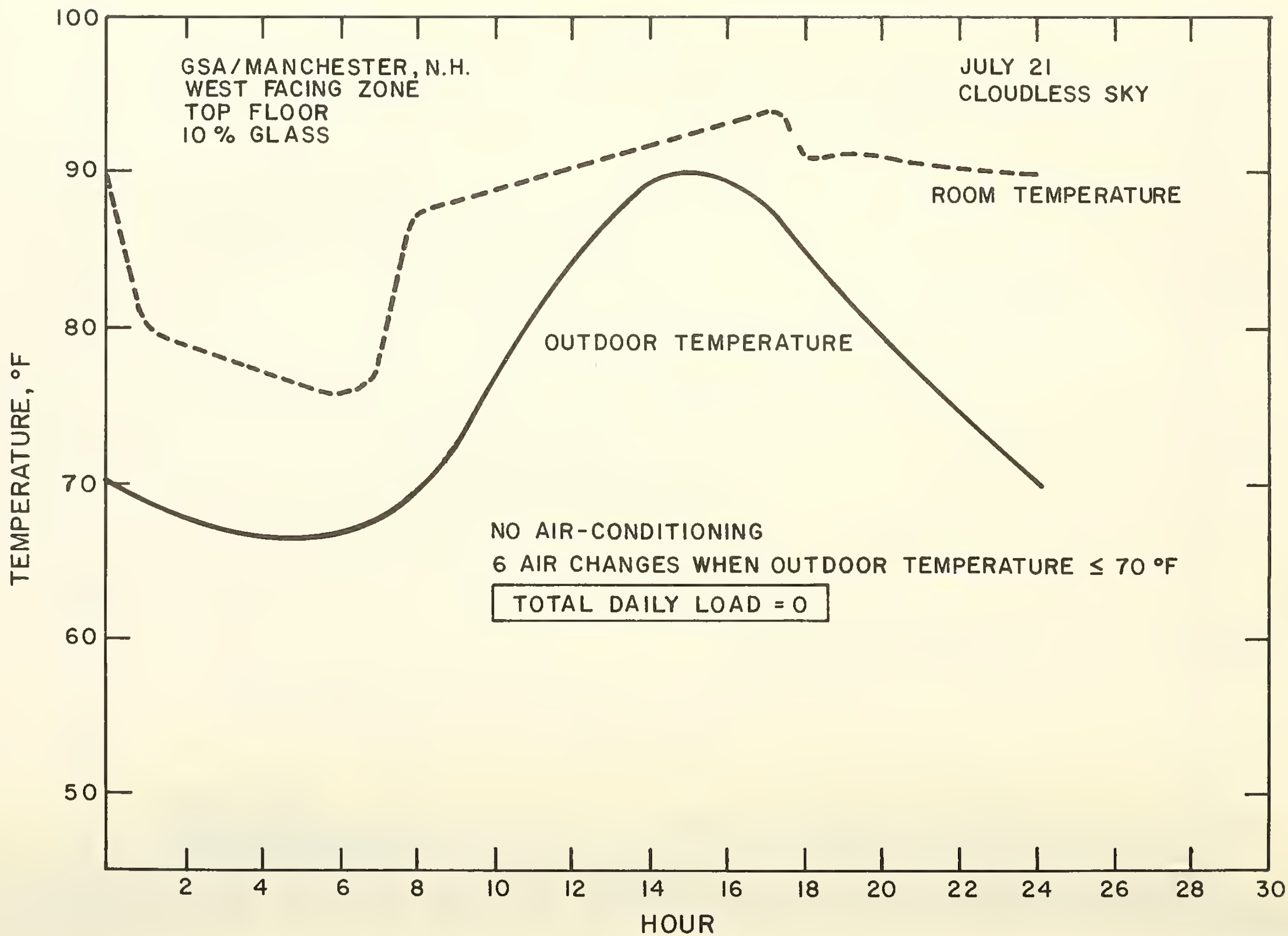

GSA/MANCHESTER, N.H.
WEST FACING ZONE
TOP FLOOR
10% GLASS
JULY 21
CLOUDLESS SKY
ROOM TEMPERATURE
OUTDOOR TEMPERATURE
NO AIR-CONDITIONING
6 AIR CHANGES WHEN OUTDOOR TEMPERATURE ≤ 70 °F
TOTAL DAILY LOAD = 0
TEMPERATURE, °F
100
90
80
70
60
50
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
HOUR

Figure 33

Building System Design:

Conduct air side system simulation analysis by using a computer

Computer simulation techniques are available and should be used for estimating the annual energy consumption of the several available air side systems. This is particularly important for those that can utilize heat conservation equipment. The usual air side systems are dual duct, variable volume and terminal reheat systems. Depending upon the particular system, the energy consumption is very much affected as shown below.

Relative Effect of Air-side System on Energy Consumption*

Systems	Economizer	Relative Annual Cooling Energy in%
Dual Duct	no	100
	yes	40
Variable Volume	no	78
	yes	37
Constant Volume	no	77

*An office building in San Francisco. Analysis by R. F. Meriwether and Associates, San Antonio, Texas.

Use heat conservation systems

There exists several heat conservation systems such as:

1) Heat recovery system: This system recovers as much as 80% of heat from exhaust air and puts it back into the outdoor makeup air through the use of rotary heat exchanger (thermal wheel), heat pump, heat pipe, or fluid circulation runs around coils.

2) Heat of light system: Heat from lighting fixtures is absorbed by air or liquid to be used for space heating or for terminal reheat in an air conditioning system.

3) Heat rejected from the compressor of the air conditioning system can be reclaimed for terminal reheat or perimeter heating, through a loop type heat pump or through double-bundle condenser systems.

4) Wherever electric space heating is employed, heat pump systems should be considered over straight electric resistance heating. Package heat pumps are well perfected at present and consume 1/2 to 1/3 times the electrical energy required by resistance type heaters in many parts of the United States during a large part of heating season. Even more attractive is gas engine driven heat pumps where the engine waste heat is recovered and can be used for space or hot water heating. The gas engine driven heat pump system with engine heat recovery can deliver approximately 40% more heat to a building than the electrically driven heap pump.

5) Heat storage systems to store off-peak output of heating

and cooling units for later peak hour usage, if carefully designed and operated, can not only reduce the peak heating/cooling hour load, but also reduce energy consumption. A recent study[12/] on a storage type off-peak cooling system showed 50% reduction in peak power demand and 6% reduction in cooling energy consumption. Similar figures can be expected for heating operations.

Central system vs. unitary system

For a larger building a central system usually uses 10 to 15% less energy than small decentralized package systems, if properly controlled. In addition, it is easier for the larger central systems to incorporate energy conservation devices. These may be impractical for the smaller package systems.

Avoid the selection of oversized equipment

Oversized equipment usually operates less efficiently than properly sized equipment operating at full load capacity. Modular systems should be considered whereby several small units could operate continuously at their peak capacity in place of one large unit operating at part-load most of the time.

Select (when prudent) equipment of high energy rating over that of low first cost

When issuing specifications for procuring heating and air conditioning systems and components, a prime consideration usually is the initial cost. However, the specification could be revised to include a requirement for an energy analysis to assure that the system and its components use minimum energy for equal performance. This would in effect encourage manufacturers to develop equipment of higher energy rating.

Ventilation system considerations

When safety permits, reduction in ventilating air from a conventional 10-20 cubic feet per minute (CFM) per person to 4-5 CFM per person in the building or occupied space can result in substantial energy saving. (Fan horsepower can consume as much as 45% of the total building electric energy in some buildings.) In some cases, reducing ventilating air by 50% can reduce the power consumption by 12.5%. The ventilation air can also be reduced by designing the air supply system in such a manner that only the occupied spaces in a given building for the occupied time be supplied with air of the correct amount instead of ventilating the entire building continuously at a constant rate.

Natural cooling

Buildings can be so designed to take advantage of nature's ability to cool. Heat dissipation from a building can be accomplished by night time cooling when the outdoor air is at its lowest temperature. In addition, the sky is a good absorber of radiant heat and its cooling effectiveness can be made equivalent to 2 tons of air conditioning if the roof of a regular home was made to radiate its internal heat to the sky. In many parts of the United States, the outdoor humidity is low enough to make the evaporative cooling very effective during a hot summer day.

Electronic ignition for gas fired furnace

Conventional pilots of gas furnaces burn 223 billion cubic feet of gas per year in 30 million gas heated houses.[13/] The substitution of the pilots by modern electric ignition devices can not only reduce gas consumption but also minimize the cooling requirements during hot summer days.

Use multiple fuel capability

If possible and feasible, consider coal or trash as alternate fuel for gas or oil for the generation of steam and hot water. Coal is still in plentiful supply in the United States.

Night time set-back and start-up cycle

When thermostat set-back for the unoccupied period is used, it is also necessary to consider a suitable "start-up" system so that the occupants will be comfortable at the beginning of the working hour. Unless carefully designed, the start-up requires a large sudden amount of heating or cooling and thus a waste of energy. The start-up time depends upon the type of building and the outdoor temperature. It is estimated that heating fuel savings during start-up of more than 50% are possible by the use of well designed "start-up" controls.

Temperature control

It is not unusual to be in a room which is either over-cooled or overheated. Equally frequent is the situation where a room is heated during the summer and cooled during the winter. These conditions could result from improper design or malfunction of the central system and of course result in an unacceptable amount of energy waste. It is expected that energy expenditure could be reduced by a factor of two or more simply by avoiding a system which requires simultaneous heating and cooling of buildings to attain a desired temperature level.

Humidity control

In some commercial and institutional buildings, heating and cooling systems are designed to provide approximately 40-50% relative humidity throughout the year. It is not necessary to maintain this narrow band of relative humidity. According to the comfort standard publication by the American Society for Heating, Refrigerating and Air Conditioning

Engineers, the room relative humidity can vary from 20% to 60% when temperature is maintained between 73°F to 78°F. A desire to maintain the relative humidity at 40% during a typical dry winter day where the outdoor temperature is 10°F requires approximately twice as much heat for generating water vapor to maintain 40% RH than to maintain 20% RH. On the other hand, to maintain 50% relative humidity indoors during a typical humid summer day (90°F and 50% relative humidity outdoors) could require 30% more energy from the air conditioning system than that needed to maintain 60% RH. Furthermore, the intent to control the humidity level at 40-50% throughout the year often destroys the advantage expected of some of the heat conservation systems such as those that use outdoor air to reduce the air conditioning load of office spaces (economizer cycles).

Solar energy utilization

A preliminary study of solar heated houses in selected areas of the United States showed that a saving of approximately 40% of the normal heating energy consumption is possible by use of a flat plate collector of 560 ft^2 in area and with 150,000 Btu of storage for an average dwelling in the Washington, D.C. area.[14/]

In many parts of the United States it may be possible to assist summer air conditioning by using absorption cooling which is operated by solar heat. It is essential that the components of the solar energy utilization system, such as collectors and storage tanks, be carefully integrated into the building design. Solar energy utilization appears to have good future potential.

Utilize waste heat

Thermal wheel type or heat pipe type heat exchangers can recover up to 80% of the heat otherwise wasted. Up to 25% in fuel savings is said to be realized by installing recuperative combustion systems in burner exhaust.

Total energy systems

Properly designed on-site electric power generation systems with the use of engine waste heat recovery for either space heating or hot water heating and summer cooling could achieve energy savings of 28 to 40% when compared to conventional systems that purchase the power from the utilities.[15/] Approximately 500 total energy systems are in operation in the United States. These could provide engineering data and operating experiences to improve future design of this type of energy conserving system.

Recycle waste as fuel

Where practical, use normally discarded waste or building trash as a fuel supplement. The heating value of trash is approximately 1/4 that of coal. Although in conventional buildings the savings in energy by the use of waste as fuel is small, for some commercial and industrial operations such as producing drain oil and sawdust, waste recycling could be significant.

Scheduling for off-peak period

Consideration should be given to the rescheduling of working hours to off-peak periods, e.g., start air conditioning system one or two hours earlier than normal and pull the temperature down a few degrees below normal. By doing this and then resetting the chiller thermostat higher than normal, the power demand during the peak load will be less. This may not result in an appreciable reduction of the daily energy consumption.

If feasible, a substantial energy savings can be realized by shutting down the chiller one hour before the normal end of the working day. If the chilled water pump and the air conditioning fans are allowed to continue operation, generally no objectionable increase in space temperature is noted.

Electrical system considerations

Wherever practical and found more economical, convert to higher voltage systems. Use of electrical demand limitors and power factor correcting condensers should be considered through a careful engineering analysis for each project to see if substantial energy saving and/or peak power shaving is possible.

Cut back lighting loads

Building illumination systems can be so designed to take care of situations where all perimeter lighting can be turned off and natural lighting used. In certain areas, every other light could be turned off without seriously impairing visual effectiveness. Since heat from the lighting fixture constitutes as much as 50% of space cooling load, rational design of illumination to cut down the lighting power input from conventional 4-5 watt/ft^2 to 2 watt/ft^2 would yield considerable reduction in cooling energy consumption. In addition, it is wasteful to leave the lights on during the unoccupied periods. Time clock controls should be employed at selected locations to turn off the unnecessary lights. The table below shows the effect of lighting design upon the annual heating and cooling energy consumption calculated for a San Francisco office building by R. F. Meriwether and Associates of San Antonio, Texas.

Relative Effect of Lighting and Operating Hours on Energy Consumption*

Operation	Watt/ft^2	Heating	Cooling
Continuous	4.5	100	100
5 1/2 days/week	2.9	39	74

*Variable volume/economizer cycle.

In some buildings the lighting for parking lots, building lighting and security flood-lighting could take as much as 30% of total building electric load (see below). Use of photocell switches to minimize the wasteful use of exterior lighting can be effective.

Energy Use by Sources for a Large Commercial Complex in Houston

	MKWH	Percent
Chillers	30,123	12
Mechanical room accessories	9,301	4
Fans	25,451	10
Illumination and Equipment	109,713	44
Parking Lot	73,416	30
Total	248,004	100

Center for Building Technology

BUILDING SYSTEM DESIGN

POTENTIAL FOR ENERGY CONSERVATION

1. ANALYZE POTENTIAL SYSTEMS USING SIMULATION
2. UTILIZE HEAT CONSERVATION SYSTEMS
3. CENTRAL SYSTEM VERSUS UNITARY SYSTEM
4. PROPERLY SIZE EQUIPMENT
5. CHOOSE EQUIPMENT BASED ON HIGH ENERGY RATING
6. VENTILATION SYSTEM OPERATION
7. UTILIZE ELECTRONIC IGNITION
8. CONSIDER MULTIPLE FUEL CAPABILITY
9. NIGHT-TIME SET-BACK
10. UTILIZE SOLAR ENERGY
11. UTILIZE WASTE HEAT
12. TOTAL ENERGY (TE)
13. RECYCLE WASTE AS FUEL
14. MODULAR INTEGRATED UTILITY SYSTEM (MIUS)

MECHANISMS FOR IMPLEMENTATION OF ENERGY CONSERVATION TECHNOLOGY IN BUILDINGS

by

Paul R. Achenbach

INTRODUCTION:

Speakers on the morning program of the Joint NCSBCS-NBS Workshop on Energy Conservation in Buildings described a variety of technical options for saving energy under three topics; viz.

1. Practices that can be carried out by owners or operators without cost
2. Practices that can be implemented with modest expenditure for readily available materials
3. Design opportunities for energy conservation in new buildings.

Obviously, the practices described under the first topic can be regarded as economically sound because they require no expenditure of money, but only a change in living habits or methods of equipment use. Enough experience and analysis are available on some of the practices described in topics two and three to demonstrate cost-effectiveness. For example, the use of significant amounts of thermal insulation in buildings will save enough in operating costs to amortize the first cost in only a few years. Likewise, storm windows are usually a good investment and the reduction of air leakage by caulking and weatherstripping is cost effective. However, the energy savings that can obtained with a considerable number of the suggested operating or design concepts have not been well documented, nor has the tradeoff between first cost and lowered operating cost been reliably determined. Laboratory and field studies are being planned or are in progress to develop the technical and economic data on many of these practices.

PREREQUISITES TO IMPLEMENTATION:

While the needed technical and economic data are being developed it is appropriate to consider the methods available for implementing energy conservation technology in the huge inventory of existing buildings and in the new buildings that are designed and constructed each year. Basic to the success of implementation is the belief on the part of many people that there is a potential for energy conservation in buildings at a price that many are willing to pay. This workshop is evidence that many State building officials believe that this concept is worthy of investigation and development. However, all of the segments of the U.S. population identified in Table 1 have a significant role in attaining energy conservation in buildings, and the level of their acceptance of the potential for energy conservation will determine the rate at which it can take place and the amount of energy savings that will be realized.

Table 1. PREREQUISITES TO IMPLEMENTATION

Acceptance of Energy Conservation Potential

- Public
- Design Professions
- Manufacturers
- Builders
- Financial Institutions
- Regulatory Bodies

IMPLEMENTATION PROCEDURES:

A variety of procedures are available for introducing energy conservation technology into the design, construction, and operation of buildings. These can conveniently be grouped in three broad classes; viz., educational, financial, and regulatory, as shown in Table 2.

Table 2. MECHANISMS FOR IMPLEMENTATION

A. Educational

1. Information media -- publication, radio, T.V.
2. Industry persuasion through advertising
3. Adoption of guidelines by design professions, owners

B. Financial

1. Energy price structure
2. Mortgage practices
3. Tax, rent, interest subsidies

C. Regulatory

1. Standards, specifications, codes
2. Government directives
3. Energy rationing

The educational procedures are the most democratic type and they require a broad spectrum of voluntary action and response to have a significant effect on the nation's energy use pattern. The financial incentives in the second category require legislation as a means of implementation, in most cases. The available regulatory procedures range from voluntary standards and specifications to directives and emergency actions taken at various governmental levels. The latter type of action would typically occur only when threats to the health, safety, or national security were involved.

A few examples of the various types of action that have been taken or proposed will be cited to illustrate their characteristics and limitations. Probably all of the newspapers and news and technical magazines have printed one or more articles in the last year on the energy shortage. Many public service programs have been shown on television. Every week, one or more seminars and symposia are held on this subject. The "7 Ways" and "11 Ways" consumer bulletins issued by the National Bureau of Standards in collaboration with the Office of Consumer Affairs and the Owens Corning energy exhibit prepared and widely displayed about two years ago were educational in purpose.

Various companies have used their advertising programs to provide worthwhile information to consumers on energy conservation and at the same time promoting the use of the products they manufacture. Three examples illustrate the process:

1. Minneapolis-Honeywell, Inc. has published a bulletin showing how much energy can be saved by the homeowner for three levels of night setback of their thermostat for 25 cities in the U.S.
2. The Electric Energy Association distributes a bulletin identified as Sav-a-watt which describes ways to use electric energy more efficiently.
3. Owens-Corning Fiberglas Corporation distributes on request a packet of material describing various methods for saving energy in building operations.

These efforts have the advantage of providing substantial amounts of money and organized procedures for distributing useful information to large numbers of people.

A few industry associations, professional societies, and some utilities have voluntarily developed or are developing design practices or product information related to energy conservation. For example:

1) The Illuminating Engineering Society has published material describing how lighting may be done more efficiently to save electrical energy.

2) The Association of Home Appliance Manufacturers publish an energy efficiency ratio for all window air conditioners on the market; and they have been active for a year or more in developing simulated use tests for refrigerators and other electrical appliances that could be used as a basis for nameplate ratings on use efficiency.

3) The American Telephone and Telegraph Co. has issued a contract for a pilot retrofitting of one of their telephone exchange buildings in New York City to explore the cost-effectiveness of various building and equipment modifications. The results of this study will be used to identify modifications to be made on all of their exchange facilities.

There has been only limited exercise of financial incentives to bring about energy conservation in buildings, but a variety of procedures are now under study and several bills have been introduced into Congress involving such incentives. The relation of supply and demand in the energy market has already brought about significant rises in the price of electricity and all of the fossil fuels. This trend will undoubtedly continue and it will inhibit to some degree the discretionary use of all these energy sources. Some have suggested that the typical sliding price scale of electrical energy, oil, and gas for which larger demands by a given customer can be obtained at progressive lower unit costs should be reversed to discourage heavy users of energy. However, the legality of this approach has been questioned because the prices charged for energy by public utilities must be demonstrably related to the cost of production.

Proposals have been made that energy and fuel be deliberately subjected to increased taxes to discourage use, but this approach would tend to place more burden on the poor than on those of higher income status. The reverse of this proposal would be to provide tax incentives or interest rate incentives to assist those who wanted to borrow money for building modifications that would conserve energy. Such proposals have been suggested in the report of the Ad Hoc Committee on Energy Efficiency in Large Buildings to the Interdepartmental Fuel and Energy Committee of the State of New York.

In the regulatory area of standards, specifications, and codes, the best known documents containing energy conservation provisions are the FHA Minimum Property Standards. These standards for One- and Two-Family Houses and for Multifamily Dwellings were recently revised to contain more stringent requirements on energy use, in response to a Presidential directive. The FHA Standards are not mandatory on the building industry unless the builder or mortgage backer wants to take advantage of the mortgage insurance programs of the Federal Housing Administration.

Thus the FHA procedures are a combination of technical standards and financial incentives through mortgage insurance. The California legislature has just made the FHA requirements on energy conservation mandatory for housing beginning January 1, 1974.

Other developments that could lead to standards or specifications in energy conservation are the following:

1) The Association of Home Appliance Manufacturers will probably incorporate typical use tests as a basis for energy ratings in their equipment standards.

2) The Federal GSA will make broader use of the energy efficiency ratio in their purchase specifications for air conditioners, and will incorporate cost-effective conservation practices into their guide specifications.

3) Research programs on energy conservation by ASHRAE, AIA, AAI, IES, NAHB, NSF, GSA, and NBS could lead to standards development by industry, professional, and standards bodies over a period of a few years.

Government directives and energy rationing are executive actions likely to be reserved to alleviate short-term emergencies in supply or distribution that threaten the health, welfare, and security of groups of citizens.

One of the principal purposes of this workshop is to explore various methods or procedures that might be used by the States to limit the use of energy in buildings in an equitable and uniform manner so as to reduce the anticipated disparity between supply and demand and still maintain a satisfactory quality of life. Very few documents have been written that attempt to set forth criteria for limiting energy use in buildings. However, many city, state, and federal groups have been considering how this might be done, and a variety of approaches have been considered. Some of these are listed in Table 3.

Table 3. CRITERIA FOR LIMITING ENERGY USE IN BUILDINGS

1. Building dimensions only
2. Building dimensions and climate
3. Number of occupants
4. Thermal properties of building elements
5. Equipment performance

The problem is complex because the criteria must apply to both the building envelope and the energy systems used in buildings; they must account for climatic variations, various occupancies, and building size; and they must allow flexibility in design and choice of materials. In addition to these technical requirements, any satisfactory set of criteria must be susceptible to effective administration and compatible with other performance objectives for buildings. Table 4 lists some of the more important administrative requirements of satisfactory criteria.

Table 4. CHARACTERISTICS OF A SATISFACTORY CRITERION

1. Understandable
2. Usable by Design Professionals
3. Compliance readily checked
4. Broadly applicable
5. Supports economic design
6. Compatible with other performance objectives

Table 5 lists a set of tests for adequacy and fairness of a set of energy criteria in relation to the variables in actual building construction. It is possible that a single set of criteria cannot cover all of the variables in Table 5.

Table 5. TESTS OF ADEQUACY AND FAIRNESS

1. Adequate for heating and cooling seasons
2. Adaptable to climatic zones
3. Suitable for residential and commercial buildings
4. Accounts for tradeoffs between space heating and cooling and electrical usage
5. Control both heat transmission and air leakage
6. Applicable to both building and equipment design
7. Promote cost-effectiveness

EXISTING CRITERIA FOR LIMITING ENERGY USE:

In order to describe the present state of the art in the development of criteria for energy conservation and to assist in the further discussion of implementation in this workshop, the requirements contained in four existing documents are summarized in Tables 6 to 8. These documents are:

1) FHA Minimum Property Standards for One and Two Family Dwellings

2) FHA Minimum Property Standards for Multifamily Dwellings

3) HUD Guide Criteria

4) Report of the Ad Hoc Committee on Energy Efficiency in Large Buildings to the Interdepartmental Fuel and Energy Committee of the State of New York.

These documents will be used to discuss the desirable features of a set of criteria for limiting energy use in buildings.

First, it should be noted that the FHA and HUD documents deal principally with the thermal properties of the building envelope; they place few limitations on lighting levels; the ventilation limits are rather

Table 6. CRITERIA FOR LIMITING ENERGY USE IN BUILDINGS

BUILDING ELEMENT	FHA-MPS ONE- AND TWO-FAMILY	FHA-MPS MULTI-FAMILY	HUD GUIDE CRITERIA
HEAT TRANSMISSION OF WHOLE BUILDINGS	MAXIMUM HEAT LOSS RELATED TO FLOOR AREA	NONE	NONE
WALLS	MAXIMUM HEAT LOSS RELATED TO FLOOR AREA AT DESIGN WINTER TEMPERATURE DIFF	U-FACTOR LIMITS VARIES WITH CLIMATE	TRANSMISSION FACTOR LIMITS
WINDOWS	"	NO LIMIT SINGLE. DOUBLE GLAZING RELATED TO CLIMATE	GLASS-WALL RATIO RELATED TO BUILDING SIZE, CLIMATE, U-FACTOR
DOORS	"	NONE	TREATED AS WINDOW OR WALL
CEILINGS	U-FACTOR LIMIT FOR HEATING	U-FACTOR LIMIT, VARIES WITH CLIMATE	MAXIMUM TRANSMISSION FACTOR
FLOORS	U-FACTOR LIMIT, VARIES WITH CLIMATE	U-FACTOR LIMIT, VARIES WITH CLIMATE	"
SLAB-ON-GRADE	MAXIMUM HEAT LOSS/LINEAR FOOT	MAXIMUM HEAT LOSS/ LINEAR FOOT	MAXIMUM HEAT LOSS/ LINEAR FOOT
FOUNDATION WALL	MAXIMUM U-FACTOR RELATED TO CLIMATE	MAXIMUM U-FACTOR FOR HEATED CRAWL SPACES	MAXIMUM TRANSMISSION FACTOR FOR HEATED CRAWL SPACES
WEATHERSTRIPPING	NONE	DOORS & WINDOWS	NONE
AIR LEAKAGE	LIMITING VALUES ASTM TEST	LIMITING VALUES ASTM TEST	MAXIMUM VALUES FOR WALLS, WINDOWS, DOORS
CAULKING	NONE	SUGGESTED	NONE

Table 7. CRITERIA FOR LIMITING ENERGY USE IN BUILDINGS

EQUIPMENT ELEMENT	A. FHA-MPS ONE- AND TWO-FAMILY	B. FHA-MPS MULTI-FAMILY	C. HUD GUIDE CRITERIA
LIGHTING	WINDOWS, 10% OF FLOOR AREA NO REQUIREMENT ON ARTIFICIAL LIGHT	SAME AS A. SAME AS A. MINIMUM IN PUBLIC SPACES	SAME AS A. SAME AS A.
NATURAL VENTILATION	OPENABLE WINDOWS 5% FLOOR AREA	SAME AS A.	MINIMUM VALUE IN HABITABLE ROOMS
MECHANICAL VENTILATION	SPECIFIED FOR KITCHEN, BATH ONLY	SPECIFIED VALUES IN ALL AREAS	SPECIFIED VALUES IN KITCHEN, BATH, PUBLIC SPACES
AIR LEAKAGE	NO REQUIREMENT	NO REQUIREMENT	LIMIT ON AIR CHANGES
DUCT INSULATION	SPECIFIED THICKNESS	SPECIFIED THICKNESS	NONE
PIPE INSULATION	SPECIFIED IN UNHEATED SPACES	MINIMUM CONDUCTANCE VALUES	NONE
BOILER INSULATION	MINIMUM CONDUCTANCE VALUES	SAME AS A.	MANUFACTURERS ENGINEERING DATA
MECHANICAL SYSTEMS	INDUSTRY STANDARDS	INDUSTRY STANDARDS	INDUSTRY STANDARDS

Table 8. REPORT OF

AD HOC COMMITTEE ON ENERGY EFFICIENCY IN LARGE BUILDINGS

TO THE

INTERDEPARTMENTAL FUEL AND ENERGY COMMITTEE

OF THE STATE OF NEW YORK

SUBJECTS COVERED:

BUILDING CONFIGURATION

SYSTEMS FOR ELECTRIC HEATING

COOLING SYSTEMS

VENTILATING SYSTEMS

LIGHTING

INSULATION

ENTRANCES AND LOBBIES

BUILDING MATERIALS

HEAT RECOVERY

COST/BENEFIT ANALYSIS

liberal; and they reference existing industry standards for most of the mechanical systems. Since industry standards at the present time contain few provisions related to energy conservation, the FHA and HUD documents provide a minimum of change from past practice in the design and application of mechanical equipment.

The FHA-MPS for one- and two-family dwellings contains limits on the overall unit heat loss and gains of a house (excluding floors) and the overall unit heat loss of the walls, windows, and exterior doors taken separately in relation to floor area. These provisions have the following advantages and disadvantages:

a) Major design flexibility in selecting materials and fenestration to satisfy an overall requirement.

b) Equal winter heat loss rates in all climatic zones. This feature might not provide the best tradeoff between first cost and operating cost.

c) The requirements as drafted allow a relatively high infiltration loss (25 to 35% in the winter time).

d) All materials combinations have to meet the same criteria.

The FHA-MPS for multi-family dwellings limits the heating and cooling requirements by limiting the heat transmission factors of the various building elements. The specified heat transmission factors vary with severity of the summer and winter climate and the values are higher for masonry buildings than for frame buildings. No limitation is placed on the amount of single glazing, but in colder climates the ratio of double glazing to single glazing is increased with the number of winter degree-days in several steps. There is no direct limitation on air leakage, but weatherstripping is required on all doors and windows and air leakage tests are required for windows.

The HUD Guide Criteria provides summer and winter limits on the heat transmission levels of all building subelements. The allowable heat transmission values are related to design indoor-outdoor temperature difference and are constant for all climates. This concept allows the U-factors to vary inversely with the design temperature difference and results in approximately equal energy use in all latitudes. The Guide Criteria provides a limitation on the ratio of glass area to exterior wall area that varies with building size, climate, and heat transmission factor of the fenestration. It also provides limits on the air leakage of walls, windows and doors and an overall limit on the structure.

The recommendations contained in the design section of the report of the Ad Hoc Committee on Energy Efficiency in Large Buildings to the executive branch of the State of New York cover ten major subjects including the design parameters of the building enclosure; the heating, cooling, ventilating, and lighting systems; insulation and building materials; heat recovery; and cost/benefit analysis, as shown in Table 8. (Other sections of the report cover the construction and operation aspects of the building process.) These recommendations are presented in three time frames; short range (0-2 years), medium range (2-5 years), and long range (more than 5 years). The recommendations were presented in March 1973 and are still under consideration at the state level.

The report of the Ad Hoc Committee is more comprehensive in its coverage of building equipment than either the FHA-MPS or the HUD Guide Criteria, but most of the guidelines are expressed in performance-type language and do not provide explicit criteria for acceptability. Specific requirements are stated for design summer and winter design weather conditions, for the level of system overload to be used in design, and for the overall goal in reduction of energy requirements for large buildings. The report recognizes the need for more detailed criteria in certain areas, for computer analysis of loads, for research to develop the potential for energy conservation of various design concepts, and for a thorough cost/benefit analysis system and a data bank on economic performance. This report constitutes a broad framework within which more specific criteria could be developed.

FUTURE CRITERIA DEVELOPMENT:

It is evident from this brief review of existing published documents of a standards or specification nature that no single set of requirements is sufficiently comprehensive to cover the perceived needs of the States in energy conservation. It is suggested that the National Conference of States for Building Codes and Standards and the energy coordinators for the states consider carefully two different approaches to the further development of criteria for limiting energy use in buildings.

The first of these utilizes the American National Standards Institutes consensus standard approach. Professional societies such as AIA and

ASHRAE and governmental organizations such as NCSBCS and NBS could serve as sponsors in the generation of a proposed national consensus standard using the Sectional committee concept or a modification thereof. This standard should cover both the building itself and all of the energy-using systems found in selected classes of buildings (perhaps limited to residential and commercial). After promulgation of the standard as a National Standard through the American National Standards Institute, it would be available for adoption by reference by the States with or without modification. The B9 National Standard of ANSI Mechanical Refrigeration Safety Code is a good model for this procedure. The principal hazards seen in this approach are the possibility that consensus would not be attained among the large number of diverse interests and the possibility that the voluntary standard, when promulgated, could be modified in so many ways by different states in the adoption process that it would lose its benefit of uniformity.

The second procedure that might be successful would be patterned after the FHA Minimum Property Standards process. In this process a governmental body with authority to implement a standard would use the resources of industry, the professions, and government agencies to generate a draft standard under its direction. When a draft had been produced it would be circulated to all appropriate industry and government bodies for comment and suggestions. The sponsoring agency would incorporate acceptable suggestions into the standard and issue it for use. Its use could be voluntary unless its application were combined with tax, interest, or mortgage payment incentive programs. The potential disadvantages in this procedure are (a) lack of commitment and acceptance for a standard produced under government leadership, and (b) non-acceptance by the segments of the building industry not requiring subsidies. The FHA Minimum Property Standards are models of this process.

Other major hurdles to be negotiated in any process for development of a standard for energy requirements in buildings are the need to establish and motivate a sufficiently broad consortium of building interests to accomplish a task of this complexity and the need to create an evolutionary type document since considerably more technical information is needed than now exists to define all of the performance requirements for buildings and building equipment.

In our opinion, energy shortages are close enough at hand, and the dependence of the United States on foreign energy resources is at such a level as to warrant willing participation of all segments of the building industry in developing an equitable set of guidelines for energy use in buildings.

Center for Building Technology

PREREQUISITES TO IMPLEMENTATION

Acceptance of Energy Conservation Potential

- PUBLIC
- DESIGN PROFESSIONS
- MANUFACTURERS
- BUILDERS
- FINANCIAL INSTITUTIONS
- REGULATORY BODIES

Center for Building Technology

MECHANISMS FOR IMPLEMENTATION

A. EDUCATIONAL

1. INFORMATION MEDIA -- PUBLICATION, RADIO, T.V.
2. INDUSTRY PERSUASION THROUGH ADVERTISING
3. ADOPTION OF GUIDELINES BY DESIGN PROFESSIONS, OWNERS

B. FINANCIAL

1. ENERGY PRICE STRUCTURE
2. MORTGAGE PRACTICES
3. TAX, RENT, INTEREST SUBSIDIES

C. REGULATORY

1. STANDARDS, SPECIFICATIONS, CODES
2. GOVERNMENT DIRECTIVES
3. ENERGY RATIONING

Center for Building Technology

CRITERIA FOR LIMITING ENERGY USE IN BUILDINGS

1. BUILDING DIMENSIONS ONLY
2. BUILDING DIMENSIONS AND CLIMATE
3. NUMBER OF OCCUPANTS
4. THERMAL PROPERTIES OF BUILDING ELEMENTS
5. EQUIPMENT PERFORMANCE

Center for Building Technology

TESTS OF ADEQUACY AND FAIRNESS

1. ADEQUATE FOR HEATING AND COOLING SEASONS
2. ADAPTABLE TO CLIMATIC ZONES
3. SUITABLE FOR RESIDENTIAL AND COMMERCIAL BUILDINGS
4. ACCOUNTS FOR TRADEOFFS BETWEEN SPACE HEATING AND COOLING AND ELECTRICAL USAGE
5. CONTROL BOTH HEAT TRANSMISSION AND AIR LEAKAGE
6. APPLICABLE TO BOTH BUILDING AND EQUIPMENT DESIGN
7. PROMOTE COST-EFFECTIVENESS

Center for Building Technology

CHARACTERISTICS OF A SATISFACTORY CRITERION

1. UNDERSTANDABLE
2. USABLE BY DESIGN PROFESSIONALS
3. COMPLIANCE READILY CHECKED
4. BROADLY APPLICABLE
5. SUPPORTS ECONOMIC DESIGN
6. COMPATIBLE WITH OTHER PERFORMANCE OBJECTIVES

Center for Building Technology

CRITERIA FOR LIMITING ENERGY USE IN BUILDINGS

BUILDING ELEMENT	FHA-MPS ONE- AND TWO-FAMILY	FHA-MPS MULTI-FAMILY	HUD GUIDE CRITERIA
HEAT TRANSMISSION OF WHOLE BUILDINGS	MAXIMUM HEAT LOSS RELATED TO FLOOR AREA	NONE	NONE
WALLS	MAXIMUM HEAT LOSS RELATED TO FLOOR AREA AT DESIGN WINTER TEMPERATURE DIFFERENCE	U-FACTOR LIMITS VARIES WITH CLIMATE	TRANSMISSION FACTOR LIMITS
WINDOWS	MAXIMUM HEAT LOSS RELATED TO FLOOR AREA AT DESIGN WINTER TEMPERATURE DIFFERENCE	NO LIMIT SINGLE DOUBLE GLAZING RELATED TO CLIMATE	GLASS-WALL RATIO RELATED TO BUILDING SIZE, CLIMATE, U-FACTOR
DOORS	MAXIMUM HEAT LOSS RELATED TO FLOOR AREA AT DESIGN WINTER TEMPERATURE DIFFERENCE	NONE	TREATED AS WINDOW OR WALL
CEILINGS	U-FACTOR LIMIT FOR HEATING	U-FACTOR LIMIT, VARIES WITH CLIMATE	MAXIMUM TRANSMISSION FACTOR
FLOORS	U-FACTOR LIMIT, VARIES WITH CLIMATE	U-FACTOR LIMIT, VARIES WITH CLIMATE	U-FACTOR LIMIT, VARIES WITH CLIMATE

Center for Building Technology

CRITERIA FOR LIMITING ENERGY USE IN BUILDINGS

BUILDING ELEMENT	FHA-MPS ONE- AND TWO-FAMILY	FHA-MPS MULTI-FAMILY	HUD GUIDE CRITERIA
SLAB-ON-GRADE	MAXIMUM HEAT LOSS/ LINEAR FOOT	MAXIMUM HEAT LOSS/ LINEAR FOOT	MAXIMUM HEAT LOSS/ LINEAR FOOT
FOUNDATION WALL	MAXIMUM U-FACTOR RELATED TO CLIMATE	MAXIMUM U-FACTOR FOR HEATED CRAWL SPACES	MAXIMUM TRANSMISSION FACTOR FOR HEATED CRAWL SPACES
WEATHERSTRIPPING	NONE	DOORS & WINDOWS	NONE
AIR LEAKAGE	LIMITING VALUES ASTM TEST	LIMITING VALUES ASTM TEST	MAXIMUM VALUES FOR WALLS, WINDOWS, DOORS
CAULKING	NONE	SUGGESTED	NONE

Center for Building Technology

CRITERIA FOR LIMITING ENERGY USE IN BUILDINGS

EQUIPMENT ELEMENT	A. FHA-MPS ONE- AND TWO-FAMILY	B. FHA-MPS MULTI-FAMILY	C. HUD GUIDE CRITERIA
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NATURAL VENTILATION	OPENABLE WINDOWS 5% FLOOR AREA	SAME AS A.	MINIMUM VALUE IN HABITABLE ROOMS
MECHANICAL VENTILATION	SPECIFIED FOR KITCHEN, BATH ONLY	SPECIFIED VALUES IN ALL AREAS	SPECIFIED VALUES IN KITCHEN, BATH, PUBLIC SPACES
AIR LEAKAGE	NO REQUIREMENT	NO REQUIREMENT	LIMIT ON AIR CHANGES
DUCT INSULATION	SPECIFIED THICKNESS	SPECIFIED THICKNESS	NONE
PIPE INSULATION	SPECIFIED IN UNHEATED SPACES	MINIMUM CONDUCTANCE VALUES	NONE
BOILER INSULATION	MINIMUM CONDUCTANCE VALUES	SAME AS A.	MANUFACTURERS ENGINEERING DATA
MECHANICAL SYSTEMS	INDUSTRY STANDARDS	INDUSTRY STANDARDS	INDUSTRY STANDARDS

Center for Building Technology

REPORT OF AD HOC COMMITTEE ON ENERGY EFFICIENCY IN LARGE BUILDINGS TO THE INTERDEPARTMENTAL FUEL AND ENERGY COMMITTEE OF THE STATE OF NEW YORK

SUBJECTS COVERED:

- BUILDING CONFIGURATION
- SYSTEMS FOR ELECTRIC HEATING
- COOLING SYSTEMS
- VENTILATING SYSTEMS
- LIGHTING
- INSULATION
- ENTRANCES AND LOBBIES
- BUILDING MATERIALS
- HEAT RECOVERY
- COST/BENEFIT ANALYSIS

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The purpose of this report is to provide reference material on the technical options for energy conservation in buildings. It was prepared for the National Conference of States for Building Codes and Standards-National Bureau of Standards Joint Emergency Workshop on Energy Conservation in Buildings held at the U. S. Department of Commerce in Washington,D.C. on June 19, 1973.

This report describes actions pertinent to existing buildings and new buildings. Regarding existing buildings, principal topics include summer cooling, winter heating, and other energy conserving features--i.e., insulation, fenestration, lighting, appliances, domestic hot water, and human comfort. Suggested actions include those which can be accomplished voluntarily or without expense, and also actions which require some modest effort or expense on the part of the building owner or occupant.

Regarding new buildings, energy conservation actions are described that deal with building design and mechanical systems. The report concludes with a summary of mechanisms for implementation of such actions and criteria for use in evaluation of them.

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