DESIGN AND EVALUATION CRITERIA FOR ENERGY CONSERVATION IN NEW BUILDINGS

NBSIR 74–452

February 27, 1974
Revised February 26, 1976

February 27, 1974

National Conference of States for
 Building Codes and Standards
c/o Mr. Bernard E. Cabelus, Chairman
State of Connecticut Delegate
State Office Building
Hartford, Connecticut 06115

Dear Mr. Cabelus:

The "Design and Evaluation Criteria for Energy Conservation in New
Buildings" was developed in response to the July 12, 1973 request
of the National Conference of States on Building Codes and Standards
to provide the technical basis for a performance-type standard.
Although this document is comprehensive in its technical scope, it
is not practical at this time to develop a single document which would
be universally applicable to all types of buildings in a uniform
manner.

It is our recommendation that this document be used as the basis for
the development of a consensus standard to apply to new construction
for all building types except those excluded in the following paragraph.
It is also our recommendation that the States be advised not to use the
document in its present form for regulatory purposes.

The following recommendations are made with respect to:

1. Residential buildings including manufactured housing (one-
    and two-family) --

    ° The Federal Housing Administration's Minimum Property
       Standard 51b should be used as an interim standard.

    ° A consensus standard for one- and two-family housing
       should be developed using this document as a guideline
       to expand the scope covered by MPS 51b. It should include
       such factors as: air infiltration, usage of glass,
       illumination levels, and electrical distribution systems.
       It should seek to eliminate wasteful practices in heating,
       ventilation, air conditioning, and service water systems.

    ° As an interim measure, the States should investigate the
       possibility of initiating a voluntary labeling program
       for buildings which meet the requirements of this document.

2

2. Mobile Homes --

    °   The Coordinating Committee of the National Mobile Home
        Standard should be requested to sponsor and appoint a
        new subcommittee to develop an energy conservation
        supplement to ANSI A119.1. This supplement should be
        completed by July 1, 1974, using this document as a
        guideline.

3. Industrial buildings, monument buildings, short-term periodic
    use buildings such as vacation shelters, or buildings contain-
    ing special laboratories --

    °   Instead of using this document, special energy conservation
        measures applying to these buildings should be developed
        which take into consideration the special conditions which
        prevail.

As indicated in your November 19, 1973 letter to Dr. Richard Roberts,
Director of the National Bureau of Standards, performance standards
cannot be utilized without changes in the structure of the building
regulatory system. It is recommended that NCSBCS at its February 27, 1974
meeting study what tasks need to be done to make performance standards
workable and designate appropriate organizations to carry out the
identified tasks. The completion of these tasks should be scheduled
so that the regulatory system is capable of handling a performance-
type standard when the consensus standard based on this document has
been completed.

Sincerely,

F. Karl Willenbrock, Director
Institute for Applied Technology

NBSIR 74-452

DESIGN AND EVALUATION CRITERIA FOR ENERGY CONSERVATION IN NEW BUILDINGS

Jim L. Heldenbrand, Editor

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

February 27, 1974
Revised February 1976

U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, *Secretary*
James A. Baker, III, *Under Secretary*
Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

FOREWORD

This document is a set of design and evaluation criteria for energy conservation in most types of new buildings. The National Conference of States on Building Codes and Standards (NCSBCS) requested that the National Bureau of Standards (NBS) develop such a document with the intent that it could serve as a basis for a national standard developed through the voluntary consensus process.

Development of these design criteria required engineering value judgments in their preparation. Two Administration energy policy directives have served as quantitative goals for the engineering judgments that guided the formulation of these criteria: these are found in the President's 1971 and 1972 Energy Messages to Congress. In 1971, the President directed the Secretary of Housing and Urban Development to reduce maximum permissible energy loss by "about one-third for a typical 1200 square foot home--and by even more for larger (federally insured) homes." In the following year, the President directed the Secretary to "issue revised insulation standards for apartments and other multifamily structures not covered by the earlier revision. The new rules will cut maximum permissible (energy) loss by 40 percent." A third Administration statement appeared part way through the criteria's development which reinforced its conservation orientation. This was Atomic Energy Commission Chairman Dixy Lee Ray's report to the President (December 1, 1973) on a plan to commit $10 billion to Federal energy research and development in fiscal 1975-79. In that report, entitled The Nation's Energy Future, conservation is central to the Federal Government's energy self-sufficiency strategy. Moreover, the Ray report ranks conservation of energy as the highest federal research and development priority.

The design and evaluation criteria focus on building subelements and service system arrangements. Special provisions offer added flexibility for both conventional and innovative designs. The technical portions of the document are organized into four complementary sections: requirements, criteria, evaluation and commentary. Existing standards and procedures promulgated by organizations such as the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), the American Society for Testing and Materials (ASTM) and the American National Standards Institute, Inc. (ANSI) are referenced whenever possible. The evaluation statements describe how to verify that candidate solutions meet the stipulated criteria. Finally, the commentary statements convey the intent of the criteria and, in a number of cases, explain how the criteria were selected.

We believe adherence to the criteria contained herein will result in significant energy savings while maintaining an acceptable level of habitability, thus advancing several national goals.

Paul R. Achenbach,   February 27, 1974
Chief
Building Environment Division
Center for Building Technology, IAT
National Bureau of Standards

DESIGN AND EVALUATION CRITERIA FOR
ENERGY CONSERVATION IN NEW BUILDINGS

CONTENTS

Page

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[1]/ Wherever the term "document" is used in this publication it refers to
these design and evaluation criteria unless the immediate context in-
dicates another meaning.

TASK GROUP FOR DEVELOPMENT OF ENERGY DOCUMENT

The energy document is the result of work by personnel of the National
Bureau of Standards Center for Building Technology augmented by a group
of advisors who met frequently over a period of three months. The fol-
lowing persons comprised the Task Group.

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*Participation in the preparation of this document does not imply endorse-
ment by the advisors or the organizations who designated them.

BACKGROUND OF PROJECT

Temporary shortages of gas, oil, and electricity have occurred during the last two years in various areas of the country. These shortages have caused temporary shutdowns of schools, offices, manufacturing, food processing, and military installations, and brought about requests to State and City executives for guidelines in the use of energy resources. Several State governments have initiated independent legislative action to control the use of limited energy resources in new buildings, thus raising the possibility that a wide variety of different requirements could be imposed on the building and equipment industries.

In an effort to provide uniformity in the requirements placed on building design by the various State and local governments, the National Conference of States on Building Codes and Standards (NCSBCS) in July 1973 requested the National Bureau of Standards (NBS) to develop an interim standard for energy conservation in new buildings which would be available for consideration by the States during their 1973-74 legislative sessions. Although NBS does not promulgate or establish engineering Standards[1], it strongly supports the concept of voluntary consensus standards. NBS agreed to develop design and evaluation criteria for energy conservation in new buildings which would be made available to a suitable organization for sponsorship through the consensus process. Toward this end NBS prepared alternative plans for expeditious promulgation of their criteria through the consensus process by such a sponsor.

NBS established a Task Group in the Center for Building Technology to develop the document. With the concurrence of NCSBCS, NBS invited three professional societies who are concerned in a broad way with the design of buildings and energy-using equipment, and NCSBCS itself to name advisors to work with the NBS Task Group. After receiving a preliminary draft, ASHRAE has offered to sponsor this document through to a national consensus voluntary standard. NCSBCS will act on this proposal at their meeting in Salt Lake City on February 27, 1974.

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[1] Exceptions to this generalization are the voluntary product standards and the limited number of mandatory standards covered by Congressional directives.

PROCEDURES USED IN DEVELOPMENT OF THE DOCUMENT

NCSBCS requested that the document be performance oriented where practicable. Since the term "performance" is subject to various interpretations, a number of different approaches were studied. The following two categories of objectives for the energy document were developed by NBS and approved by NCSBCS, and the various performance approaches were rated for their ability to attain these objectives:

ESSENTIAL OBJECTIVES

1. Be available by January 1974.

2. Effect significant energy savings.

3. Be applicable to a range of building construction, occupancies, climates, and equipment.

4. Be amenable to consistent interpretation.

5. Be compatible with existing health, safety, and environmental regulations.

6. Be useful as a design guide.

7. Be an improvement over existing documents.

8. Merit a high level of voluntary compliance.

DESIRABLE OBJECTIVES

1. Maximize energy savings.

2. Be an acceptable basis for a voluntary consensus standard.

3. Reflect due consideration of cost implications.

4. Permit design flexibility and choice of materials and equipment within given constraints.

5. Maintain acceptable standards of space, environmental conditions, and convenience.

6. Clearly differentiate requirements for each type of occupancy.

7. Suggest methods of preconstruction evaluation.

8. Include provision for different (emergency) conformance levels.

The approach which rated the highest probability of attaining the above objectives can be described as a "framework of performance statements supported by performance requirements for subelements," and was followed in preparing this document.

The timeframe within which the document was developed permitted the use of state-of-the-art technology only. A public workshop was held on November 12 and 13, 1973, after announcement in the Commerce Business Daily and the issuance of written invitations to State officials and to a broad selection of professional and industrial associations for its provisions. During the preparation of this document, meetings were held at NBS between the Task Group and officials of various industry associations representing types of energy resources, mechanical equipment for buildings, the housing and mobile home industries, and building materials, to obtain their views and recommendations of building requirements. In advance of making the resulting design and evaluation criteria available for sponsorship through a consensus review process an opportunity was provided to selected industry, professional and government groups to review a working draft. In addition NBS contracted for economic and technical impact analyses of the draft document from nine architectural and engineering firms and industry associations. These comments and analyses have received consideration in the preparation of this document.

Design requirements were developed for only those features of energy-using equipment for which enough technical information was available to support a definitive criterion. Other parameters can be covered now by guidelines to designers on an advisory basis, and may be incorporated into future revisions of the document as the experience and technology of energy conservation expands.

APPLICATION

As illustrated in Figure 1, the document provides three paths to acceptance of a building's design energy requirement. Path 1 is basic since it provides the most direct approach and also provides the basis of comparison for establishing acceptable levels of energy usage for the alternative approaches afforded by Path 2 and Path 3.

By choosing only Path 1 in Figure 1, the building designer chooses to comply with the performance statements of Chapters 5 through 9 of this document.1/ These chapters contain a set of detailed performance requirements and criteria directed toward the saving of energy through design of building envelopes with good thermal resistance and low air leakage, and utilization of energy-saving practices in the design of mechanical and electrical systems. Provisions for acceptance of alternative designs for the building envelope are also included in Chapter 5. Conformance with Chapters 5 through 9 will result in energy conservation in buildings, and will provide design guidelines suitable for most building applications without the necessity for analysis of annual energy use.

In choosing Path 2 in Figure 1, the designer must perform a dynamic energy analysis on the building and service systems selected in Path 1. The resulting computed annual energy consumption becomes a reference energy budget. An alternative building design which does not necessarily meet each and every subelement requirement will be acceptable if an energy analysis of that design shows that the calculated annual energy use is equal to or less than the reference energy budget. Details regarding the Path 2 approach are given in Chapter 10 and illustrated in Figure 10-1.

Path 3 provides the designer with an allowable increase in total design annual energy consumed by the total building system, as a bonus for substituting solar or wind powered energy for part or all of the energy otherwise generated from mineral energy sources such as fossil fuel and uranium. The reference energy budget is based on a building designed to meet the requirements of Path 1. The basis for claiming an energy bonus is a dynamic energy analysis to establish both the reference energy budget and the annual design energy contribution provided by the solar or wind powered energy source. Details regarding the Path 3 approach are given in Chapter 11 and are illustrated in Figure 11-1 and the Commentary on Chapter 11.

1/ Chapters 1 through 4 apply to all three paths.
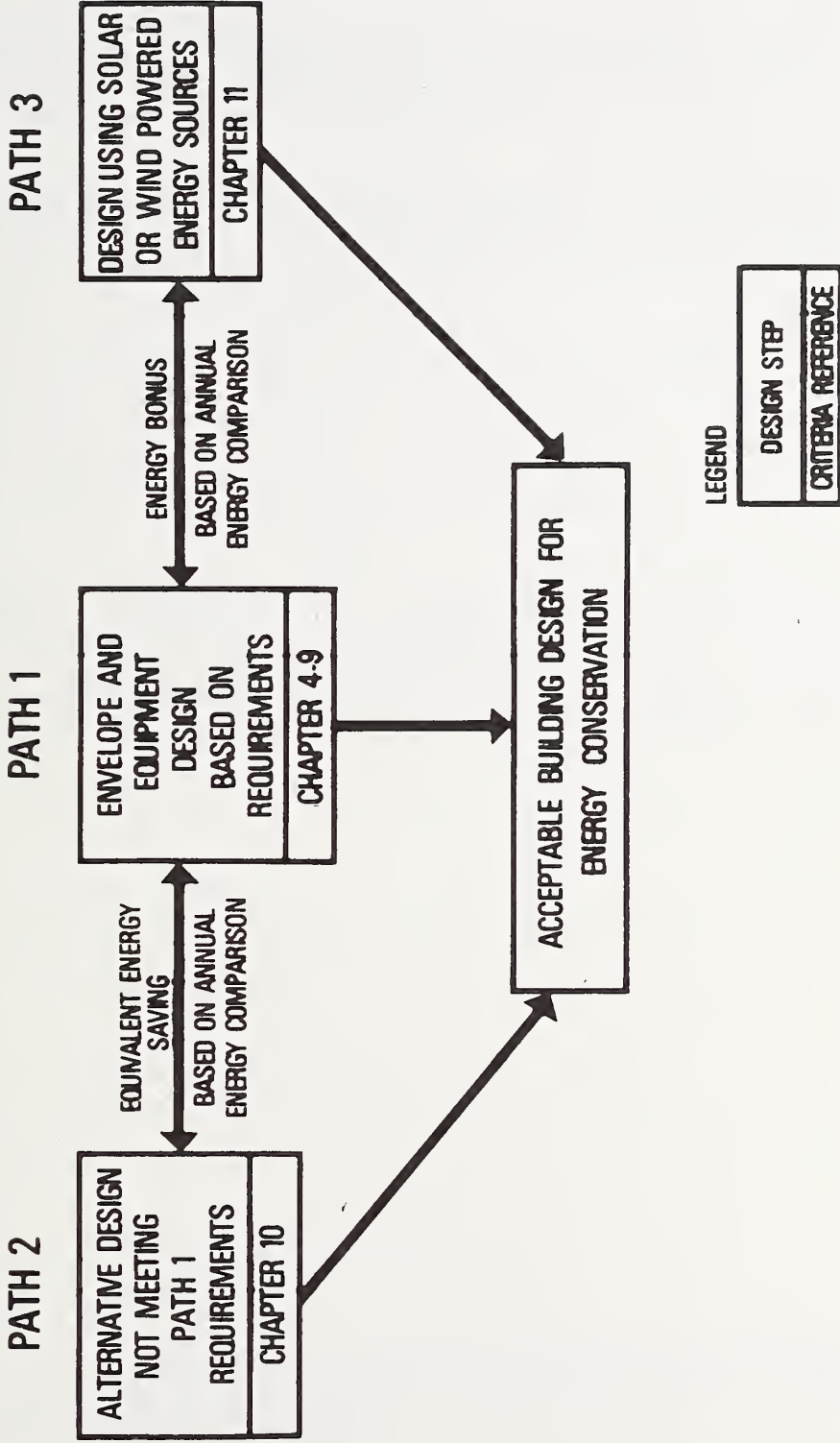
Figure 1

DESIGN CRITERIA WITH
EVALUATION AND COMMENTARY STATEMENTS

The Requirement and Criteria statements contained in this document are supplemented where necessary with Evaluation and Commentary statements.

The Evaluation statements are intended to identify suggested procedures for evaluating a building design for conformance with the Criteria. The Commentary statements provide examples and sample calculations to illustrate design options and procedures and, in some instances, provide rationale for the Criteria.

Where no Evaluation or Commentary statement is given, the Criteria statement is presumed to be self-explanatory.

CHAPTER 1

OBJECTIVE

These design and evaluation criteria contain performance-oriented re-
quirements for energy conservation in buildings. This document[1] was
prepared in response to a request by the National Conference of States
on Building Codes and Standards to the National Bureau of Standards.
It is intended to be the forerunner of a consensus standard to be
promulgated by a national standards organization.

The document is performance-based to the extent permitted by present
building design technology. The performance concept is applied at the
subelement or subsystem level to synthesize an energy-efficient total
system. The detailed performance requirements and criteria are directed
toward the design of building envelopes with good thermal resistance and
low air leakage, and toward requiring practices in the design of mechanical
and electrical systems which conserve energy. Design flexibility is
achieved by providing for acceptance of alternative design solutions that
can be shown to save equivalent amounts of energy without following each
and every detailed requirement. Such alternative designs, as well as
those based on subelement requirements, must be supported by drawings,
specifications, and calculations to demonstrate compliance.

The draft design and evaluation criteria can be made effective only by
the application of its provisions in the design process, by review and
evaluation of design proposals, and by the inspection of resulting con-
struction. It is not the intent of this document to require tests and
measurements of the completed building and its service systems to dem-
onstrate compliance with its provisions except where explicitly stated.

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[1] Wherever the term "document" is used in this publication, it refers
to these proposed design and evaluation criteria unless the immediate
context indicates another meaning.

CHAPTER 2

SCOPE

These design criteria are applicable to the design and construction of most new buildings for human occupancy except to buildings or portions thereof that are primarily an envelope over an industrial process; to buildings designed as monuments, to buildings intended for short-term periodic use, such as vacation shelters, or to portions of buildings containing special laboratories.

It is the intent of these design criteria to cover principally the features of a building and its equipment that determine its use of energy, and is not intended to abridge any safety or health requirements. The operation and use of buildings is not covered by this document, although some of the equipment requirements will inherently promote more efficient operation.

CHAPTER 3

DEFINITIONS

The following definitions are stipulated for the purposes of this document:

<u>Building</u> -- Any combination of materials, whether portable or fixed, which comprises a structure affording facilities or shelter for assembly, education, business, mercantile, institutional, or residential occupancies, as well as those portions of factory and industrial, and hazardous and storage occupancies which are used for office space. The word <u>building</u> shall be construed herein as if followed by the words "or part or parts thereof and all <u>energy-significant equipment</u> therein" unless the context clearly requires a different meaning. Unless otherwise stipulated, the term <u>buildings</u> as used in this document includes mobile homes and manufactured buildings.

<u>Coefficient of Performance (COP)</u> -- For cooling systems, the ratio of the rate of net heat removal to the rate of energy input, in consistent units. For heat pumps in the heating mode, the ratio of the rate of heat delivered to the rate of energy input, in consistent units.

<u>Engineered System</u> -- A system assembled at the point of application largely from standard components and packaged subsystems to meet a unique set of design requirements for a specific application, as contrasted with a mass produced system identified and sold as an integral product identified by a model number.

<u>Energy Converting Equipment</u> -- Equipment used principally to convert energy from one form to another, such as furnaces, electric motors, etc.

<u>Energy Processing Equipment</u> -- Equipment used principally to exchange energy, such as condensers, heat exchangers, etc. Specifically excluded are piping, ducting, and electrical distribution components.

<u>Energy-Significant Equipment</u> -- Means (1) central, unitary, or room space conditioning equipment, including but not limited to energy converting/processing equipment used in engineered systems and energy converting/processing packaged subsystems, and (2) service water-heating equipment.

<u>Full-Load Energy-Utilization Efficiency</u> (η_{fl}) -- The energy-utilization efficiency of <u>energy-significant equipment</u>, when operated at full-load rated capacity, computed as a ratio of useful output divided by energy input, including any auxiliaries, and converted to a percentage figure, as follows:

$$\eta_{fl} = \frac{\text{Output}}{\text{Thermal Input x } C_1 + \text{Electrical Input x } C_2} \ (100), \text{ percent.}$$

Where: Output = Useful effect (e.g., heating or cooling, shaft output energy, moisture added or removed, etc.) converted to Btu/hr.

Thermal Input = Thermal equivalent input of energy to direct fired equipment, in Btu/hr.

Electrical Input = Input to electrically energized equipment or components of equipment, in kw.

C_1 = 1.15 for off-cycle draft (exfiltration) losses on fuel burning equipment lacking devices to minimize air flow through the combustion chamber during burner off-cycles. C_1 = 1.0 for equipment utilizing such controls.

C_2 = 12,000 Btu/hr (kw) for electrical generation and transmission to load.

HVAC System -- A system that provides either collectively or individually the processes of comfort heating, ventilating, and/or cooling within or associated with buildings.

Manufactured Building -- Any building which is of closed construction and which is made or assembled in manufacturing facilities, on or off the building site; also any building of open construction for which certification under this document is sought by the manufacturer and which is made or assembled in manufacturing facilities away from the building site for installation, or assembly and installation on the building site. The term does not mean "mobile home."

Mobile Home -- A factory-assembled, movable dwelling designed and constructed to be towed on its own chassis, comprised of frame and wheels, usually used without a permanent foundation, and distinguishable from other types of dwellings in that the standards to which it is built include provisions for its mobility on that chassis as a vehicle.

New Energy -- Energy obtained by increasing the output of the basic energy conversion process as contrasted to energy recovered from or wasted by a primary energy-utilization system.

Opaque Areas -- All exposed areas of a building envelope which enclose conditioned space, except openings for windows, skylights, doors, and building service systems.

Recovered Energy -- Energy utilized which would otherwise be wasted (or rejected) from an energy-utilization system.

Reheat -- Sensible heat added to condition a zone to overcome cooling produced by expenditure of energy within the HVAC system serving that zone.

Solar Energy Sources -- Sources of thermal or photoelectric energy derived directly from conversion of incident solar radiation.

10

<u>Test Year</u> -- A year of hourly weather data recommended by the ASHRAE Technical Committee on Weather Data and Design Conditions for the purpose of energy consumption analysis. It is a weather year chosen from past weather in a given locality in terms of frequency, duration, and severity of hot and cold spells and in terms of overall energy requirements for heating and cooling buildings. In the absence of ASHRAE recommendations the designer may designate a test year for the locality concerned.

<u>Thermal Break</u> -- A relatively poor conductor of heat used to interrupt the path of heat flux between the inner and outer surfaces of a building element.

<u>Total Energy System</u> -- A system in which electric power is generated on or near the building site by means of engines or turbines, with exhaust and jacket heat recovered and used for space heating, water heating, absorption air conditioning, and/or process applications. For the purposes of this document, a qualifying total energy system shall have a minimum annual energy-utilization efficiency of 50 percent, including energy inputs to necessary auxiliary equipment. Combination electric generating and district heating or district cooling plants which have a minimum annual energy-utilization efficiency of 50 percent are also defined as total energy systems for the purpose of this document.

<u>Unheated Space</u> -- Means a ventilated crawl space, an unheated attic, basement or garage, or the outdoors. A basement or unheated portion thereof within which a heating system is located, shall be considered heated space if no insulation is provided at the basement ceiling, and shall be considered unheated space if insulation is provided at the basement ceiling. In mobile homes, spaces shall not be considered unheated which fall within an insulated envelope which provides one-half or more or the total resistance to the flow of heat, as required by Chapter 5.

<u>Unitary Air Conditioner</u> -- Means one or more factory made assemblies which normally include an evaporator or cooling coil, a compressor and condenser combination, and may include a heating function as well. Where such equipment is provided in more than one assembly, the separated assemblies are to be designed to be used together.

<u>Zone</u> -- With respect to the temperature control requirements in this document, a zone is defined as a portion of the space within a building which, recognizing the nature of its heating/cooling loads, could be satisfactorily controlled to desired temperature limits under varying outdoor conditions by the operation of a single automatic temperature control at an appropriate location within the zone. For actual temperature control criteria, refer to 6.4.2 and 6.4.3.

11

Full-Load Energy Utilization Efficiency -- This definition is provided in conjunction with paragraphs 6.3 and 6.4 to give system designers an interim basis for selection of efficient equipment. Efficiency information is needed for design of efficient systems, regardless of the nature of the energy source. Under the section on "New Information Needed for Energy Conservation Criteria" it is recognized that part-load efficiency data are not widely available at present for all types of energy-significant equipment. A requirement for part-load efficiency data should be incorporated in the criteria as soon as standard test procedures can be developed, in order to a) refine energy calculations affecting the design and selection of systems and equipment, and b) to avoid competitive pressures to optimize equipment efficiency at a load condition (such as 100% of design-rated load) which may not be typical of seasonal operation.

Referring to the constants used in the definition for Full-Load Energy-Utilization Efficiency, it is recognized that there are different values for energy conversion and transmission processes using direct-fired equipment. Because these factors are not all well documented at the present time, and because the order of magnitude of their values is nearest to unity, a value of one is assigned to C_1. Where off-cycle exfiltration is a factor, a 15-percent loss is assigned, pending receipt of better data. The C_2 figure of 12,000 Btu/kw hr was computed from national fuel consumption and energy production figures based on "Electric Power Statistics," Federal Power Commission, 1972, rounded to the nearest 1,000. It is necessary to use constants representing national averages to simplify the manufacturer's task of answering requests for the efficiency information stipulated in 6.4 or of publishing such data in sales literature or catalogs. This approach provides a simple yet fair method of including relative comparisons of efficiency among the considerations for deciding between competitive equipment.

12

CHAPTER 4

GENERAL PERFORMANCE REQUIREMENTS

The following general performance requirements shall be the basis for the
more detailed statements of requirements and criteria which make up this
performance document.

4.0 REQUIREMENT

Buildings and their service systems shall be designed to use energy
efficiently while maintaining an acceptable thermal and visual environ-
ment and preserving their essential functional characteristics. The
constraints put on energy use shall allow flexibility in the choice of
materials and subsystems in the design process.

4.1 REQUIREMENT

The thermal resistance and air tightness of the exterior envelope of a
building shall be designed to conserve energy under the applicable
climate and occupancy conditions.

4.2 REQUIREMENT

The service systems in buildings used for heating, cooling, ventilation,
domestic water heating, and lighting shall be designed for the efficient
use of energy whether the energy conversion to useful effect occurs in
the building or at some other location.

4.3 REQUIREMENT

Waste heat shall be recovered for useful purposes wherever practicable.

CHAPTER 5

EXTERIOR ENVELOPE REQUIREMENTS

5.0 REQUIREMENT

A building which is heated or cooled for comfort purposes shall be designed to restrict the flow of heat through the building exterior envelope.

CRITERIA (DESIGN CONDITIONS)

5.0.1 Combined Heating/Cooling -- A building designed to be both heated in winter and cooled in summer shall meet the higher of the summer and winter thermal resistance values for ceilings and roofs, opaque walls, foundation walls, slabs-on-grade, and the air leakage criteria requiring the greater airtightness. The winter design criteria shall be used to determine the area, heat transmission factors, and air leakage of doors and windows; water-vapor condensation control, and properties of caulking and sealants. The summer design criteria shall be used to determine shading requirements for windows. The preceding guidelines for selecting design criteria shall apply when establishing the reference energy budget for comparison with alternative designs provided for in Chapters 10 and 11.

EVALUATION

The design requirements for heating and cooling will be compared, where appropriate, to select the criteria which require the greater insulation resistance and airtightness.

COMMENTARY

This criterion is provided to require the designer and evaluator to design to the greatest need. For example, buildings in warm climates should restrict heat gain to minimize cooling loads, while buildings in cold climates should restrict heat loss to minimize heating loads. This criterion also requires more insulation in the coldest climates where it is most needed.

CRITERIA

5.0.2 Design Temperatures -- For the purpose of determining the thermal resistance to the flow of heat, indoor and outdoor design temperatures shall be used as specified below and in the ASHRAE Handbook of Fundamentals, 1972.

Design Temperatures, dry-bulb, °F

Indoor   Outdoor*

Heating 70 °F   Heating -- see Column 4, subheading 97-1/2%
Cooling 78 °F   Cooling -- see Column 6, subheading 2-1/2%

_____
* See next page.

14

* For locations in the United States and Canada, values given in
  Table 1, page 669, 1972 American Society of Heating, Refrigerating
  and Air Conditioning Engineers (ASHRAE) Handbook of Fundamentals,
  shall be required.

    EVALUATION

    Engineering examination of design temperatures used in calculations.

CRITERIA (HEATING)

5.0.3 Opaque Ceilings/Roof - Heating -- The heat flow through opaque
areas of roofs or ceilings facing heated interiors shall not exceed the
values of q/A (Btu/hr ft^2 of ceiling area) given in Table 5.1 for regions
classified by heating degree-days when calculated at the indoor and out-
door design temperatures specified in 5.0.2.

$$q/A = U(t_i - t_o) \tag{1}$$

$$U = \frac{q/A}{t_i - t_o} \tag{2}$$

where q/A = heat flux, Btu/hr ft^2.
    U = overall coefficient of heat transmission or thermal trans-
        mittance, air to air, Btu/hr ft^2 °F.
    t_i = indoor design temperature, °F.
    t_o = outdoor design temperature, °F.

5.0.3.1 Degree-day Values -- For locations in the United States and
Canada, yearly total heating degree-days values given in Table 2, page
433, American Society of Heating, Refrigerating and Air Conditioning
Engineers 1973 Systems Handbook shall be required. For degree-day values
falling between the values tabulated in Table 5.1, intermediate values
of q/A for ceilings and roofs may be read from Figure 5.1.

Table 5.1

Maximum Heat Flow Through Opaque
Areas of Roofs or Ceilings at Design Conditions

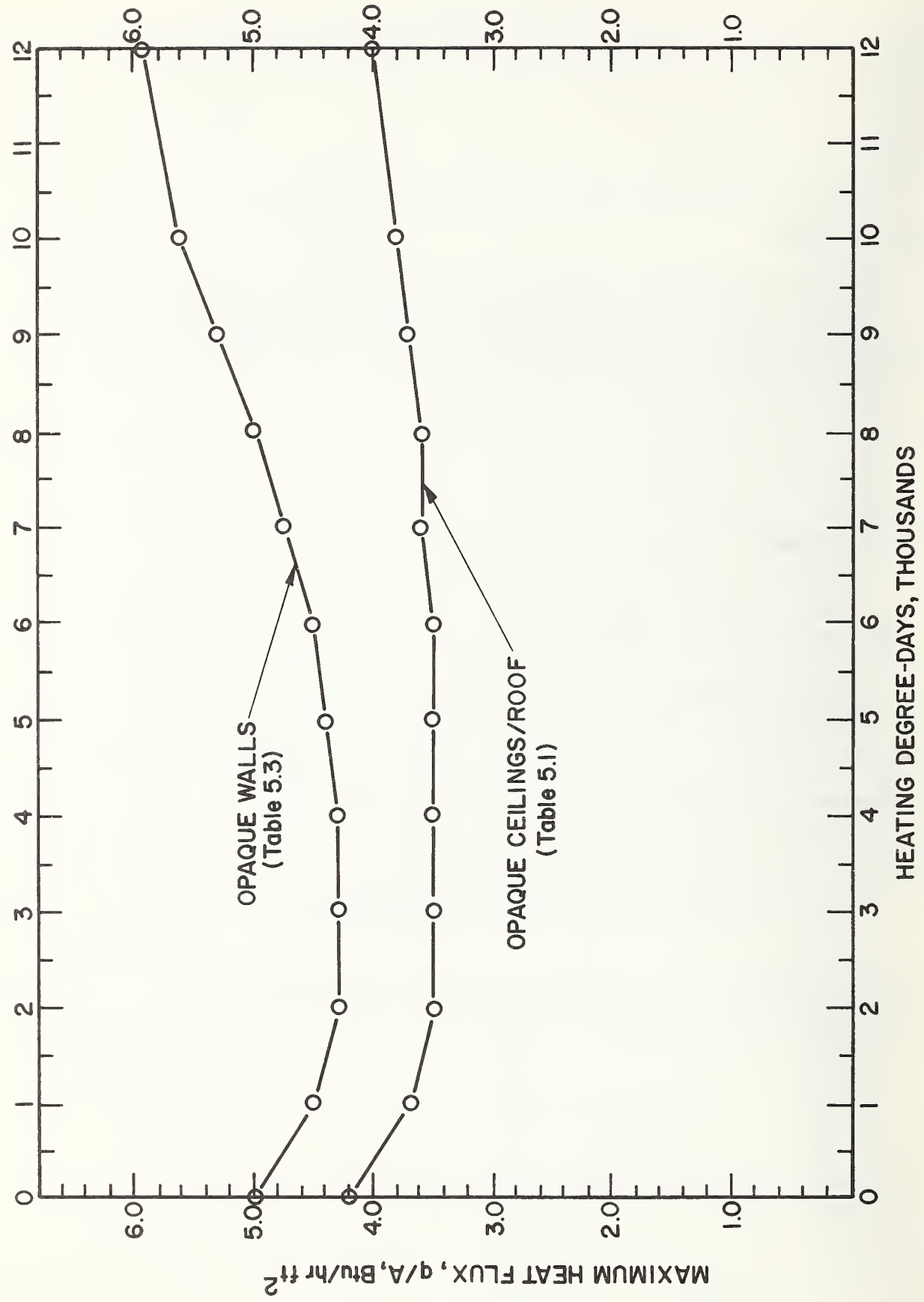| Heating Degree-days	q/A, Btu/hr (ft^2 Roof or Ceiling Area)
0	4.2
1,000	3.7
2,000	3.5
3,000	3.5
4,000	3.5
5,000	3.5
6,000	3.5
7,000	3.6
8,000	3.6
9,000	3.7
10,000	3.8
12,000	4.0
14,000 or greater	4.4

15

Figure 5.1 MAXIMUM HEAT FLUX FOR OPAQUE AREAS OF CEILING/ROOFS AND WALLS

EVALUATION

Engineering examination and evaluation of heat flow computations or
test results. Design values of the thermal resistance of building
materials as given on pages 357-363, ASHRAE 1972 Fundamentals Vol-
ume shall be used for evaluation.

COMMENTARY

A limit is placed on the heat flow through ceiling surface areas.
The required overall thermal resistance of the ceiling/roof con-
struction for each geographic area of the U. S. can be determined
by the procedure used in the illustrative examples given in Appen-
dix 1 to Chapter 5. A plot of q/A vs Heating Degree-days is shown
in Figure 5.1. Design values of the thermal resistance of build-
ing materials to be used for evaluation are given on pages 357-363,
ASHRAE 1972 Fundamentals Volume.

Heating energy used in a building correlates more closely with heat-
ing degree days than with design temperature difference. Degree
days are not precisely related to design temperature differences
referenced in handbooks. Therefore the criteria for heat flux
through building elements was made to correlate with heating degree
days and the thermal resistance was adjusted to meet the heat flux
criteria at design temperature conditions. A building in a city
having a greater design temperature difference but the same degree
days as for an identical building in another city will have greater
thermal resistance. This will result in somewhat less annual energy
usage. The rationale for this approach is to maintain approximately
equivalent comfort conditions for cities having lower extremes of
design temperature.

CRITERIA

5.0.4 Gross Exterior Walls (Including Opaque Wall, Window, and Door Areas -
Heating -- The combined thermal transmittance value (U value) for the gross
area of exterior walls consisting of opaque wall areas, window areas, and
door areas, all facing a heated interior, shall not exceed the values given
in Table 5.2 for regions as classified by heating degree-days (see 5.0.3.1)
when calculated at the indoor and outdoor design temperatures specified in
5.0.2. For degree-day values falling between the values tabulated in
Table 5.2, intermediate values of the combined thermal transmittance of
exterior walls, U_o, shall be read from Figure 5.2.

Table 5.3 provides guidelines for using equation (3) to select combina-
tions of opaque wall, fenestration, and door areas and thermal resistances
to satisfy the requirements of Table 5.2. The thermal transmittance values
for window areas and door areas, and the amount of wall, window, and door
area and its distribution in the periphery of the exterior walls of the
building are at the option of the designer, providing the criteria for com-
bines thermal transmittance are satisfied. For additional options see
5.0.9. For degree-day values falling between the values tabulated in
Table 5.3, intermediate values of q/A for opaque walls shall be read from
Figure 5.1.

17

Table 5.2

U_Q Values, Gross Exterior Wall Area, Btu/hr ft^2 °F

Heating Degree-days	One- and Two-Family Living Units and Mobile Homes	All Other Buildings
0	0.60	0.63
500	0.48	0.51
1,000	0.36	0.40
2,000	0.29	0.37
3,000	0.27	0.36
4,000	0.25	0.34
5,000	0.22	0.32
6,250	0.20	0.30
7,500	0.18	0.28
10,000	0.17	0.27
12,000	0.16	0.26

Table 5.3

Guidelines for Maximum Heat Flow Through
Opaque Areas of Walls at Design Conditions

Heating Degree-days	q/A, Btu/hr (ft^2 Opaque Wall Area)
0	5.0
1,000	4.5
2,000	4.3
3,000	4.3
4,000	4.3
5,000	4.4
6,000	4.5
7,000	4.8
8,000	5.0
9,000	5.3
10,000	5.6
12,000	5.9
14,000	6.0

For convenience of the user of this document, the heat flux (q/A), thermal resistance (R), and thermal transmittance (U) values meeting the design criteria of Tables 5.1 and 5.3 for 243 U. S. cities are tabulated in Appendix 2, along with corresponding degree-day and winter design temperature data from the ASHRAE Fundamentals and Systems Volumes, 1972 and 1973, respectively.
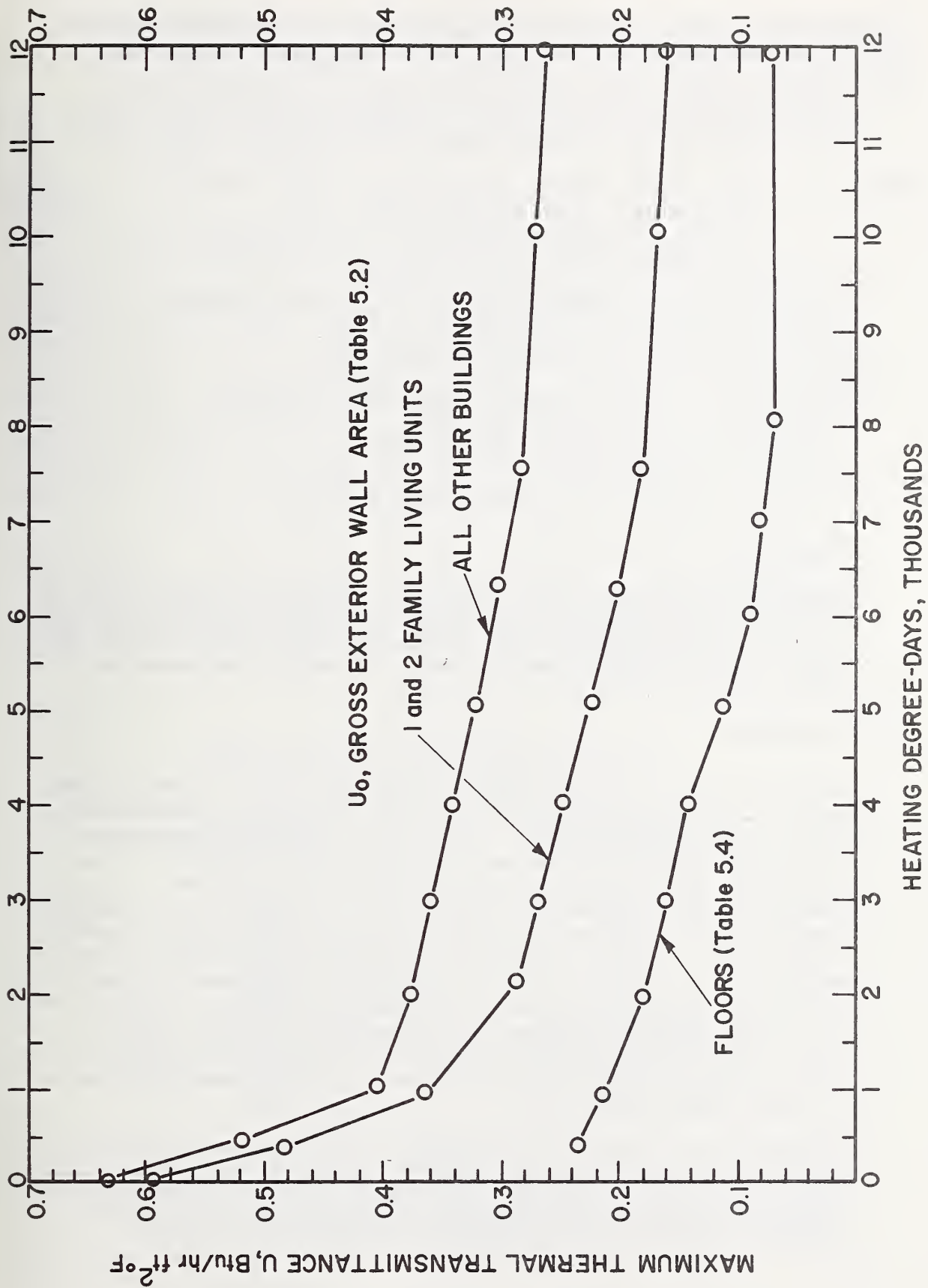
Figure 5.2 MAXIMUM THERMAL TRANSMITTANCE FOR GROSS EXTERIOR WALLS AND FLOORS FACING UNHEATED SPACES

The following formula shall be used to determine acceptable combinations of wall, window, and door areas, and thermal properties to meet the requirements of Table 5.3.

$$U_o A_o = U_{wall} A_{wall} + U_{window} A_{window} + U_{door} A_{door} \qquad (3)$$

where: U_o = the average thermal transmittance of the gross wall area and A_o = a unit area of gross wall

U_{wall} = thermal transmittance of opaque wall area

A_{wall} = ratio of opaque wall area to gross wall area

U_{window} = thermal transmittance of window

A_{window} = ratio of window area to gross wall area

U_{door} = thermal transmittance of door

A_{door} = ratio of door area to gross wall area.

EVALUATION

Engineering examination and evaluation of overall U_o-value computations. Design values of the thermal resistance of building materials, thermal transmission for windows and slab doors as given on pages 357-363, Tables 8 and 9 on page 370, ASHRAE Fundamentals Volume, shall be used for evaluation.

COMMENTARY

A limit is placed on the thermal transmittance (U_o - value) of the gross wall area around the periphery of the building, including the wall, window and door areas. The required thermal transmittance for the gross wall area for each geographic area of the U. S. can be determined by the procedure used in the illustrative examples given in Appendix 1 to Chapter 5. A plot of U_o vs Heating Degree-days is shown in Figure 5.2. Design coefficients of thermal transmission for windows and slab doors are given in Tables 8 and 9, respectively, on page 370 of the ASHRAE 1972 Fundamentals Volume and for the thermal resistance of building materials on pages 357-363. All of the thermal resistance values required by Tables 5.1, 5.2, and 5.3 can be met throughout the United States, except Alaska, without using oversized studs and joists, by using available plastic or dense fibrous insulation.

The objective of Table 5.3 is twofold: (1) to provide criteria for designers wishing to prepare energy conserving designs without performing the trade-off analysis permitted in applying Table 5.2 and paragraph 5.09; and (2) to simplify the first trial step of a

20

trade-off analysis for those designers using the alternative criteria of Table 5.3 or paragraph 5.9.9. The thermal resistance of the opaque wall construction for each geographic area of the U. S. can be determined by the procedure used in the illustrative examples given in Appendix 1 to Chapter 5. A plot of q/A vs Heating Degree-days is shown in Figure 5.1.

CRITERIA

5.0.5 Floors, Foundation Walls, and Slabs-on-Grade - Heating

Floors/Heated Spaces -- For floors that face heated areas both above and below the floor line, there is no requirement for thermal resistance of the floor area, except that the peripheral edges of the floor must contain thermal resistance equivalent to that of the thermal transmittance values of Table 5.2 for Gross Exterior Wall Area above or below the floor and the thermal resistance must be continuous vertically. If the above thermal resistance criteria for the peripheral edge of a conventional structural floor system cannot be met, the peripheral edge shall be considered a part of the gross exterior wall area which is to be designed to meet the combined thermal transmittance values in Table 5.2.

Floors/Unheated -- For floors that face unheated spaces, the required maximum thermal transmittance is given in Table 5.4. For degree-day values falling between the values tabulated in Table 5.4, intermediate values of the maximum thermal transmittance, U, shall be read from Figure 5.2.

Table 5.4

Maximum Thermal Transmittance (U-Value)
for Floors Facing Unheated Spaces

Heating Degree-days	Maximum U-value, Btu/hr ft^2 °F
0	no requirement
500	0.23
1,000	0.21
2,000	0.18
3,000	0.16
4,000	0.14
5,000	0.11
6,000	0.09
7,000	0.08
8,000 or greater	0.07

Foundation Walls -- Foundation walls and the windows and doors therein enclosing heated space and exposed to outdoor air shall contain thermal resistance equal to that required for gross exterior walls as specified in 5.0.4. The thermal resistance of foundation wall enclosing heated space below grade shall be not lower than 50% of that required for gross exterior walls above grade.

21

Slab-on-Grade -- For slab-on-grade floors the thermal resistance of the insulation around the perimeter of the floor shall be equal to 50% of the thermal resistance of the opaque wall area above the floor and shall extend downward below the grade line to the footing or the design frost line, or an equivalent distance horizontally inward from the edge under the floor.

EVALUATION

Engineering examination and evaluation of U-value and thermal resistance computations. Design values of the thermal resistance of building materials to be used for evaluation are given on pages 357-363, ASHRAE 1972 Fundamentals Volume.

COMMENTARY

Heated space is considered to be space that is heated for human occupancy or for prevention of physical damage from freezing. The meaning of "unheated space" is given in Chapter 3, Definitions. The "U" value approach is used for Table 5.4, rather than q/A, because the temperature difference at design conditions across floors over unheated spaces is more uncertain than the design indoor-outdoor temperature difference.

CRITERIA

5.0.6 Air Leakage Control

5.0.6.1 Overall Air Leakage -- The natural (not mechanically forced) leakage of air between indoors and outdoors shall not exceed 0.7 air change per hour for one- and two-family dwellings and 0.5 air change per hour for all other buildings and mobile homes.

Compliance with the overall air leakage requirement shall be determined by calculations from certified data furnished by the manufacturer or supplier on doors, windows, and exterior walls, and supplemented by calculations using the crack method given in the ASHRAE Handbook of Fundamentals, at the appropriate prevailing design wind conditions for the area of application. The 0.5 air change-per-hour criterion for all buildings other than one- and two-family dwellings and mobile homes contains an allowance for chimney effect in tall buildings.

5.0.6.2 Windows and Storm Windows -- Windows shall be designed to limit air leakage into or from the building. The air infiltration rate of aluminum, steel, and wood windows shall not exceed the rates specified in the following applicable national and industry standards, when tested at a pressure differential of 1.567 lb/ft^2, equivalent to the impact pressure of a 25 mph wind.

22

ANSI A134.1-1972   Specifications for Aluminum Prime Windows
ANSI A134.3-1972   Specifications for Aluminum Combination
                   Vertically-sliding or Horizontally-operating
                   Storm Windows for External Application.
AAMA 303.2-Jan. 1973 Specifications for Aluminum Mobile Home
                      Windows (proposed ANSI 134.5)
Steel Window Institute Recommended Specifications for Steel
                      Windows - 1973
NAAMM Standard SW-1-71 Specifications for Metal Windows
NWMA Industry Standard for Wood Window Units I.S. 2-73

Compliance with the criteria for air leakage of all types of windows shall
be determined by ASTM E283-73, Standard Method of Test for Rate of Air
Leakage Through Exterior Windows, Curtain Walls, and Doors.

5.0.6.3 Doors -- All exterior doors shall be designed to limit air leakage
into or from the building when in the closed position.

The air infiltration rates of aluminum and wood sliding glass doors shall
not exceed the rates specified in the following national and industry
standards, when tested at a pressure differential of 1.567 lb/ft^2.

    ANSI A134.2-1972 Specifications for Aluminum Sliding Glass Doors.
    NWMA I.S. 3-70 Industry Standard for Wood Sliding Patio Doors.

The air infiltration rate of swinging doors shall not exceed 1 cfm per
foot of crack in the closed position, when tested at a pressure differ-
ential of 1.567 lb/ft^2.

Compliance with the criteria for air leakage of all types of doors shall
be determined by ASTM 283.73, Standard Method of Test for Rate of Air
Leakage through Exterior Windows, Curtain Walls, and Doors.

5.0.6.4 Exterior Walls -- Panelized exterior walls shall be designed to
limit air leakage at all joints between adjacent panels and at the joints
between panels and other building elements.

The air infiltration rate of the exterior walls, excluding window elements,
shall not exceed 3 ft^3/hr ft^2 of area, when tested at a pressure differ-
ential of 1.567 lb/ft^2.

Compliance with the criteria for air leakage of all types of exterior walls
shall be determined by ASTM E238-73, Standard Method of Test for Rate of
Air Leakage through Exterior Windows, Curtain Walls, and Doors.

5.0.6.5 Caulking and Sealants -- Caulking, sealants, or gasketing meeting
the requirements of the specifications cited in the following paragraphs
shall be used at the joints around all window and door frames, at the
joints between walls and foundations, at the joints between walls and roof,
around the frames of all other openings in the exterior envelope, and at
the penetration of utility services through walls, floor, and ceiling.

The properties of the sealants, caulking, and gaskets must meet the requirements of the following ASTM and Federal Government Specifications, as applicable, when tested as specified therein:

FS-TT-S-00227E (Com-NBS) Nov. 4, 1969
Interim Fed. Spec. "Sealing Compound: Elastomeric Type, Multi-Component (For Caulking, Sealing, and Glazing in Buildings and Other Structures)."

FS-S-00230C (Com-NBS) Feb. 2, 1970
Interim Fed. Spec. "Sealing Compound: Elastomeric Type, Single Component (For Caulking, Sealing, and Glazing in Buildings and Other Structures)."

FS-TT-C-00598C (Com-NBS) June 23, 1970[1]
Interim Fed. Spec. "Caulking Compound, Oil and Resin Base Type (For Building Construction)."

FS-TT-S-001657 (Com-NBS) Oct. 8, 1970
Interim Fed. Spec. "Sealing Compound: Single Component, Butyl Rubber Based, Solvent Release Type For Buildings and Other Types of Construction)."

FS-TT-001543A (Com-NBS) June 9, 1971
Interim Fed. Spec. "Sealing Compound: Silicone Rubber Base (For Caulking, Sealing, and Glazing in Buildings and Other Structures)."

ASTM C509-70
"Standard Specification for Cellular Elastomeric Preformed Gasket and Sealing Material."

ASTM C542-71a
"Standard Specification for Lock-Strip Gaskets."

ASTM C570-72[2]
"Oil and Resin-Base Caulking Compound for Building Construction."

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[1] Same as ASTM C570-72

[2] Same as FS-TT-C00598C (Com-NBS) June 23, 1970

EVALUATION

Engineering examination and evaluation and test results data.
Evaluation against materials and assemblies specifications as published
by the Federal Government and the American Society for Testing and
Materials. The crack method as given in the 1972 ASHRAE Handbook
of Fundamentals shall be used as the basis for engineering evaluation.

COMMENTARY

The air leakage into and out of a building in winter is a significant
portion of the energy requirement necessary to maintain indoor temper-
ature. The process creating natural air leakage consists of the buoy-
ancy or chimney pressure difference of the dense cold outdoor air and
the lighter warmer indoor air plus the effect of wind velocity pressure
on the building. The air leakage limitation specified is based on
what is attainable in construction practice including allowance for
exhaust fan openings fitted with self-closing devices when the fan is
not in use. This criteria is not intended to cover purposely designed
forced ventilation systems in buildings.

Weatherstripping and caulking are required to minimize the loss of
heat energy from air infiltration and to protect the exterior enve-
lope from the elements.

CRITERIA

5.0.7 Condensation Control - Heating -- The design of the building
envelope shall provide protection against cold weather water-vapor
condensation on or in roofs, attics, walls, windows, doors, and floors.
For opaque areas of ceilings, roofs, floors, and walls containing dry
thermal insulation, a continuous vapor barrier having a water vapor
permeance not exceeding 0.5 perm (grains/hr ft^2 (in.-Hg)) is required
on the winter-time warm side of the insulation.

Slab-on-grade floors shall have a vapor barrier with lapped joints under
the slab not exceeding 0.1 perm.

A vapor barrier not exceeding 0.1 perm shall be required to cover the
ground area of a crawl space beneath floors.

Ceiling, roof, floor, and wall constructions shall contain thermal breaks
to prevent excessive heat transmission through framing members.

EVALUATION

Engineering examination and evaluation of the design and design
calculations. ASTM Recommended Practice E 241-68 for general design
information, ASTM Test Methods E 96-66 (Procedures A - dry cup) for
materials such as paper, plastic films and other sheet materials that
are less than 1/8 inch thick, and C355-64 (dessicant method) for

materials greater than 1/8 inch thick such as fiberboards, gypsum
and plaster products on wood products, shall be used to evaluate
vapor barriers, when applicable. A simulated service test or
comparison with systems known to be effective shall be used to
evaluate complete wall, floor, ceiling or roof systems.

COMMENTARY

The purpose of these criteria is to prevent indoor water vapor from
condensing on cool surfaces whose temperatures are below the dew-
point temperature of the indoor air and to prevent condensation
within the construction of indoor water vapor that permeates through
indoor surfaces.

CRITERIA

5.0.8 Orientation and Shape Analysis - Heating -- The proposed design
shall show that energy conservation was among the considerations taken
into account in determining building orientation and shape. The design
submittal shall show that the following factors have been considered in
the orientation analysis: (a) compass orientation of the building on
the site; (b) aspect ratio (ratio of length to width); and (c) the number
of stories for a given floor area requirement.

EVALUATION:

Engineering evaluation of heat loss and energy calculations.

COMMENTARY

The intent of these criteria is to require analysis of the options
available to the designer and owner of the building to conserve
energy by taking into account prevalent solar and wind conditions.
For example, if the predominant cold winds come from the north,
the north wall of the building can be designed to reduce the heat
flux, while the east, south, and west facades can be positioned to
take advantage of winter solar heat and designed for minimum solar
heat gain through windows in summer. The length-to-width ratio
and the number of stories for a given building can sometimes be
used as flexible design parameters. Subject to site constraints and
user needs, the shape of the building that defines the amount of
facade area can be varied and the energy consumption examined to
select a minimum and yet allow the functional requirements of the
building to be satisfied.

CRITERIA

5.0.9 <u>Alternative Building Envelope Heat Transmission Design Criteria -</u>
<u>Heating</u> -- Alternate designs and methods of construction that show total
building heat loss at design conditions to be equal to or less than designs
developed to satisfy all of the above criteria shall be acceptable if sub-
mitted as certified by a registered engineer or architect. For the pur-
pose of computing the total building heat loss of the building used as a
basis for comparison, the heat transmitted through the ceiling/roof shall
be based on the assumption of 100 percent opaque ceiling/roof area (not
containing skylights or saw-tooth shaped roofs containing windows). The
design heat loss calculation for any alternative building envelope or
subelement construction proposed under this criterion shall be determined
for the same indoor and outdoor design temperatures, common occupancy and
use schedules, and equivalent useful floor area, perimeter, and building
volume as for the design complying with all of the preceding criteria in
this Chapter.

    EVALUATION

    Engineering evaluation of heat loss and energy consumption calcu-
    lations.

    COMMENTARY

    The intent of these criteria is to allow a separate performance
    approach where maximum flexibility and innovation can be used that
    would result in overall conservation of energy from a process of
    trading off savings in one area of the building against losses that
    exceed the above criteria in other areas of the building. When
    this approach is used it is usually done with the aid of a computer
    where many options or changes can be examined rapidly and simultane-
    ously for the building as a whole.

CRITERIA (COOLING)

5.0.10 <u>Opaque Ceilings/Roof and Wall - Cooling</u> -- The heat flow through
opaque surface areas of roof/ceilings or[2] walls facing cooled
interiors shall not exceed 2.0 Btu/hr/ft^2 of ceiling or wall area when
calculated at an indoor design temperature of 78 °F and an outdoor sol-air
temperature calculated as follows:

$$t_{ea} = t_{oa} + \frac{\alpha}{h_o} \left(\frac{I_{DT}}{24}\right) - \frac{\epsilon \Delta R}{h_o} \qquad (4)$$

where:

    α = absorptance of the surface for solar radiation

    h_o = coefficient of heat transfer by radiation and convection of
        the outer surface, Btu/hr ft^2 °F

_____

    1/ Reference equation 42 of Chapter 22, ASHRAE Handbook of Fundamentals,
        1972.   27

t_{ea} = average sol-air temperature, °F

t_{oa} = average summer design outdoor temperature, °F

t_{oa} = t_d - $\Delta t/2$, where t_d is the summer design dry-bulb temperature listed in Table 1, page 669, 1972 ASHRAE Fundamentals Volume, Column 6 2 1/2%. Δ t is the value given in Column 7, Outdoor Daily Range.

ϵ = hemispherical emittance of the surface.

The average equivalent temperature difference, t_ϵ, is

$$t_\epsilon = t_{ea} - t_i \tag{5}$$

where t_i is the indoor design temperature, 78 °F.

The minimum thermal resistance, R, of the opaque ceiling/roof or wall is

$$R = \frac{t_\epsilon}{q/A} \; . \tag{6}$$

Inclusion of the effect of the mass (weight) of the roof or wall in addition to the above procedures shall be allowed in meeting the heat flow criteria.

R = the difference between the longwave radiation incident on the surface from the sky and surroundings, and the radiation emitted by a blackbody at outdoor air temperature Btu/hr ft^2.

α/h_o = 0.15 for light colored surfaces
0.30 for dark colored surfaces

I_{DT} = 1.15 times the maximum sum of the two half-day totals of solar heat gain factors for each wall as given in Tables 2 to 6, pages 388-392, 1972 ASHRAE Handbook of Fundamentals, Btu/hr ft^2.

$\epsilon\Delta R/h_o$ = 7 °F for horizontal surfaces
= 0 °F for vertical surfaces.

EVALUATION

Examination and evaluation of engineering calculations.

COMMENTARY

The average equivalent temperature difference, t_ϵ, is used in the criterion instead of actual indoor air to outdoor air temperature differential to account for solar heating of outdoor surfaces to temperatures greater than the outdoor air temperature. The examples in Appendix 1 at the end of Chapter 5 will serve to illustrate the procedure for limiting the heat flux and determining the required overall thermal resistance and thermal transmittance (U-value).

CRITERIA

5.0.11 Window Heat Gain - Cooling -- The heat gain through transparent
window areas of the exterior envelope shall be controlled during the
cooling season in relation to the geographic location and the compass
orientation of the building on its site. Plain glass without a shading
device is not permitted (e.g., shades, venetian blinds, draperies,
awnings, eyebrow reveals, or vertical/horizontal fins must be used). The
windows shall be equipped with shading devices, interior or exterior,
that will limit, during the cooling season, the maximum instantaneous
combined solar and air-to-air heat transmission at design conditions to
70 Btu/hr ft^2 of transparent window area, as an average for the entire
window.

EVALUATION

Engineering examination and evaluation of calculations. For evalu-
ation of design, calculation procedures given on pages 386 through
410 of the 1972 ASHRAE Handbook of Fundamentals shall be used.

CRITERIA

5.0.12 Doors - Cooling -- Heating criteria apply (see 5.0.4. and 5.0.6.3).

EVALUATION

See Heating Evaluation, 5.0.4.

COMMENTARY

See Heating Commentary, 5.0.4.

CRITERIA

5.0.13 Floors, Foundation Walls, and Slabs-on-Grade - Cooling --
Heating criteria apply (see 5.0.5).

EVALUATION

See Heating Evaluation, 5.0.5.

COMMENTARY

See Heating Commentary, 5.0.5.

CRITERIA

5.0.14 Air Leakage Control - Cooling -- Heating criteria apply except
that the natural (not forced) leakage of air from cooled spaces to the
outdoors shall not exceed 0.5 volume air change per hour at design condi-
tions for one- and two-family dwellings. (See 5.0.6.1)

EVALUATION

See Heating Evaluation following 5.0.6.5

COMMENTARY

See Heating Commentary following 5.0.6.5

CRITERIA

5.0.15 Orientation on Site - Cooling -- The proposed design shall show
that energy conservation was among the considerations taken into account
in determining building orientation and shape. The design submittal shall
show that the following factors have been considered in the orientation anal-
ysis: (a) compass orientation of the building on the site; (b) aspect ratio
(ratio of length to width); and (c) the number of stories for a given floor
area requirement.

EVALUATION

See Heating Evaluation, 5.0.8

COMMENTARY

See Heating Commentary, 5.0.8

CRITERIA

5.0.16 Alternative Building Envelope Heat Transmission - Cooling --
Alternative designs and methods of construction that show design total
building heat gains equal to or less than designs developed to satisfy
all of the above criteria shall be acceptable if submitted as certified
by a registered engineer or architect. The purpose of these criteria is
to allow energy trade-offs that would result in equivalent overall con-
servation of energy, even though the criteria for selected subelements
of the building may not precisely meet the specified requirements. For
the purpose of computing the total heat gain of the basic building used
for comparison, the heat gain through the ceiling/rood shall be based on
the assumption of 100-percent opaque ceiling/roof area (not containing
skylights or saw-tooth shaped roofs containing windows).

The design cooling load calculation for any alternative building envelope
or subelement construction proposed under this criterion shall be deter-
mined for the same indoor and outdoor design temperatures, common occu-
pancy and use schedules, and equivalent useful floor area, perimeter, and

30

building volume as for the design complying with all of the preceding criteria in this Chapter that are applicable to cooling.

EVALUATION

See Heating Evaluation, 5.0.9.

COMMENTARY

See Heating Commentary, 5.0.9.

5.0.3 Opaque Ceilings/Roof - Heating

1) Location, Duluth, Minnesota

Heating Degree-Days, 10,000 (from p. 43.5 ASHRAE 1973 Systems Vol)

Required q/A, 3.8 Btu/hr. ft^2 of ceiling area from Criteria 5.0.3.

Design Temperatures
   Indoor , 70 °F (from Criteria 5.0.2)
   Outdoor, -15 °F (from p.674 ASHRAE 1972 Fundamentals Volume)

Design Temperature Difference, $[70 - (-15)] = 85°F$

Overall Thermal Resistance, R
$$R = \frac{\text{Design Temperature Difference}}{q/A} = \frac{85}{3.8} = 22.37$$
Overall Thermal Transmittance, (U-value)
$$U = \frac{1}{R} = \frac{1}{22.37} = 0.0447 \text{ Btu/hr ft}^2 \text{ °F}$$

2) Location - Scranton/Wilkes-Barre, Pennsylvania

Heating Degree-Days - 6254

Required q/A - 3.52

Design Temperature Difference - $[70 - 6] = 64$

Overall Thermal Resistance - $\frac{64}{3.52} = 18.18$

Overall Thermal Transmittance - $\frac{1}{18.18} = 0.055$

3) Location - Atlanta, Georgia

Heating Degree-Days - 2961

Required q/A - 3.5

Design Temperature Difference - $[70 - 23] = 47$

Overall Thermal Resistance - $\frac{47}{3.5} = 13.43$

Overall Thermal Transmittance - $\frac{1}{13.43} = 0.074$

4) Location - San Diego, California

Heating Degree-Days - 1458

Required q/A - 3.59

Design Temperature Difference − $[70 − 44] = 26$

Overall Thermal Resistance − $\dfrac{26}{3.59} = 7.24$

Overall Thermal Transmittance − $\dfrac{1}{7.24} = 0.14$

5) Location − Key West, Florida

Heating Degree-Days − 108

Required q/A − 4.1

Design Temperature Difference − $[70 − 58] = 12$

Overall Thermal Resistance − $\dfrac{12}{4.1} = 2.93$

Overall Thermal Transmittance − $\dfrac{1}{2.93} = 0.34$

33

5.0.4   Gross Exterior Walls (Including Opaque Walls, Window, and Door Areas) Heating -- Table 5.2

1) Duluth, Minnesota, 10,000 heating degree-days

Single-Family

U_{wall} = 0.066 from Opaque wall criteria

Assume 10% single glass and 4% metal storm doors

$$U_o x \ 1 = 0.066 \times 0.86 + 1.13 \times 0.1 + 0.33 \times 0.04$$
$$= 0.057 + 0.113 + 0.013$$
$$= 0.183 \text{ will not meet 0.17 Criteria}$$

Assume 10% storm windows and 4% metal storm doors

$$U_o x \ 1 = 0.066 \times 0.86 + 0.56 \times 0.1 + 0.33 \times 0.04$$
$$= 0.057 + 0.056 \times 0.013$$
$$= 0.126 \text{ will meet 0.17 Criteria}$$

Assume U_{wall} = 0.11 10% storm windows and 4% metal storm doors

$$U_o x \ 1 = 0.11 \times 0.86 + 0.56 \times 0.1 + 0.33 \times 0.04$$
$$= 0.095 + 0.056 + 0.013$$
$$= 0.164 \text{ will meet 0.17 Criteria}$$

Assume 15% storm windows and 4% metal storm doors

$$U_o x \ 1 = 0.066 \times 0.81 + 0.56 \times 0.15 + 0.33 \times 0.04$$
$$= 0.053 + 0.084 + 0.013$$
$$= 0.15 \text{ will meet 0.17 Criteria}$$

Assume 20% storm windows and 4% metal storm doors

$$U_o x \ 1 = 0.066 \times 0.76 + 0.56 \times 0.2 + 0.33 \times 0.04$$
$$= 0.05 + 0.112 + 0.013$$
$$= 0.175 \text{ will not meet 0.17 Criteria}$$

All other buildings

Assume 10% insulating glass area and 1% insulated steel door

$$U_o x \ 1 = 0.066 \times 0.89 + 0.65 \times 0.1 + 0.59 \times 0.01$$
$$= 0.059 + 0.065 + 0.006$$
$$= 0.13 \text{ will meet 0.27 Criteria}$$

Assume 30% insulating glass area and 1% insulated steel door

$$U_o x \ 1 = 0.066 \times 0.69 + 0.65 \times 0.3 + 0.59 \times 0.01$$
$$= 0.046 + 0.195 + 0.006$$
$$= 0.247 \text{ will meet 0.27 Criteria}$$

34

Assume 30% single glass area and 1% insulated steel door

$$U_o \times 1 = 0.066 \times 0.69 + 1.13 \times 0.3 + 0.59 \times 0.01$$
$$= 0.046 + 0.339 + 0.006$$
$$= 0.39 \text{ will not meet } 0.27 \text{ Criteria}$$

Assume $U_{wall} = 0.16$, 10% single glass and 1% insulated steel door

$$U_o \times 1 = 0.16 \times 0.89 + 1.13 \times 0.1 + 0.59 \times 0.01$$
$$= 0.142 + 0.113 + 0.006$$
$$= 0.261 \text{ will meet } 0.27 \text{ Criteria}$$

Assume 50% insulating glass emissivity coating = 0.2 and 1% insulated steel door

$$U_o \times 1 = 0.066 \times 0.49 + 0.38 \times 0.5 + 0.59 \times 0.01$$
$$= 0.032 + 0.19 + 0.006$$
$$= 0.23 \text{ meets } 0.27 \text{ Criteria}$$

2) Scranton/Wilkes-Barre, Pennsylvania, 6254 heating degree-days

$U_{wall} = 0.072$ from opaque wall criteria

Single-Family

Assume 5% single-glass, 10% storm windows and 4% metal storm door

$$U_o \times 1 = 0.072 \times 0.81 + 1.13 \times 0.05 + 0.56 \times 0.1 + 0.33 \times 0.04$$
$$= 0.058 + 0.057 + 0.056 + 0.013$$
$$= 0.184 \text{ meets } 0.20 \text{ Criteria}$$

Assume $U_{wall} = 0.12$, 15% storm windows and 4% metal storm doors

$$U_o \times 1 = 0.12 \times 0.81 + 0.56 \times 0.15 + 0.33 \times 0.04$$
$$= 0.097 + 0.084 + 0.013$$
$$= 0.194 \text{ will meet } 0.20 \text{ Criteria}$$

All other buildings

Assume 30% insulating glass area and 1% insulated door area

$$U_o \times 1 = 0.072 \times 0.69 + 0.65 \times 0.3 + 0.59 \times 0.01$$
$$= 0.050 + 0.195 + 0.006$$
$$= 0.251 \text{ meets } 0.30 \text{ Criteria}$$

Assume 50% insulating glass area emissivity coating, 0.6, and 1% insulating steel doors

$$U_o \times 1 = 0.072 \times 0.49 + 0.52 \times 0.5 + 0.59 \times 0.01$$
$$= 0.035 + 0.26 + 0.006$$
$$= 0.30 \text{ meets } 0.30 \text{ Criteria}$$

35

Assume U_{wall} = 0.20, 10% single glass and 1% insulating steel doors

U_o x 1 = 0.20 x 0.89 + 1.13 x 0.1 + 0.59 x 0.01
= 0.178 + 0.113 + 0.006
= 0.297 meets 0.30 Criteria

3) Atlanta, Georgia, 2961 heating degree-days

U_{wall} = 0.091 from opaque wall criteria

<u>Single-Family</u>

Assume 15% single glass and 4% metal storm doors

U_o x 1 = 0.091 x 0.81 + 1.13 x 0.15 + 0.33 x 0.04
= 0.074 + 0.17 + 0.013
= 0.257 meets 0.27 Criteria

<u>All other buildings</u>

Assume 25% single glass and 1% insulated door area

U_o x 1 = 0.091 x 0.74 + 1.13 x 0.25 + 0.59 x 0.01
= 0.067 + 0.283 + 0.006
= 0.356 meets 0.36 Criteria

Assume U_{wall} = 0.27, 10% single glass and 1% insulated door area

U_o x 1 = 0.27 x 0.89 + 1.13 x 0.1 + 0.59 x 0.01
= 0.24 + 0.113 + 0.006
= 0.359 meets 0.36 Criteria

Assume 45% insulating glass and 1% insulated door area

U_o x 1 = 0.091 x 0.54 + 0.65 x 0.45 + 0.59 x 0.01
= 0.049 + 0.293 + 0.006
= 0.348 meets 0.36 Criteria

4) San Diego, California, 1458 heating degree-days

U_{wall} = 0.17 from opaque wall criteria

<u>Single-Family</u>

Assume 15% single glass and 4% wood doors

U_o x 1 = 0.17 x 0.81 + 1.13 x 0.15 + 0.49 x 0.04
= 0.137 + 0.169 + 0.02
= 0.32 meets 0.32 Criteria

36

All other buildings

Assume 20% single glass, 1% insulated door area

$U_o \times 1 = 0.17 \times 0.79 + 1.13 \times 0.2 + 0.59 \times 0.01$
$ = 0.134 + 0.226 + 0.006$
$ = 0.37$ meets 0.38 Criteria

Assume 40% insulating glass and 1% insulated door area

$U_o \times 1 = 0.17 \times 0.59 + 0.65 \times 0.4 + 0.59 \times 0.01$
$ = 0.10 + 0.26 + 0.006$
$ = 0.37$ meets 0.38 Criteria

5) Key West, Florida, 108 heating degree-days

$U_{wall} = 0.41$ from opaque wall criteria

Single-Family

Assume 25% single glass and 4% wood doors

$U_o \times 1 = 0.41 \times 0.71 + 1.13 \times 0.25 + 0.49 \times 0.04$
$ = 0.29 + 0.283 + 0.02$
$ = 0.59$ meets 0.60 Criteria

All other buildings

Assume 30% single glass and 1% insulated door area

$U_o \times 1 = 0.41 \times 0.69 + 1.13 \times 0.3 + 0.59 \times 0.01$
$ = 0.283 + 0.339 + 0.006$
$ = 0.628$ meets 0.63 Criteria

Assume 50% insulating glass and 1% insulated door area

$U_o \times 1 = 0.41 \times 0.49 + 0.65 \times 0.5 + 0.59 \times 0.01$
$ = 0.20 + 0.325 + 0.006$
$ = 0.53$ meets 0.63 Criteria

37

5.0.4 Opaque Walls - Heating, Table 5.3

    (1) <u>Location</u> - Duluth, Minnesota

        <u>Heating Degree-Days</u> - 10,000 (from p. 43.5 ASHRAE 1973 Systems
                                            Volume)

        <u>Required q/A</u> - 5.6 Btu/hr. ft^2 of wall area from Criteria 5.2.2

        <u>Design Temperatures</u>

            Indoor, 70 °F (from Criteria 5.1.2)
            Outdoor, -15 °F (from p. 674 ASHRAE 1972 Fundamentals
                        Volume)

        <u>Design Temperature Difference</u> - [70 - (-15)] = 85 °F

        <u>Overall Thermal Resistance, R</u>

$$R = \frac{\text{Design Temperature Difference}}{q/A} = \frac{85}{5.6} = 15.18$$

        <u>Overall Thermal Transmittance, (U-value)</u>

$$U = \frac{1}{R} = \frac{1}{15.18} = 0.066$$

    (2) <u>Location</u> - Scranton/Wilkes-Barre, Pennsylvania

        <u>Heating Degree-Days</u> - 6254

        <u>Required q/A</u> - 4.58

        <u>Design Temperature Difference</u> - [70 - 6] = 64

        <u>Overall Thermal Resistance</u> - $\frac{64}{4.58}$ = 13.97

        <u>Overall Thermal Transmittance</u> - $\frac{1}{13.97}$ = 0.072

    (3) <u>Location</u> - Atlanta, Georgia

        <u>Heating Degree-Days</u> - 2961

        <u>Required q/A</u> - 4.3

        <u>Design Temperature Difference</u> - [70 - 23] = 47

        <u>Overall Thermal Resistance</u> - $\frac{47}{4.3}$ = 10.93

        Overall Thermal Transmittance - $\frac{1}{10.93}$ = 0.091

(4) Location - San Diego, California

Heating Degree-Days - 1458

Required q/A - 4.41

Design Temperature Difference - [70 - 44] = 26

Overall Thermal Resistance - $\frac{26}{4.41}$ = 5.9

Overall Thermal Transmittance - $\frac{1}{5.9}$ = 0.17

(5) Location - Key West, Florida

Heating Degree-Days - 108

Required q/A - 4.95

Design Temperature Difference - [70 - 58] = 12

Overall Thermal Resistance - $\frac{12}{4.95}$ = 2.42

Overall Thermal Transmittance - $\frac{1}{2.42}$ = 0.41

5.0.4 Opaque Ceilings/Roof and Wall - Cooling

1) Key West, Florida

From Table 1, p. 671, 1972 ASHRAE Handbook of Fundamentals

Latitude = 24° 3"
Design dry-bulb temperature, Δt_d = 89 °F
Outdoor daily range, Δt = 9 °F

From Table 2, p. 388, 1972 ASHRAE Handbook of Fundamentals

Horizontal Roofs, the maximum half-day total value occurs on June 21, and is equal to 1095

For walls, maximum half-day totals are:

North, 282 a.m. and 282 p.m. on June 21
East, 936 a.m. and 176 p.m. on June 21
South, 451 a.m. and 451 p.m. on September 21
West, 176 a.m. and 936 p.m. on June 21

$$t_{ea} = t_{oa} + \frac{\alpha}{h_o} \left(\frac{I_{DT}}{24}\right) - \frac{\varepsilon \Delta R}{h_o}$$

For Roofs

light colored, $t_{ea} = \left(89 - \frac{9}{2}\right) + 0.15 \left[\frac{1.15\ (1095 + 1095)}{24}\right] - 7$

$$t_{ea} = 93.2 \ °F$$

$\Delta t_\varepsilon = t_{ea} - t_i$
$= 93.2 - 78$
$= 15.2$

$R = \dfrac{\Delta t_\varepsilon}{q/A} = \dfrac{15.2}{2.0} = 7.6$

$U = 0.13$

<u>dark colored,</u>

$$t_{ea} = (89 - \frac{9}{2}) + 0.3 \left[\frac{1.15 \ (1095 + 1095)}{24} \right] - 7 = 109.$$

$$\Delta t_\ell = t_{ea} - t_i$$
$$= 109 - 78$$
$$= 31$$

$$R = \frac{\Delta t_\ell}{q/A} = \frac{31}{2.0} = 15.5$$

$$U = 0.065$$

<u>For walls</u>

<u>light colored</u>

North, $t_{ea} = (89 - \frac{9}{2}) + 0.15 \left[\frac{1.15 \ (282 + 282)}{24} \right] - 0 = 88.6 \ °F$

$$\Delta t_\ell = t_{ea} - t_i$$
$$= 88.6 - 78$$
$$= 10.6$$

$$R = \frac{\Delta t_\ell}{q/A} = \frac{10.6}{2.0} = 5.3$$

$$U = 0.19$$

East, $t_{ea} = (89 - \frac{9}{2}) + 0.15 \left[\frac{1.15 \ (936 + 176)}{24} \right] - 0 = 92.5 \ °F$

$$\Delta t_\ell = t_{ea} - t_i$$
$$= 92.5 - 78$$
$$= 14.5$$

$$R = \frac{\Delta t_\ell}{q/A} = \frac{14.5}{2.0} = 7.25$$

$$U = 0.14$$

South, $t_{ea} = (89 - \frac{9}{2}) + 0.15 \left[\frac{1.15 \ (451 + 451)}{24} \right] - 0 = 90. \ °F$

$$\Delta t_\ell = t_{ea} - t_i$$
$$= 90 - 78$$
$$= 12$$

$$R = \frac{\Delta t_\ell}{q/A} = \frac{12}{2.0} = 6.0$$

$$U = 0.17$$

West, $t_{ea} = (89 - \frac{9}{2}) + 0.15 \left[\frac{1.15 \ (176 + 936)}{24} \right] - 0 = 92.4 \ °F$

$$\Delta t_\ell = t_{ea} - t_i$$
$$= 92.4 - 78$$
$$= 14.4$$

$$R = \frac{\Delta t_\ell}{q/A} = \frac{14.4}{2.0} = 7.2$$

$$U = 0.14$$

dark colored

North, $t_{ea} = (89 - \frac{9}{2}) + 0.30 \left[\frac{1.15 \ (282 + 282)}{24} \right] - 0 = 92.7 \ °F$

$$\Delta t_\ell = 92.7 - 78 = 14.7$$

$$R = \frac{\Delta t_\ell}{q/A} = \frac{14.7}{2.0} = 7.35$$

$$U = 0.14$$

East, $t_{ea} = (89 - \frac{9}{2}) + 0.30 \left[\frac{1.15 \ (936 + 176)}{24} \right] - 0 = 100.5$

$$\Delta t_\ell = t_{ea} - t_i$$
$$= 100.5 - 78$$
$$= 22.5$$

$$R = \frac{\Delta t_\ell}{q/A} = \frac{22.5}{2.0} = 11.25$$

$$U = 0.09$$

South, $t_{ea} = (89 - \frac{9}{2}) + 0.30 \left[\frac{1.15 \ (451 + 451)}{24} \right] - 0 = 97.5 \ °F$

$$\Delta t_\ell = t_{ea} - t_i$$
$$= 97.5 - 78$$
$$= 19.5$$

$$R = \frac{\Delta t_\ell}{q/A} = \frac{19.5}{2.0} = 9.75$$

$$U = 0.10$$

42

West, $t_{ea} = (89 - \frac{9}{2}) + 0.30 \left[\frac{1.15 \ (176 + 936)}{24} \right] - 0 = 100.3 \ °F$

$\Delta t_{\xi} = t_{ea} - 78$

$\qquad = 100.3 - 78$

$\qquad = 22.3$

$R = \frac{\Delta t_{\xi}}{q/A} = \frac{22.3}{2.0} = 11.15$

$U = 0.09$

(2) San Diego, California

Latitude = 32° 4'
Design dry-bulb temperature, t_d = 83 °F
Outdoor daily range, Δt = 12 °F
Horizontal Roofs, max. half-day total = 1119 on June 21
For walls, max. half-day totals are:

  North, 252 a.m. and 252 p.m. on June 21
  East , 972 a.m. and 180 p.m. on June 21
  South, 844 a.m. and 844 p.m. on December 21
  West , 172 a.m. and 983 p.m. on May 21

$t_{ea} = t_{oa} + \frac{\alpha}{h_o} \left(\frac{I_{DT}}{24} \right) - \frac{\mathcal{E}\Delta R}{h_o}$

For Roofs

light colored, $t_{ea} = (83 - \frac{12}{2}) + 0.15 \left[\frac{1.15 \ (1119 + 1119)}{24} \right] - 7 = 86 \ °F$

$\Delta t_{\xi} = t_{ea} - t_i$

$\qquad = 86 - 78$

$\qquad = 8 \ °F$

$R = \frac{\Delta t_{\xi}}{q/A} = \frac{8}{2.0} = 4.0$

$U = 0.25$

43

<u>dark colored</u>, $t_{ea} = (83 - \frac{12}{2}) + 0.3 \left[\frac{1.15\ (1119 + 1119)}{24} \right] - 7 = 102\ °F$

$$\Delta t_\xi = t_{ea} - t_i$$
$$= 102 - 78$$
$$= 24\ °F$$

$$R = \frac{\Delta t_\xi}{q/A} = \frac{24}{2.0} = 12.0$$

$$U = 0.08$$

For walls

light colored

North, $t_{ea} = (83 - \frac{12}{2}) + 0.15 \left[\frac{1.15\ (252 + 252)}{24} \right] - 0 = 80.6\ °F$

$$\Delta t_\xi = t_{ea} - t_i$$
$$= 80.6 - 78$$
$$= 2.6$$

$$R = \frac{\Delta t_\xi}{q/A} = \frac{2.6}{2.0} = 1.3$$

$$U = 0.77$$

East, $t_{ea} = (83 - \frac{12}{2}) + 0.15 \left[\frac{1.15\ (972 + 180)}{24} \right] - 0 = 85.3\ °F$

$$\Delta t_\xi = t_{ea} - t_i$$
$$= 85.3 - 78$$
$$= 7.3\ °F$$

$$R = \frac{\Delta t_\xi}{q/A} = \frac{7.3}{2.0} = 3.65$$

$$U = 0.27$$

44

South, $t_{ea} = (83 - \frac{12}{2}) + 0.15 \left[\frac{1.15 \ (844 + 844)}{24} \right] - 0 = 89.1 \ °F$

$$\Delta t_{\xi} = t_{ea} - t_i$$
$$= 89.1 - 78$$
$$= 11.1$$

$$R = \frac{\Delta t_{\xi}}{q/A} = \frac{11.1}{2.0} = 5.55$$

$$U = 0.18$$

West, $t_{ea} = (83 - \frac{12}{2}) + 0.15 \left[\frac{1.15 \ (983 + 172)}{24} \right] - 0 = 85.3 \ °F$

$$\Delta t_{\xi} = t_{ea} - t_i = 85.3 - 78 = 7.3$$

$$R = \frac{\Delta t_{\xi}}{q/A} = \frac{7.3}{2.0} = 3.65$$

$$U = 0.27$$

dark colored

North, $t_{ea} = (83 - \frac{12}{2}) + 0.30 \left[\frac{1.15 \ (252 + 252)}{24} \right] - 0 = 90.2 \ °F$

$$\Delta t_{\xi} = t_{ea} - t_i$$
$$= 90.2 - 78$$
$$= 12.2$$

$$R = \frac{\Delta t_{\xi}}{q/A} = \frac{12.2}{2.0} = 6.1$$

$$U = 0.16$$

East, $t_{ea} = (83 - \frac{12}{2}) + 0.30 \left[\frac{1.15 \ (972 + 180)}{24} \right] - 0 = 93.6 \ °F$

$$\Delta t_{\xi} = t_{ea} - t_i$$
$$= 93.6 - 78 = 15.6$$

$$R = \frac{\Delta t_{\xi}}{q/A} = \frac{15.6}{2.0} = 7.8$$

$$U = 0.13$$

45

South, $t_{ea} = (83 - \frac{12}{2}) + 0.30 \left[\frac{1.15 \ (844 + 844)}{24} \right] - 0 = 101.2 \ °F$

$\Delta t_{\xi} = t_{ea} - t_i = 101.2 - 78 = 23.2$

$R = \frac{\Delta t_{\xi}}{q/A} = \frac{23.2}{2.0} = 11.6$

$U = 0.09$

West, $t_{ea} = (83 - \frac{12}{2}) + 0.30 \left[\frac{1.15 \ (983 + 172)}{24} \right] - 0 = 93.6 \ °F$

$\Delta t_{\xi} = t_{ea} - t_i = 93.6 - 78 = 15.6$

$R = \frac{\Delta t_{\xi}}{q/A} = \frac{15.6}{2.0} = 7.8$

$U = 0.13$

APPENDIX 2

HEAT FLUX, THERMAL RESISTANCE, AND THERMAL
TRANSMITTANCE VALUES[1] FOR CEILINGS, ROOFS,
AND OPAQUE WALLS MEETING THE DESIGN
CRITERIA OF TABLES 5.1 AND 5.3 FOR
243 U. S. CITIES

[1] The degree-day and winter outside design temperature
in this Appendix are taken from ASHRAE Systems Volume
(1973) and the ASHRAE Fundamentals Volume (1972),
respectively.

STATE	STATION	DEGREE DAY	DESIGN TEMP.	DESIGN ΔT	CEILING/ROOF			WALL		
					Q/A	R	U	Q/A	R	U
ALA.	BIRMINGHAM	2551	22	48	3.50	13.71	.07	4.30	11.16	.09
	HUNTSVILLE	3070	17	53	3.50	15.14	.07	4.30	12.33	.08
	MOBILE	1560	29	41	3.59	11.43	.09	4.39	9.34	.11
	MONTGOMERY	2291	26	44	3.50	12.57	.08	4.30	10.23	.10
ALASKA	ANCHORAGE	10864	-20	90	3.89	23.16	.04	5.73	15.71	.06
	FAIRBANKS	14279	-50	120	4.40	27.27	.04	6.00	20.00	.05
	JUNEAU	9075	-4	74	3.71	19.96	.05	5.32	13.90	.07
	NOME	14171	-28	98	4.40	22.27	.04	6.00	16.33	.06
ARIZ.	FLAGSTAFF	7152	5	65	3.60	18.06	.06	4.83	13.46	.07
	PHOENIX	1765	34	36	3.55	10.15	.10	4.35	8.28	.12
	TUCSON	1800	32	38	3.54	10.73	.09	4.34	8.76	.11
	WINSLOW	4782	13	57	3.50	16.29	.06	4.38	13.02	.08
	YUMA	974	40	30	3.71	8.08	.12	4.51	6.65	.15
ARK.	FORT SMITH	3292	19	51	3.50	14.57	.07	4.30	11.86	.08
	LITTLE ROCK	3219	23	47	3.50	13.43	.07	4.30	10.93	.09
	TEXARKANA	2533	26	44	3.50	12.57	.08	4.30	10.23	.10
CALIF.	BAKERSFIELD	2122	33	37	3.50	10.57	.09	4.30	8.60	.12
	BURBANK	1646	38	32	3.57	8.96	.11	4.37	7.32	.14
	EUREKA	4643	35	35	3.50	10.00	.10	4.36	8.02	.12
	FRESNO	2611	31	39	3.50	11.14	.09	4.30	9.07	.11
	LONGBEACH	1803	38	32	3.54	9.04	.11	4.34	7.37	.14
	LOS ANGELES	2061	43	27	3.50	7.71	.13	4.30	6.28	.16
	OAKLAND	2870	37	33	3.50	9.43	.11	4.30	7.67	.13
	SACRAMENTO	2502	32	38	3.50	10.86	.09	4.30	8.84	.11
	SAN DIEGO	1458	44	26	3.61	7.21	.14	4.41	5.90	.17
	SAN FRANCISCO	3015	37	33	3.50	9.43	.11	4.30	7.67	.13
	SANTA MARIA	2967	34	36	3.50	10.29	.10	4.30	8.37	.12
COLO.	COLORADO SPRINGS	6423	4	66	3.54	18.63	.05	4.63	14.26	.07
	DENVER	6283	3	67	3.53	18.99	.05	4.58	14.61	.07
	GRAND JUNCTION	5641	11	59	3.50	16.86	.06	4.46	13.22	.08
	PUEBLO	5462	-1	71	3.50	20.29	.05	4.45	15.97	.06
CONN.	BRIDGEPORT	5617	8	62	3.50	17.71	.06	4.46	13.90	.07
	HARTFORD	6235	5	65	3.52	18.45	.05	4.57	14.22	.07
	NEW HAVEN	5897	9	61	3.50	17.43	.06	4.49	13.59	.07
DEL.	WILMINGTON	4930	15	55	3.50	15.71	.06	4.39	12.52	.08
D.C.	WASHINGTON	4224	19	51	3.50	14.57	.07	4.32	11.80	.08
FLA.	DAYTONA BEACH	879	36	34	3.76	9.04	.11	4.56	7.46	.13
	FORT MYERS	442	42	28	3.98	7.04	.14	4.78	5.86	.17
	JACKSONVILLE	1239	32	38	3.65	10.40	.10	4.45	8.54	.12
	KEY WEST	108	58	12	4.15	2.89	.35	4.95	2.43	.41
	LAKELAND	661	39	31	3.87	8.01	.12	4.67	6.64	.15
	MIAMI	214	47	23	4.09	5.62	.18	4.89	4.70	.21
	MIAMI BEACH	141	48	22	4.13	5.33	.19	4.93	4.46	.22
	ORLANDO	766	37	33	3.82	8.65	.12	4.62	7.15	.14
	PENSACOLA	1463	32	38	3.61	10.53	.09	4.41	8.62	.12
	TALLAHASSEE	1485	29	41	3.60	11.38	.09	4.40	9.31	.11
	TAMPA	683	39	31	3.86	8.03	.12	4.66	6.65	.15
	WEST PALM BEACH	253	44	26	4.07	6.38	.16	4.87	5.33	.19
GA.	ATHENS	2929	21	49	3.50	14.00	.07	4.30	11.40	.09
	ATLANTA	2961	23	47	3.50	13.43	.07	4.30	10.93	.09

STATE	STATION	DEGREE DAY	DESIGN TEMP.	DESIGN ΔT	CEILING/ROOF Q/A	CEILING/ROOF R	CEILING/ROOF U	WALL Q/A	WALL R	WALL U
	AUGUSTA	2397	23	47	3.50	13.43	.07	4.30	10.93	.09
	COLUMBUS	2383	26	44	3.50	12.57	.08	4.30	10.23	.10
	MACON	2136	27	43	3.50	12.29	.08	4.30	10.00	.10
	ROME	3326	20	50	3.50	14.29	.07	4.30	11.63	.09
	SAVANNAH	1819	27	43	3.54	12.16	.08	4.34	9.92	.10
HAWAII	HONOLULU	0	62	8	4.20	1.90	.52	5.00	1.60	.63
	HILO	0	61	9	4.20	2.14	.47	5.00	1.80	.56
IDAHO	BOISE	5809	10	60	3.50	17.14	.06	4.48	13.39	.07
	LEWISTON	5542	12	58	3.50	16.57	.06	4.45	13.02	.08
	POCATELLO	7033	-2	72	3.60	20.00	.05	4.81	14.98	.07
ILL.	CHICAGO (O'HARE)	6639	0	70	3.56	19.64	.05	4.69	14.92	.07
	CHICAGO (MIDWAY)	6155	1	69	3.52	19.63	.05	4.55	15.18	.07
	CHICAGO	5882	1	69	3.50	19.71	.05	4.49	15.37	.07
	MOLINE	6408	-3	73	3.54	20.62	.05	4.62	15.79	.06
	PEORIA	6025	2	68	3.50	19.41	.05	4.51	15.09	.07
	ROCKFORD	6830	-3	73	3.58	20.37	.05	4.75	15.37	.07
	SPRINGFIELD	5429	4	66	3.50	18.86	.05	4.44	14.86	.07
IND.	EVANSVILLE	4435	10	60	3.50	17.14	.06	4.34	13.81	.07
	FORT WAYNE	6205	5	65	3.52	18.46	.05	4.56	14.25	.07
	INDIANAPOLIS	5699	4	66	3.50	18.86	.05	4.47	14.77	.07
	SOUTH BEND	6439	3	67	3.54	18.91	.05	4.63	14.47	.07
IOWA	BURLINGTON	6114	0	70	3.51	19.94	.05	4.53	15.44	.06
	DES MOINES	6586	-3	73	3.56	20.51	.05	4.68	15.61	.06
	DUBUQUE	7376	-7	77	3.60	21.39	.05	4.88	15.79	.06
	SIOUX CITY	6951	-6	76	3.60	21.14	.05	4.79	15.88	.06
	WATERLOO	7320	-8	78	3.60	21.67	.05	4.86	16.04	.06
KANS.	DODGE CITY	4986	7	63	3.50	18.00	.06	4.40	14.32	.07
	GOODLAND	6141	4	66	3.51	18.78	.05	4.54	14.53	.07
	TOPEKA	5182	6	64	3.50	18.29	.05	4.42	14.49	.07
	WICHITA	4620	9	61	3.50	17.43	.06	4.36	13.98	.07
KY.	COVINGTON	5265	8	62	3.50	17.71	.06	4.43	14.01	.07
	LEXINGTON	4683	10	60	3.50	17.14	.06	4.37	13.74	.07
	LOUISVILLE	4660	12	58	3.50	16.57	.06	4.37	13.28	.08
LA.	ALEXANDRIA	1921	29	41	3.52	11.66	.09	4.32	9.50	.11
	BATON ROUGE	1560	30	40	3.59	11.15	.09	4.39	9.12	.11
	LAKE CHARLES	1459	33	37	3.61	10.25	.10	4.41	8.39	.12
	NEW ORLEANS	1385	35	35	3.62	9.66	.10	4.42	7.91	.13
	SHREVEPORT	2184	26	44	3.50	12.57	.08	4.30	10.23	.10
MAINE	CARIBOU	9767	-14	84	3.78	22.24	.04	5.53	15.19	.07
	PORTLAND	7511	0	70	3.60	19.44	.05	4.90	14.28	.07
MD.	BALTIMORE	4654	15	55	3.50	15.71	.06	4.37	12.60	.08
	FREDERICK	5087	11	59	3.50	16.86	.06	4.41	13.38	.07
MASS.	BOSTON	5634	10	60	3.50	17.14	.06	4.46	13.44	.07
	PITTSFIELD	7578	-1	71	3.60	19.72	.05	4.92	14.44	.07
	WORCESTER	6969	1	69	3.60	19.18	.05	4.79	14.40	.07
MICH.	DETROIT	6232	8	62	3.52	17.60	.06	4.57	13.57	.07
	ESCANABA	8481	-3	73	3.65	20.01	.05	5.14	14.19	.07
	FLINT	7377	3	67	3.60	18.61	.05	4.88	13.74	.07
	GRAND RAPIDS	6894	6	64	3.59	17.83	.06	4.77	13.42	.07
	LANSING	6909	6	64	3.59	17.83	.06	4.77	13.41	.07

49

STATE	STATION	DEGREE DAY	DESIGN TEMP.	DESIGN ΔT	CEILING/ROOF Q/A	R	U	WALL Q/A	R	U
	MARQUETTE	8393	-4	74	3.64	20.33	.05	5.12	14.46	.07
	MUSKEGON	6696	8	62	3.57	17.37	.06	4.71	13.17	.08
	SAULT STE. MARIE	9048	-8	78	3.70	21.95	.05	5.31	14.68	.07
MINN.	DULUTH	10000	-15	85	3.80	22.37	.04	5.60	15.18	.07
	MINNEAPOLIS	8383	-10	80	3.64	21.99	.05	5.11	15.64	.06
	ROCHESTER	8295	-13	83	3.63	22.87	.04	5.09	16.31	.06
MISS.	JACKSON	2239	24	46	3.50	13.14	.08	4.30	10.70	.09
	MERIDIAN	2289	24	46	3.50	13.14	.08	4.30	10.70	.09
	VICKSBURG	2041	26	44	3.50	12.57	.08	4.30	10.23	.10
MO.	COLUMBIA	5040	6	64	3.50	18.29	.05	4.40	14.53	.07
	KANSAS CITY	4711	8	62	3.50	17.71	.06	4.37	14.18	.07
	ST. JOSEPH	5484	3	67	3.50	19.14	.05	4.45	15.06	.07
	ST. LOUIS	4900	8	62	3.50	17.71	.06	4.39	14.12	.07
	ST. LOUIS	4484	11	59	3.50	16.86	.06	4.35	13.57	.07
	SPRINGFIELD	4900	10	60	3.50	17.14	.06	4.39	13.67	.07
MONT.	BILLINGS	7049	-6	76	3.60	21.11	.05	4.81	15.80	.06
	GLASGOW	8996	-20	90	3.70	24.33	.04	5.30	16.98	.06
	GREAT FALLS	7750	-16	86	3.60	23.89	.04	4.95	17.37	.06
	HAVRE	8700	-15	85	3.67	23.16	.04	5.21	16.31	.06
	HELENA	8129	-13	83	3.61	22.97	.04	5.04	16.47	.06
	KALISPELL	8191	-3	73	3.62	20.17	.05	5.06	14.43	.07
	MILES CITY	7723	-15	85	3.60	23.61	.04	4.94	17.19	.06
	MISSOULA	8125	-3	73	3.61	20.21	.05	5.04	14.49	.07
NEB.	GRAND ISLAND	6530	-2	72	3.55	20.26	.05	4.66	15.45	.06
	LINCOLN	5864	0	70	3.50	20.00	.05	4.49	15.60	.06
	NORFOLK	6979	-7	77	3.60	21.40	.05	4.79	16.06	.06
	NORTH PLATTE	6684	-2	72	3.57	20.18	.05	4.71	15.30	.07
	OMAHA	6612	-1	71	3.56	19.94	.05	4.68	15.16	.07
	SCOTTSBLUFF	6673	-4	74	3.57	20.74	.05	4.70	15.74	.06
NEVADA	ELKO	7433	-7	77	3.60	21.39	.05	4.89	15.76	.06
	ELY	7733	-2	72	3.60	20.00	.05	4.95	14.56	.07
	LAS VEGAS	2709	26	44	3.50	12.57	.08	4.30	10.23	.10
	RENO	6332	7	63	3.53	17.83	.06	4.60	13.70	.07
	WINNEMUCCA	6761	5	65	3.58	18.18	.06	4.73	13.75	.07
N.H.	CONCORD	7383	-7	77	3.60	21.39	.05	4.88	15.79	.06
N.J.	ATLANTIC CITY	4812	18	52	3.50	14.86	.07	4.38	11.87	.08
	NEWARK	4589	15	55	3.50	15.71	.06	4.36	12.62	.08
	TRENTON	4980	16	54	3.50	15.43	.06	4.40	12.28	.08
N.M.	ALBUQUERQUE	4348	17	53	3.50	15.14	.07	4.33	12.23	.08
	RATON	6228	2	68	3.52	19.30	.05	4.57	14.88	.07
	ROSWELL	3793	19	51	3.50	14.57	.07	4.30	11.86	.08
	SILVER CITY	3705	18	52	3.50	14.86	.07	4.30	12.09	.08
N.Y.	ALBANY	6875	0	70	3.59	19.51	.05	4.76	14.70	.07
	BINGHAMTON	7286	2	68	3.60	18.89	.05	4.86	14.00	.07
	BUFFALO	7062	6	64	3.60	17.78	.06	4.81	13.30	.08
	NEW YORK(CENT.PK.)	4871	15	55	3.50	15.71	.06	4.39	12.54	.08
	NEW YORK(LA GUARDIA)	4811	16	54	3.50	15.43	.06	4.38	12.33	.08
	NEW YORK(KENNEDY)	5219	21	49	3.50	14.00	.07	4.42	11.08	.09
	ROCHESTER	6748	5	65	3.57	18.18	.05	4.72	13.76	.07
	SCHENECTADY	6650	-1	71	3.56	19.92	.05	4.69	15.12	.07

STATE	STATION	DEGREE DAY	DESIGN TEMP.	DESIGN ΔT	CEILING/ROOF Q./A	R	U	WALL Q/A	R	U
	SYRACUSE	6756	2	68	3.58	19.02	.05	4.73	14.39	.07
N.C.	ASHEVILLE	4042	17	53	3.50	15.14	.07	4.30	12.31	.08
	CHARLOTTE	3191	22	48	3.50	13.71	.07	4.30	11.16	.09
	GREENSBORO	3805	17	53	3.50	15.14	.07	4.30	12.33	.08
	RALEIGH	3393	20	50	3.50	14.29	.07	4.30	11.63	.09
	WILMINGTON	2347	27	43	3.50	12.29	.08	4.30	10.00	.10
	WINSTON-SALEM	3595	17	53	3.50	15.14	.07	4.30	12.33	.08
N.D.	BISMARK	8851	-19	89	3.69	24.15	.04	5.26	16.94	.06
	DEVILS LAKE	9901	-19	89	3.79	23.48	.04	5.57	15.98	.06
	FARGO	9226	-17	87	3.72	23.37	.04	5.37	16.21	.06
	WILLISTON	9243	-17	87	3.72	23.36	.04	5.37	16.19	.06
OHIO	AKRON-CANTON	6037	6	64	3.50	18.27	.05	4.51	14.19	.07
	CINCINNATI	4410	12	58	3.50	16.57	.06	4.34	13.36	.07
	CLEVELAND	6351	7	63	3.54	17.82	.06	4.61	13.68	.07
	COLUMBUS	5660	7	63	3.50	18.00	.06	4.47	14.11	.07
	DAYTON	5622	6	64	3.50	18.29	.05	4.46	14.34	.07
	MANSFIELD	6403	3	67	3.54	18.92	.05	4.62	14.50	.07
	SANDUSKY	5796	8	62	3.50	17.71	.06	4.48	13.84	.07
	TOLEDO	6494	5	65	3.55	18.31	.05	4.65	13.98	.07
	YOUNGSTOWN	6417	6	64	3.54	18.07	.06	4.63	13.84	.07
OKLA.	OKLAHOMA CITY	3725	15	55	3.50	15.71	.06	4.30	12.79	.08
	TULSA	3860	16	54	3.50	15.43	.06	4.30	12.56	.08
OREGON	ASTORIA	5186	30	40	3.50	11.43	.09	4.42	9.05	.11
	EUGENE	4726	26	44	3.50	12.57	.08	4.37	10.06	.10
	MEDFORD	5008	23	47	3.50	13.43	.07	4.40	10.68	.09
	PENDLETON	5127	10	60	3.50	17.14	.06	4.41	13.60	.07
	PORTLAND	4635	24	46	3.50	13.14	.08	4.36	10.54	.09
	ROSEBURG	4491	29	41	3.50	11.71	.09	4.35	9.43	.11
	SALEM	4754	25	45	3.50	12.86	.08	4.38	10.28	.10
PENN.	ALLENTOWN	5810	5	65	3.50	18.57	.05	4.48	14.51	.07
	ERIE	6451	11	59	3.55	16.64	.06	4.64	12.73	.08
	HARRISBURG	5251	13	57	3.50	16.29	.06	4.43	12.88	.08
	PHILADELPHIA	5144	15	55	3.50	15.71	.06	4.41	12.46	.08
	PITTSBURGH	5987	9	61	3.50	17.43	.06	4.50	13.56	.07
	READING	4945	9	61	3.50	17.43	.06	4.39	13.88	.07
	SCRANTON	6254	6	64	3.53	18.15	.06	4.58	13.99	.07
	WILLIAMSPORT	5934	5	65	3.50	18.57	.05	4.49	14.47	.07
P.I.	PROVIDENCE	5954	10	60	3.50	17.14	.06	4.50	13.35	.07
S.C.	CHARLESTON	2033	27	43	3.50	12.29	.08	4.30	10.00	.10
	COLUMBIA	2484	23	47	3.50	13.43	.07	4.30	10.93	.09
	FLORENCE	2387	25	45	3.50	12.86	.08	4.30	10.47	.10
	GREENVILLE-SPARTENBURG	2980	23	47	3.50	13.43	.07	4.30	10.93	.09
S.D.	HURON	8223	-12	82	3.62	22.64	.04	5.07	16.18	.06
	RAPID CITY	7345	-6	76	3.60	21.11	.05	4.87	15.61	.06
	SIOUX FALLS	7839	-10	80	3.60	22.22	.04	4.97	16.10	.06
TENN.	BRISTOL	4143	16	54	3.50	15.43	.06	4.31	12.52	.08
	CHATTANOOGA	3254	19	51	3.50	14.57	.07	4.30	11.86	.08
	KNOXVILLE	3494	17	53	3.50	15.14	.07	4.30	12.33	.08
	MEMPHIS	3232	21	49	3.50	14.00	.07	4.30	11.40	.09
	NASHVILLE	3578	16	54	3.50	15.43	.06	4.30	12.56	.08

STATE	STATION	DEGREE DAY	DESIGN TEMP.	DESIGN ΔT	CEILING/ROOF Q/A	CEILING/ROOF R	CEILING/ROOF U	WALL Q/A	WALL R	WALL U
TEXAS	ABILENE	2624	21	49	3.50	14.00	.07	4.30	11.40	.09
	AMARILLO	3985	12	58	3.50	16.57	.06	4.30	13.49	.07
	AUSTIN	1711	29	41	3.56	11.52	.09	4.36	9.41	.11
	BROWNSVILLE	600	40	30	3.90	7.69	.13	4.70	6.38	.16
	CORPUS CHRISTI	914	36	34	3.74	9.08	.11	4.54	7.48	.13
	DALLAS	2363	24	46	3.50	13.14	.08	4.30	10.70	.09
	EL PASO	2700	25	45	3.50	12.86	.08	4.30	10.47	.10
	FORT WORTH	2405	24	46	3.50	13.14	.08	4.30	10.70	.09
	GALVESTON	1274	36	34	3.65	9.33	.11	4.45	7.65	.13
	HOUSTON	1396	32	38	3.62	10.49	.10	4.42	8.60	.12
	LAREDO	797	36	34	3.80	8.94	.11	4.60	7.39	.14
	LUBBOCK	3578	15	55	3.50	15.71	.06	4.30	12.79	.08
	MIDLAND	2591	23	47	3.50	13.43	.07	4.30	10.93	.09
	PORT ARTHUR	1447	33	37	3.61	10.25	.10	4.41	8.39	.12
	SAN ANGELO	2235	25	45	3.50	12.86	.08	4.30	10.47	.10
	SAN ANTONIO	1546	30	40	3.59	11.14	.09	4.39	9.11	.11
	VICTORIA	1173	32	38	3.67	10.37	.10	4.47	8.51	.12
	WACO	2030	26	44	3.50	12.57	.08	4.30	10.23	.10
	WICHITA FALLS	2832	19	51	3.50	14.57	.07	4.30	11.86	.08
UTAH	SALT LAKE CITY	6052	9	61	3.51	17.40	.06	4.52	13.51	.07
VT.	BURLINGTON	8269	-7	77	3.63	21.23	.05	5.08	15.16	.07
VA.	LYNCHBURG	4166	19	51	3.50	14.57	.07	4.32	11.81	.08
	NORFOLK	3421	23	47	3.50	13.43	.07	4.30	10.93	.09
	RICHMOND	3865	18	52	3.50	14.86	.07	4.30	12.09	.08
	ROANOKE	4150	18	52	3.50	14.86	.07	4.31	12.05	.08
WASH.	OLYMPIA	5236	25	45	3.50	12.86	.08	4.42	10.17	.10
	SEATTLE-TACOMA	5145	24	46	3.50	13.14	.08	4.41	10.42	.10
	SEATTLE	4424	32	38	3.50	10.86	.09	4.34	8.75	.11
	SPOKANE	6655	4	66	3.57	18.51	.05	4.70	14.05	.07
	WALLA WALLA	4805	16	54	3.50	15.43	.06	4.38	12.33	.08
	YAKIMA	5941	10	60	3.50	17.14	.06	4.49	13.35	.07
W.VA.	CHARLESTON	4476	14	56	3.50	16.00	.06	4.35	12.88	.08
	ELKINS	5675	5	65	3.50	18.57	.05	4.47	14.55	.07
	HUNTINGTON	4446	14	56	3.50	16.00	.06	4.34	12.89	.08
	PARKERSBURG	4754	12	58	3.50	16.57	.06	4.38	13.26	.08
WISC.	GREEN BAY	8029	-7	77	3.60	21.37	.05	5.01	15.37	.07
	LA CROSSE	7589	-8	78	3.60	21.67	.05	4.92	15.86	.06
	MADISON	7863	-5	75	3.60	20.83	.05	4.97	15.08	.07
	MILWAUKEE	7635	-2	72	3.60	20.00	.05	4.93	14.61	.07
WYO.	CASPER	7410	-5	75	3.60	20.83	.05	4.88	15.36	.07
	CHEYENNE	7381	-2	72	3.60	20.00	.05	4.88	14.77	.07
	LANDER	7870	-12	82	3.60	22.78	.04	4.97	16.49	.06
	SHERIDAN	7680	-7	77	3.60	21.39	.05	4.94	15.60	.06

52

CHAPTER 6

HEATING, VENTILATING, AND COOLING SYSTEM REQUIREMENTS

HEATING AND COOLING LOADS

6.0 REQUIREMENT

Heating and cooling loads shall be determined for the purpose of sizing
heating, ventilating and air conditioning, (HVAC) systems and components
for efficient utilization of energy.

CRITERIA

Note: The following items, 6.0.1 through 6.0.2.6, refer only to
parameters for use in calculating heating/cooling loads. For equipment
and system requirements refer to 6.1 through 6.5.

6.0.1 Procedures -- Heating and cooling loads shall be determined in
accordance with procedures described in the American Society of Heating,
Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbook of Funda-
mentals, Chapters 21 and 22, or procedures for which similarity to ASHRAE
procedures can be demonstrated.

6.0.2 Design Parameters -- The following design parameters shall be used
in the heating and cooling load determination: (If for special cases
other design conditions are selected, heating and cooling load calculations
shall be based on the selected conditions.)

6.0.2.1 Outdoor Design Conditions -- Winter and summer outdoor design
conditions shall be the 97-1/2 and 2-1/2 percent values, respectively,
as given in Chapter 33, Weather Data and Design Conditions, of the ASHRAE
Handbook of Fundamentals, 1972.

6.0.2.2 Indoor Design Conditions -- Winter indoor design conditions shall
be 70 °F dry-bulb temperature, with humidification, if provided, to not
more than 30% relative humidity. Summer indoor design conditions shall
be 78 °F dry-bulb temperature, with controlled dehumidification, if pro-
vided, to not less than 60% relative humidity.

COMMENTARY

ASHRAE procedures will be used to determine the adequacy of submitted
calculations.

The winter and summer design temperature levels selected for load
calculations were chosen to discourage oversizing in the selection
of HVAC equipment.

CRITERIA

6.0.2.3 General Ventilation -- For load design of all building types ex-
cept one- and two-family dwelling units, mechanical ventilation with out-
side air, for the purpose of meeting normal respiratory and odor control
needs shall be taken as 5 cfm[1] per person for certain spaces or two
air changes for other spaces (see 6.0.2.4 and 6.4.15 for description and
criteria).

6.0.2.4 Special Ventilation -- For load design, mechanical ventilation
capacity in excess of 5 cfm per person (or two air changes per hour) for
the purpose of controlling smoking contaminants, toxic gases, or other
contaminants, shall be the actual amount included in the design (see 6.4.15).

   EVALUATION

   Examination and evaluation of engineering calculations.

CRITERION

6.0.2.5 Infiltration -- For load design, infiltration shall be taken as
0.7 air change per hour for one- and two-family dwellings and mobile homes,
and 0.5 air change per hour for all other buildings. (see 5.0.6.1)

   EVALUATION

   See Evaluation for 5.0.6.

CRITERION

6.0.2.6 Heat Gains -- Internal heat gains shall be included in both
heating and cooling loads as appropriate.

   EVALUATION

   Examination and evaluation of engineering calculations.

   COMMENTARY

   In buildings that have a reasonably steady internal heat release of
   appreciable magnitude from sources other than the heating system, a
   computation of this heat release under design conditions should be made
   for deduction from the total of the computed heat losses.

_____

[1] Wherever the term cfm is used in this document it shall be inter-
     preted as standard cubic feet per minute, unless the immediate
     context indicates another meaning.

EQUIPMENT EFFICIENCY

6.1 <u>REQUIREMENT</u>

Manufacturers of building equipment defined as energy-significant equipment shall make available to prospective building owners or their representatives the full-load energy-utilization efficiency of such equipment, taken by itself.

<u>CRITERIA</u>

6.1.1 <u>Full-load Efficiency</u> -- The manufacturer shall make available to prospective purchasers the full-load energy-utilization efficiency (n_{fl}) of the specific models to be furnished based on equipment in new condition. Furnishing of certified test data is deemed to satisfy the requirements of this paragraph.

6.1.2 <u>Rounding-Off</u> -- For the purpose of publication, the energy-utilization efficiency shall be rounded off to the nearest even whole number within a range of two percentage points, e.g., 72 $\pm$ 1 percent.

    COMMENTARY

    The "two percent" criterion effectively allows an actual spread of up to four percent and is an arbitrary value based on engineering judgment.

<u>CRITERIA</u>

6.1.3 <u>Procedure</u> -- A document shall be furnished to prospective equipment purchasers, upon request, summarizing the methods used to determine the efficiency, or referencing a national consensus voluntary standard test procedure. Publication of such test methods or references by commercial data services or trade organizations is deemed to satisfy the requirements of this paragraph.

6.1.4 <u>Availability of Data</u> -- Where the data specified in 6.1.1 are not immediately available, the manufacturer shall obtain and furnish the data specified in 6.1.1.

6.1.5 <u>Multi-Mode Operation</u> -- Where equipment is designed for multi-mode operation (e.g., multi-speed forced warm air furnace with provision for a cooling coil), full-load energy-utilization efficiency (η_{fl}) data shall be provided for each separate mode of operation applicable to the proposed system.

6.1.6 Full-Load Efficiency Data -- Full-load efficiency data shall be furnished as required under 6.1.1 for each different basic model and sub-type numbered energy-significant equipment, except that a typical unit may be selected to represent a group of units, each of which meets all the following criteria:

   (1) The function, capacity, and performance characteristics are similar.

   (2) The basic model numbers are the same.

   (3) The units are all manufactured at the same plant.

   (4) The units are sold to the same class of market. Examples of different classes of market include residential, commercial, contractor, retail, etc.

6.1.7 Identify Test Model -- Where full-load energy-utilization efficiency data are published for a group of similar units based on testing or analysis of a typical unit, the actual unit type number tested or analyzed shall be clearly identified.

6.2 REQUIREMENT

Energy-significant equipment used in building systems shall be designed for efficient utilization of energy.

CRITERION

6.2.1 Minimum Full-Load Energy-Utilization Efficiency -- No equipment shall be specified in the design of new buildings which has a full-load energy-utilization efficiency less than the equivalent of that presently specified in nationally recognized voluntary standards.

   EVALUATION

   Verification that selected energy-significant equipment meets full-load efficiency requirements of applicable national consensus standards.

6.3 REQUIREMENT

Energy-significant equipment which requires periodic routine maintenance actions to maintain efficient operation shall be furnished complete with the necessary maintenance information.

CRITERION

6.3.1 Required Maintenance Actions -- Required routine maintenance actions shall be clearly stated as required and incorporated on a permanent label affixed to a normally visible, external surface of the equipment. The label may be limited to identifying required actions explained in greater detail in a service manual. The label should identify by title and/or publication number the service manual for that particular model and type of product.

6.4   REQUIREMENT

HVAC systems shall be energy-efficient.

CRITERIA

6.4.1 <u>System Design Heating/Cooling Capacity</u> -- The heating system(s) for spaces in buildings intended to provide comfort for human occupancy shall be designed with capacity to heat such spaces to 70 °F at the winter outdoor design temperature (see 6.0.2.1). Similarly, the cooling system(s), if provided, shall be designed with capacity to cool such spaces to 78 °F at the summer outdoor design temperature (see 6.2.2.1). Heating/cooling systems shall be capable of functioning to accomplish the requirements for the control system in 6.4.2, 6.4.3, 6.4.4, 6.4.5 and 6.5.9, as applicable.

EVALUATION

Review of HVAC system plans and specifications. Comparison of system capacity design and building load calculations.

COMMENTARY

The design criteria of Chapter 6 do not limit the operation of HVAC systems in buildings to the design indoor temperatures specified in the criteria. For special cases such as hospitals or homes for the elderly, requiring higher indoor temperatures, designers may wish to size systems toward the high end of the 120 percent capacity range allowed in 6.4.10.

CRITERIA

6.4.2 <u>Temperature Control</u> -- Each space heating/cooling system shall be provided with at least one readily adjustable automatic control for the regulation of interior temperature. Each separate zone served by space heating/cooling system shall be equipped with readily adjustable auto- matic control or conveniently located manual means for temperature regu- lation as required in 6.4.1, 6.4.3, and 6.5.9. Automatic comfort space temperature controls shall be capable of being set to control heating at least from 55 °F to 70 °F and to control cooling (if cooling is provided) at least from 78 °F to 85 °F. For space (or zone) temperatures between 70 °F and 78 °F the automatic control system shall be capable of being set such that neither heating or cooling is provided. Combination, sep- arate or multiple heating/cooling thermostats used to control heating and cooling in any one room or zone shall be interlocked or the systems other- wise controlled to avoid simultaneous heating and cooling in any one room or zone except for reheat as allowed in 6.4.7. Means for shutting off the heating or cooling to each zone shall be provided at a convenient location, either within the zone or at an appropriate central building supervisory monitoring station.

COMMENTARY

Central supervisory/monitoring systems can be used to meet the re-
quirements of 6.4.2.

CRITERIA

6.4.3 Multiple-Zone Temperature Control

6.4.3.1 Single-Family Dwelling Units, Attached or Detached, and Mobile
Homes -- At least one automatic temperature control as required in 6.4.2
shall be provided for each single-family dwelling unit and mobile home.
Each separate heating/cooling system in a single-family dwelling unit
shall be equipped with an automatic temperature control. Each separate
zone in a single-family dwelling unit or mobile home shall be provided
with either a readily adjustable automatic temperature control or suffi-
cient conveniently located manually-adjustable devices capable of being
adjusted to both partially restrict and shut off the heating or cooling input
to the rooms or spaces in that zone. For single-family dwelling units or
mobile homes, there shall be at least one separate zone in each cumulative
full story height of the complete dwelling unit, excluding non-conditioned
basements and garages. Intermediate floor levels in split-level construction
are not considered full stories under this criterion.

6.4.3.2 Multi-Family Occupancies -- For multi-family occupancies, each
individual living unit shall be considered separately for zoning purposes
and shall be provided with automatic space temperature control as required
in 6.4.2. For any single living unit, there shall be at least one separate
zone in each cumulative full story height of the complete living unit,
and each zone shall be provided with controls as required in 6.4.3.1.
Intermediate floor levels in split level construction are not considered
full stories under this criterion. Spaces other than living units in
multi-family buildings shall be treated as in 6.4.3.3.

6.4.3.3 Other Buildings -- For other buildings, each space or group of
spaces to be conditioned for comfort and having different demands for
heating or cooling (because of varying solar loads, changing occupancies,
or other internal heat gains) shall be considered as a separate zone,
and shall be provided with automatic space temperature control as required
in 6.4.2. Each floor shall be considered as at least one zone. For
buildings greater than 2000 ft^2 of floor area per story, at least each
cumulative 2000 ft^2 of floor area or fraction thereof of conditioned
space(s) on each floor adjacent to each major orientation of exterior ex-
posure shall be considered as a separate zone and shall be provided with
automatic space temperature control as required in 6.4.2. At least each
cumulative 3000 ft^2 of floor area or fraction thereof of conditioned
space(s) on each floor having no exterior exposure shall be considered
as a separate zone and shall be provided with automatic space temperature
control as required in 6.4.2.

EVALUATION

Review of control systems plans and specifications.

COMMENTARY

Areas or spaces within a building having different and varying demands for heating and cooling (called zones) each need a means for controlling its temperature to prevent overheating (or overcooling) which could be caused by having the system control in another space. In addition, large open spaces require multiple zoning to provide ability to operate the heating and cooling in only those areas being utilized. Multiple zone control can be accomplished by modulating or varying the heating or cooling effect being delivered to each zone or by using separate systems for each zone. The 2000 ft^2 of floor area adjacent to an exterior exposure would accommodate, for example, 13 offices 10 ft by 15 ft or equivalent spaces.

CRITERIA

6.4.4 System Design for Humidity Control -- This document does not require that heating/cooling systems be designed for or equipped with controls for maintaining selected relative humidities in spaces or zones to provide comfort for human occupancy.

If the heating system is equipped with means for adding moisture to maintain selected relative humidities in spaces or zones during heating operation, the capacity of the humidifying function shall be designed to produce relative humidities not higher than 30 percent at winter design conditions, and the system shall be equipped with automatic humidity control(s) capable of being set to control indoor relative humidity to 30 percent or lower.

If automatic control of indoor space humidity is provided as a part of the cooling system design, the minimum indoor design relative humidity shall be 60 percent. Means for raising humidity during cooling operation is not required. The automatic humidity control system shall be capable of being set such that cooling apparatus shall not operate for the sole purpose of lowering the space (or zone) relative humidity below 60 percent. See 6.4.7 Reheat for limitations on use of new and recovered energy. The control system shall be capable of being set such that neither the humidifying or dehumidifying functions of the HVAC system shall operate for the sole purpose of space (or zone) humidity control in the range from 30 to 60 percent relative humidity.

59

6.4.5 Control Set-Back -- All heating and cooling systems shall be equipped
with manually adjustable automatic timing or other devices capable of re-
ducing the energy for heating and cooling during periods of non-use or
alternate uses of the building spaces or zones served by such systems.
Buildings designed for continuous manual or automatic supervisory control
are considered to meet this criterion. The change in setting required to
reduce the heating or cooling effect (set-back) shall not cause energy
to be expended to produce the set-back conditions.

COMMENTARY

"Set-back" as used in 6.4.5 means the ability to change the automatic
temperature control setting to a value which will reduce the heating
or cooling produced during periods of reduced needs. Night set-back
during the heating season (e.g., a thermostat setting change from
70 °F to 55 °F), should not cause the cooling system to operate to
cool the building to the set-back temperature of 55 °F. Similarly,
under cooling conditions a set-back of the thermostat should not
cause the heating system to raise the indoor temperature.

6.4.6 Simultaneous Heating/Cooling -- HVAC systems serving one or more
rooms or zones in a building shall be so arranged that no one room or
zone can be heated and cooled simultaneously by the HVAC system except
for reheat as permitted in 6.4.7.

COMMENTARY

Separate heating and cooling systems should be interlocked or other-
wise controlled to prevent simultaneous operation for one room or
zone. See Criterion 6.4.7 for limitation on reheat.

CRITERIA

6.4.7 Reheat -- Energy for reheat to accomplish either humidity or tem-
perature control in any HVAC system shall be limited to the following
conditions:

a. The total amount of new energy for either humidity or tempera-
ture control used for reheat shall not exceed 5 percent of the
cooling system design capacity.

b. Recovered energy shall not be used for reheat for control of
temperature in excess of 10 percent of the cooling system de-
sign capacity.

c. Recovered energy may be used as needed for humidity control
in accordance with 6.4.4.

EVALUATION

Review of HVAC system plans and specification.

COMMENTARY

Use of excessive amount of either new or recovered energy for reheat purposes for temperature control only (as opposed to reheat for required humidity control purposes) is wasteful, and can be eliminated by suitable distribution design. Use of small amounts of energy for reheat for either temperature or humidity control in isolated areas may be more economical than providing a separate system.

CRITERIA

6.4.8 Energy Recovery -- Each air exhaust-makeup system having more than 4000 cfm capacity which imposes non-beneficial heat gains or losses on space conditioning systems shall employ energy recovery equipment if either the winter or summer outdoor design temperature is 15 °F or more lower or higher, respectively, than the indoor design temperature. This equipment shall be capable of recovery of at least 50 percent of the potential heating or cooling effect in the exhaust air, whenever the temperature difference between the exhaust air and makeup air is 10 °F or greater. This requirement does not include contaminant-laden process exhaust systems such as kitchen range hoods. Energy recovery systems shall be capable of intermittent operation to accommodate beneficial outdoor air conditions and the exhaust-makeup system shall be designed to operate in accord with the design requirements whether the energy recovery system is functioning or not.

COMMENTARY

Possible proximity of the air intakes and outlets can create a need in design to assure the effective separation of the two air streams.

CRITERIA

6.4.9 Cooling with Outdoor Air -- Each HVAC system with cooling capacity greater than 120,000 Btu/hr in buildings not equipped with internal/external zone heat recovery equipment shall be designed to use outdoor air for cooling whenever cooling is needed at an outdoor temperature of 65 °F or lower, and when the enthalpy of the outdoor air is lower than that of the indoor air.

6.4.10 System Sizing -- HVAC systems and subsystems for a building shall be selected such that the aggregate capacity at design conditions shall not be more than 120 percent of the design heating, cooling, humidifying, and dehumidifying loads, standby equipment not included. The cooling equipment in heat pumps may exceed the 120 percent requirement. The heating equipment in heat pumps shall not exceed the 120 percent requirement.

EVALUATION

Examination of HVAC system plans and specifications. Comparison of load requirements and system capacity data.

COMMENTARY

The 20-percent over-design in system capacities indicated by this criterion is an allowance for additional capacity that may be needed following night-time change in thermostat setting and weather conditions above or below design levels. Generally, excessive oversizing of system capacities results in less efficient operation. Standby equipment as used in 6.4.10 refers to equipment designed and intended for use when primary equipment is off-line due to maintenance or repair.

In order to minimize inefficiencies due to oversized system designs, it shall be a design objective that the HVAC system be sized so as to be capacity limited at the stated design conditions. At outdoor temperature extremes, the conditioned space temperature may drift from the normal control point, and at or near extreme conditions, the heating/cooling system may recover slowly after temperature control setting change.

CRITERIA

6.4.11 Special Zones -- Individual zones in large buildings or groups of buildings served by a central HVAC system which (1) must maintain zone operation when main building loads are minimal or are shut down, or (2) comprise unusual heating or cooling loads different from main building loads, shall be served by the central system only if the central system is designed to accommodate efficiently this special zone conditioning by such means as efficient capacity reduction of refrigerating units and boilers, adequate distribution zoning and zoning control, and use of multiple subsystem elements (compressors, heaters, fans and pumps, etc); otherwise, these special zones shall be equipped with separate space conditioning systems. For cumulative special zone loads equal to one-half or more of the total system design load, the system shall be energy efficient to at least 85 percent of the full-load efficiency (see 6.4.13).

EVALUATION

Examination of plans and specifications with particular regard to system design related to special zones and capacity reduction. Comparison of computed load requirements with selected equipment performance data.

CRITERION

6.4.12 System Performance Instrumentation -- Central heating and cooling systems in buildings of more than 10,000 ft^2 of floor area shall be equipped with instruments or other indicating devices from which a deter-

mination can be made of need for adjustment or service to maintain energy-efficient operation.

EVALUATION

Examination of plans and specifications

COMMENTARY

The indicating devices envisioned by this criterion include but are not limited to pressure gages, water level devices on boilers, flow meters for various critical fluids, thermometers for flue and other temperatures, etc.

CRITERIA

6.4.13 Half-Load Efficiency -- HVAC systems operating at 1/2 rated load at design conditions shall have an efficiency not less than 85 percent of the system efficiency at full load operation at design conditions. HVAC systems shall be designed and equipped with means for operating at highest available system efficiencies as loads are reduced.

EVALUATION

Certification by designer or manufacturer of HVAC systems or major subsystems.

CRITERION

6.4.14 Interzone Heat Recovery -- Each HVAC system with a cooling capacity greater than 240,000 Btu/hr and which simultaneously provides heating to one or more zones and cooling to one or more different zones shall be designed to recover heat rejected by the cooling unit whenever the heat rejected is equal to at least 50 percent of the heat required by that system at that time. In such systems, new energy shall be used only for supplemental heating needed in excess of the recoverable heat.

EVALUATION

Comparison of design heating/cooling loads and system design capacities. Examination of plans and specifications.

CRITERIA

6.4.15 Ventilation by Mechanical Means -- Outdoor air for mechanical ventilation designed as a part of an HVAC system, for the purpose of meeting normal respiratory and odor control needs in conditioned offices, stores, meeting rooms, auditoriums, schools, living units and similar spaces, shall be limited to 5 cfm per person. Outdoor air for mechanical ventilation of conditioned corridors, lobbies, stairways, halls, laundries, storage areas and similar public spaces in multi-family and other buildings

shall be limited to 2 air changes per hour for normal respiratory and odor control needs. Special ventilating capacity in excess of 5 cfm per person (or 2 air changes per hour) for the purpose of controlling smoking contaminants, toxic gases, or other contaminants in the two classes of conditioned spaces listed above shall be equipped with volume or cyclic controls capable of remote adjustment if necessary, so that the ventilation rate can be readily adjusted to the amount needed for actual occupancy conditions and shut off when not required.

These ventilation-limiting requirements do not apply to intermittently-operated locally-controlled ventilation units such as kitchen vent fans, range hoods, bathroom fans, or to attic ventilating fans, or to the sizing of ventilation systems using outdoor air for temperature control in the occupied spaces, or to ventilation of non-conditioned spaces.

ASHRAE Standard 62-73, Standards for Natural and Mechanical Ventilation, recommends special ventilation rates.

All mechanical ventilation systems shall be equipped with conveniently located means for volume reduction or shut-off when ventilation is not required.

COMMENTARY

If outdoor air ventilation rates in conditioned spaces greater than shown are desired, consideration can be given to use of heat recovery apparatus to minimize adverse loads on the space conditioning system (see 6.4.8.) The criteria values for outdoor ventilation rates were were selected to save energy and yet provide needed ventilation. For unusual non-toxic odor control, consideration should be given to odor removal devices in lieu of increased ventilation rates.

COMPONENT AND SUBSYSTEM REQUIREMENTS

6.5 REQUIREMENT

Components of HVAC systems shall be energy-efficient.

CRITERIA

6.5.1 Fluid Transport Thermal Losses/Gains -- See 6.5.2 and 6.5.3 for
minimum insulation requirements. In addition, the non-beneficial heat
gain/loss to/from each separate subsystem of piping and ductwork trans-
porting liquids, vapors, or gases used for space heating/cooling shall
be limited to 3 percent of the heating/cooling thermal transfer design
capacity for the fluid in that subsystem. In any case, the aggregate
total non-beneficial gain/loss shall not exceed 5 percent of the total
system design capacity including all piping, ductwork, and unit casings,
etc., forming the entire heating/cooling system within the building. A
subsystem is a section of the entire system which contains only one type
of transfer fluid, such as hot or chilled water, steam, refrigerant,
brine, air, etc. Non-beneficial heat gain/loss means heat transfer into/
from non-conditioned space(s) or heat transfer into/from conditioned
space(s) in excess of or opposition to the energy requirement of that space.

EVALUATION

Examination of plans and specifications. Review of heat loss/gain
calculation.

COMMENTARY

A simple heating/cooling system may have only air ducts to consider
under 6.5.1. More complex systems may have chilled water lines,
steam or hot water lines, primary and secondary air ducts, etc, for
which the several subsystem losses or gains must be determined for
comparison with the design heating/cooling loads served by that
subsystem, and the total losses/gains compared with the total system
design capacity.

CRITERIA

6.5.2 Thermal Resistance of Ducts, Plenums, and Other Enclosures for
Air Systems-Heating -- Air ducts and other surfaces installed in non-
heated spaces (e.g., attics, garages, crawl spaces, etc.) shall be therm-
ally insulated to provide a surface-to-surface thermal resistance of not
less than $R = \Delta T/20$ hr ft^2 °F/Btu, where ΔT is the maximum temperature
difference between the air in the duct or enclosure and the surrounding
air, or shall be insulated to a value of $R = 4$ hr ft2 °F/Btu, whichever
is greater.

COMMENTARY

Examination and evaluation of engineering calculations.

65

CRITERIA

6.5.3 <u>Thermal Resistance and Condensation Control, Ducts, Pipes and
Surfaces - Cooling</u> -- For air ducts and surfaces installed in non-cooled
spaces, the thermal resistance criteria of 6.5.2 shall apply. Addition-
ally, all ducts, pipes, and cool surfaces shall be insulated sufficiently
to prevent surface condensation under operating conditions. The insul-
ation shall be protected by a vapor barrier, maximum permeance 0.1 perm,
and all joints shall be sealed against vapor penetration.

    EVALUATION

    Engineering examination and evaluation of the design and design cal-
    culations. ASTM recommended practice E241-68 for general design in-
    formation, ASTM Test Methods E96-66 (Procedures A, dry cup) for
    materials such as paper, plastic films and other sheet materials that
    are less than 1/8-inch thick shall be used for the purpose of evalu-
    ation.

    COMMENTARY

    Access doors and similar removable panels in duct system enclosures
    should be tight fitting (see 6.5.4) and insulation at joints of such
    doors should be adequately sealed to minimize moisture entering the
    insulation.

6.5.4 <u>Duct Air Leakage</u> -- The entire duct system for HVAC systems shall
not leak more than 5 percent of the design air flow at design duct pressure.

    EVALUATION

    Review of duct plans and specifications. Tests patterned after
    SMACNA procedures.

    COMMENTARY

    Medium and high pressure ducts are customarily designed for duct
    leakage of 1 percent or less. Duct air leakage in any system defeats
    the intended function of the system. Leakage in non-conditioned
    areas is a total loss and in addition, leakage even in conditioned
    areas may prevent adequate delivery to intended locations.

CRITERION

6.5.5 <u>Automatic Ignition</u> -- Automatically controlled gaseous or liquid
fuel-fired devices providing space heating shall be equipped with means
for fuel ignition which operates only when the burner is required to
operate. Automatic ignition devices shall conform to life safety stand-
ards, such as:

    ANSI Z21.20 Automatic Burner Ignition and Safety Shut-off Devices
    ANSI Z226.1 Primary Safety Controls for Gas and Oil Fired Appliances

EVALUATION

Certification or listing of selected ignition devices.

6.5.6 Off-Cycle Air Flow Heat Loss -- Combustion heating equipment with greater than 250,000 Btu/hr input shall be equipped with devices to minimize air flow through the combustion chamber during burner off-cycles. These devices shall be safety listed. All vented fireplaces shall be equipped with tight closing dampers or other comparable draft closures.

EVALUATION

Examination of proposed heating system design. Certification or listing of stack or combustion chamber off-cycle air flow control devices.

6.5.7 Cooling Efficiency - Electric Motor-Driven Cooling Systems -- Electric motor-driven cooling systems rated at standard rating conditions as listed in ARI 210-67 and including all system fan and pump motors shall have a ratio of net system cooling capacity to energy input of not less than 8.0 Btuh/watt for cooling capacities of 60,000 Btuh or greater and 7.0 Btuh/watt for cooling capacities less than 60,000 Btuh. All cooling systems with rated output greater than 240,000 Btuh shall have a ratio of system capacity to energy input of not less than 8.5 Btuh/watt.

EVALUATION

Certification of selected equipment.

COMMENTARY

The term "Btuh/watt" is used here as a means of expressing efficiency of electric motor-driven cooling equipment because of its adoption by the industry. As used it means (Btu/hr)/watt, where "Btu/hr" is the net cooling capacity of the complete system at its defined rating condition, and "watt" is the electrical input rate to the complete system at the same conditions. The values of "Btuh/watt" do not include correction for electric power generation, transmission and distribution efficiency for either the compressor motor or for other auxiliary electrically-operated elements. If electric power generation transmission and distribution requires 12000 Btu/kwh, the values of 7.0, 8.0 and 8.5 "Btuh/watt" indicate net cooling capacity-to-energy source input COP values of 0.58, 0.67, and 0.71 respectively. Net cooling as used here includes both sensible and latent heat.

CRITERIA

6.5.8 Cooling Efficiency - Heat-Operated Cooling Systems -- Heat-operated cooling systems with a COP of less than 0.5 at standard rating conditions including all system auxiliaries, and fan and pump motors (determined in accordance with Appendix 2 of Chapter 6) shall not be used to provide more than 25 percent of the design cooling requirement unless recovered energy, solar energy or energy derived from waste processes is used as the principal energy source.

EVALUATION

Comparison of selected system performance data and efficiency of
energy source. Review of calculated overall system COP.

COMMENTARY

Pending availability of standard industry rating procedures for
determining the overall system net cooling capacity-to-system energy
input COP, a procedure is given in Appendix 2 of Chapter 6. Net
cooling as used here includes both sensible and latent heat. Using
the procedure in Appendix 2, as an example, a heat-operated cooling
system with a <u>unit</u> COP of 1.0 or more, energized by a steam supply
of at least 70 percent efficiency, and with system control, condenser
and cooling circuit power inputs equal to not more than 20 percent
of the chiller capacity would satisfy the requirement of 6.5.8 for
use of "new" energy.

6.5.9 _Electric Resistance Heating_-- This document does not limit the use of electric resistance heating systems as the principal means of comfort space heating in the following buildings:

-all buildings in geographic areas having 2000 heating degree-days or less annually

-buildings utilizing electric energy for heating which is gen-erated either by solar or wind-produced energy, by combustion of waste materials, by recovery of waste energy, or by a total energy system conforming to the definition in Chapter 3.

-buildings smaller than 500 ft^2 of floor area.

-mobile homes

For all other buildings the use of electric resistance heating as the principal means for comfort space heating shall be limited to the fol-lowing conditions:

1. Buildings shall have a design heat loss at least 15 percent lower than permitted in Chapter 5

2. In addition to the minimum temperature control requirements for any heating system in 6.4.2 and 6.4.3, (a) one or more readily-adjustable automatic temperature controls as required in 6.4.2 shall be provided for control of each zone described in 6.4.3.1, 6.4.3.2, or 6.4.3.3 as applicable, and (b) at least one readily-adjustable automatic temperature control as required in 6.4.2, or sufficient readily-adjustable manual devices capable of being set to both partially restrict and shut off. Such heating input controls shall be provided (1) in each separate heated room or other enclosed spaces of more than 100 ft^2 of floor area which has one or more exterior walls, and (2) in each heated room or other enclosed space of more than 500 ft^2 of floor area, having no exterior walls. If in response to 2(b), each separate heated space in a zone is provided with automatic control, 2(a) is satisfied, and a separate zone control is not required.

EVALUATION

Examination of plans and specification.

COMMENTARY

Electricity is a highly refined source of heat which, in typical generating plants, has already lost about two thirds of the available potential energy of the fuel used in the generating process by the time it reaches the electric heating load in a building. Because of this loss in energy potential, logic indi-cates that a highly refined form of energy should be applied more carefully at the point of use. 6.5.9 (2) is intended to eliminate unnecessary input of this highly refined heat energy when solar or other heat gains reduce the demand for heating.

Central electric resistance warm air or hydronic systems can satisfy the automatic zone temperature control requirements by using individual automatically-controlled heat outlets or fixtures in all the spaces in a zone.

The rationale for not recommending a differential reduction of heat loss even greater than 15 percent for electric resistance heating is based on the following:

(1) The thermal resistance criteria in Chapter 5 may already be equal to or greater than previously existing guidelines for electrically heated buildings, and the technical/esthetic feasibility of requiring thermal resistance differential requirements much greater than 15 percent is in doubt for some climatic regions.

(2) The criteria of 6.5.9 do not limit using forms of electrically energized heating other than the resistance type. In many applications, an electric driven heat pump system uses electricity more efficiently than does electric resistance heat, and its use should be encouraged.

(3) Depending upon the application, anywhere from one-fifth to one-half of the source potential energy is lost in direct heat conversion systems using fossil fuels. The 15 percent criteria brings the efficiency of electric resistance heat within the same general area as that of the low end of the range for fossil fuels.

The exception made for mobile homes is based on two factors:

(1) Dimensional space and weight limitations due to transportation requirements.

(2) Mobile homes typically use central forced warm air heating systems because this type of system is adaptable to various fuels used at different installation sites. The specific site (and fuel) is unknown at the time of manufacture. Under these conditions, it is usually unfeasible for the mobile home manufacturer to use those forms of electric resistance heating that readily lend themselves to zone control.

CRITERIA

6.5.10 Heat Pumps -- Electric motor driven vapor compression heat pumps with supplemental electric resistance heat shall be sized to provide by compression at least 60 percent of the calculated annual heating requirement for the building or space served. A control shall be provided which can be set to prevent use of supplemental electrical resistance heat at outdoor temperatures above 32 °F. Air-source heat pumps shall have seasonal performance factors (S.P.F.), including supplemental heating of:

Design Temperature, °F	S.P.F.
> 35	> 2.25
20 to 35	> 2.0
0 to 20	> 1.5
-20 to 0	> 1.25

$$S.P.F. = \frac{X}{Y+Z}$$

where:

X = heat delivered to space during heating season, kWh.

Y = energy to motors during the heating season, kWh.

Z = supplemental heat during heating season, kWh.

EVALUATION

Comparison of calculated annual heat loss and certified seasonal
performance factors. Review of design calculations, plans, and
specification.

COMMENTARY

Heat pump seasonal performance factors (S.P.F.) can be computed
as shown below from building heat loss, heat pump performance
characteristics, including supplemental heat, and seasonal heat-
ing hours below 65 °F for outdoor air temperature increments of
5 °F. Engineering Weather Data AFM 88-8, Chapter 6, lists heat-
ing season hours at 5 °F intervals for many locations in the
U. S. This information is also available from the U. S. Weather
Bureau. Using data such as is furnished by several heat pump
manufacturers, the analytical procedure may consist of a summation
by 5 °F increments of the building heat loss, the varying steady-state
heat pump performance characteristics and hours of operation, and hours
of required supplementary heat operation. A computerized dynamic
analysis is not necessarily required. The S.P.F. shall take into
account all system energy requirements, including defrost operation
and supplementary heat. Specifically, the items, X, Y, and Z
necessary for determining S.P.F. can be calculated in tabular form
from the following information:

A - Outdoor temperature range, °F
    outdoor air temperature increments of 5 °F below 65 °F
B - Seasonal heating hours for A, hrs
C - Average building heat loss for A, Btu/hr
D - Heat pump capacity for A, Btu/hr
E - Percent running time for heat pump, %
    If C>D, E = 100; otherwise E = 100 x C/D
F - Rate of energy input to heat pump for A, kW
G - Energy input to heat pump, kWh
    G = B x E x F/100
H - Energy input to building from electric resistance heaters, kWh.
    If C<D, H = 0; otherwise H = B x (C-D)/3412.
J - Energy input to building from heat pump, kWh.
    J = E x D/341200

Summing over the outdoor air temperature increments gives

$Y = \Sigma G$
$Z = \Sigma H$
$X = \Sigma J + \Sigma H$

for substitution in the definition for S.P.F.

The purpose of the control to prevent use of supplemental electric resistance at outdoor temperature above 32 °F is to eliminate unnecessary use of the less efficient supplemental heating at times when the heat pump can supply adequate heating. It also assures that failure of the heat pump will be detected if it occurs. The temperature of 32 °F will permit use of supplemental heating to prevent freezing damage in the event of heat pump failure. The 32 °F temperature is not intended as a balance point requirement for determining heat pump size.

APPENDIX 1

LISTING OF STANDARDS FOR HVAC
EQUIPMENT WHICH INCLUDE EFFICIENCY

ANSI Z21.11 - 1971

Gas-Fired Room Heaters
Volume I (Z21.11.1) Vented Room Heaters - Efficiency 70 percent based on
        total volume of gas.
Volume II (Z21.11.2) Unvented Room Heaters - 1971 -
        Performance - No number for efficiency.

ANSI Z21.13 - 1972

Gas-Fired Steam and Hot Water Boilers
    Shall have a thermal efficiency of 75 percent based on total heating
    value of the fuel.

ANSI Z21.34 - 1971

Gas-Fired Duct Furnaces
    Thermal efficiency of 75 percent based on total heating value of
    fuel.

ANSI Z21.43 - 1968

Unvented Gas-Fired Infrared Radiant Heaters
    Radiant efficiency of at least 35 percent.

ANSI Z21.44 - 1971

Gas-Fired Gravity and Fan Type Sealed Combustion System Wall Furnaces
    Gravity type - Efficiency 70 percent based on total heating value of
    fuel.
    Fan type - Efficiency 75 percent based on total heating value of fuel.

ANSI Z21.47 -

Gas-Fired Gravity and Forced Air Central Furnaces
    Thermal efficiency gravity 70 percent based on total heat value of
    gas.

ANSI Z21.48 - 1976 (48a - 1968

Gas-Fired Gravity and Fan Type Floor Furnaces
    Gravity type - Efficiency 65 percent based on total heating value of
    fuel.
    Fan type - Efficiency 70 percent based on total heating value of fuel.

73

ANSI Z21.51 - 1971

Vented Gas-Fired Infrared Radiant Heaters
    Efficiency - shall have a radiant efficiency of at least 35 percent.

ANSI Z21.52 - 1971

Gas-Fired Single Firebox Boilers
    Steam and hot water boilers shall have efficiency 75 percent based on
    total heating value of fuel.

ANSI Z21.53 - 1967

Gas-Fired Heavy-Duty Forced Air Heaters

    Shall have thermal efficiency of not less than 75 percent based on
    total heating value of fuel.

ANSI Z91.1 - 1972

Oil-Powered Central Furnaces
    Performance - Output capacity in Btu/hr 0.75 times input.

APPENDIX 2

PROCEDURE FOR DETERMINING COEFFICIENT OF PERFORMANCE (COP) FOR
HEAT-OPERATED COOLING SYSTEMS MEETING THE REQUIREMENTS OF 6.5.8

At the present no standard industry rating conditions have been promul-
gated for heat-operated cooling units. Unit performance shall be based
on the following rating conditions which shall be considered "standard"
for this document:

Leaving chilled-water temperature	44 °F
Chilled water ΔT across chiller	10 °F
Temperature of condensing water entering unit	85 °F
Condenser water flow	3.6 gpm/ton of condenser load
Steam inlet pressure (single effect)	12 psig
Entering hot water temperature (single effect)	270 °F
Hot water ΔT across unit (single effect)	40 °F
Steam inlet pressure (double effect)	123 psig or 144 psig
Entering hot water temperature (double effect)	370 °F
Hot water ΔT across unit (double effect)	40 °F
Outdoor air Temperature, DB	95 °F
Outdoor air temperature, WB	75 °F
Indoor air temperature, DB	80 °F
Indoor air temperature, WB	67 °F

The COP of the proposed system based on the above conditions shall be
determined by:

COP = net refrigerating effect
      ───────────────────────────
      rate of total energy input

where the net refrigerating effect is the rate of heat removal from the
chilled water passing through the chiller minus the power input to all
cooling circuit fans and pumps, and the rate of total energy input is
the sum of all power used by the unit accessories, the condenser water
cooling process pumps, fans, etc plus the product of the rate of fuel
consumption and the higher heating value of the fuel used as the source
of heat energy to the absorption unit itself, all expressed in consis-
tent units. For the COP determination, energy input to all auxiliary
devices (other than the absorption unit) such as controls, fan and
pump motors shall be based on the power input to the various devices.
Where steam or hot water is used as the unit energy source, the rate
of energy input to the unit shall be based on the fuel used to produce
the steam or hot water. If the unit is direct-fired, the rate of energy
input to the unit shall be the product of the rate of fuel consumption
and the higher heating value of the fuel.

75

CHAPTER 7

SERVICE WATER HEATING REQUIREMENTS

7.0 REQUIREMENT

Hot water for domestic and sanitary purposes shall be generated and
delivered in a manner conducive to saving energy.

CRITERIA

7.0.1 Insulation -- All service hot water storage tanks and pipes
containing heated water shall be insulated. Minimum insulation values
for storage tanks and piping shall be R=6 and R=4, respectively.

> EVALUATION

> Review of system plans and specifications.

> COMMENTARY

> The heat loss of domestic hot water systems due to intermittent
> use and from the piping or recirculating systems is significant,
> and adds to the cooling loads in spaces requiring cooling.

CRITERIA

7.0.2 Pump Operation -- Circulating service hot water systems shall
be so arranged that the circulating pump(s) can be turned off when
the portion of the building served by that pump is not in use.

7.0.3 Combination Service Water Heating/Space Heating Boilers -- Service
water heating equipment shall not be dependent on year-round operation
of boilers otherwise required only for winter space heating if the boiler
capacity is more than 120 percent of the design service water heating
demand load.

> COMMENTARY

> A boiler may operate at low efficiencies during summer months if
> used to provide domestic hot water under conditions where the
> water heating load is small in relation to the space heating load.

CRITERIA

7.0.4 Temperature Control -- Service water heating systems shall be
equipped with automatic temperature controls capable of adjustment
to the lowest acceptable temperature setting for the intended use.
These settings shall be 120 °F or less for domestic dishwashing/clothes
washing machines and 180 °F or less for commercial application.

7.0.5 Electric Resistance Service Water Heating -- For systems
serving more than four single-family living units, service water
heaters shall not use electric resistance heating unless 1) electricity
is used as the principal means for heating the building, or 2) the
electric power used for water heating is generated either by solar
or wind-produced energy, by combustion of waste materials, by recovery
of waste energy, or by a total energy system conforming to the
definition in Chapter 3.

CRITERIA

7.0.6 Fossil-Fuel-Fired Service Water Heating -- Fossil-fuel-fired
service water heaters with input heating capacities greater than
250,000 Btu/hr shall be equipped with automatic ignition (which
operates only when the burner is required to operate) and off-cycle
air-flow heat-loss control devices. Each of these devices shall
be safety listed.

APPENDIX 1

LISTING OF STANDARDS FOR SERVICE WATER
HEATING EQUIPMENT WHICH INCLUDE EFFICIENCY

<u>ANSI A21.10 - 1971</u>

Gas Water Heaters
Volume 1 (Z21.10.1) Automatic Storage Type Water Heaters With
        Inputs Less Than 75,000 Btu/hr - Performance Test.
Volume II (Z21.10.2) Side-Arm Type Water Heaters
Volume III (Z21.10.3) Circulating Tank, Instantaneous and Large
        Automatic Storage Type Water Heaters - Thermal efficiency
        of not less than 70 percent based on the gas input.

ELECTRICAL DISTRIBUTION AND
POWER FACTOR REQUIREMENTS

8.0 REQUIREMENT

The electrical distribution system in a building shall be designed for
efficient distribution of energy from the service entrance to the outlets,
and shall not impose inefficient conditions on the electric utility dis-
tribution system.

CRITERIA

8.0.1 Power Factor -- In each building having one or more electric ser-
vices aggregating 600 amperes or more, a graphic (recording) power factor
meter shall be provided during the first year of operation and the power
factor shall be continuously monitored. If the power factor falls below
0.9 lagging for periods accumulating one-half hour in any 24-hour period,
power factor corrective devices shall be installed to raise the power
factor to 0.9 or higher. If after the initial power factor correction
additional reactive loading is introduced in the building, the power
factor shall be continuously monitored again for a period of one year,
and additional correction performed to meet the above criterion.

It is recommended that the electric utility be responsible for installation,
upkeep, and removal of the graphic power factor meter.

COMMENTARY

Low power factor causes greater losses in transmission and distri-
bution of electricity. Typically, most commercial and public
buildings during the non-air conditioning season have a power
factor of at least 0.9, unless the power factor is reduced by re-
active loads such as fluorescent lighting units and elevator motors.
Where the loads of the building are such that they create a power
factor at the building service of less than 0.9 lagging, capacitance
corrective devices can be placed at those loads or at the feeders
to those loads. Power factor correction at the generating plant does
not prevent the losses associated with transmission of the reactive
power component through the distribution network.

CRITERION

8.0.2 Power Factor Correction for Cooling Equipment -- In a building
which is wholly or partly cooled with one or more units aggregating
120,000 Btuh or higher, power factor correction devices shall be pro-
vided so that the power factor of the entire air conditioning system,
including fans, shall be not less than 0.9 lagging at any load condition.

EVALUATION

The designer shall indicate on the plans a calculation of the lagging
kilovars of the air conditioning equipment, the corrective leading
kilovars provided, and the resultant power factor of not less than
0.9.

Power factor improvement, especially during periods of peak summer load, will reduce peak demand in the public utility peak power output and reduce losses in the transmission and distribution system.

CRITERIA

8.0.3 Service Voltage -- In each building having one or more electric services aggregating 600 amperes or more, the service voltage shall be nominally 277/480 volts, 3-phase, 4-wire, or 480 volts, 3-phase, 3-wire. In such buildings, the portion of the lighting system defined as "efficient" under 9.1.1 shall be served directly at 277 volts or higher, and transformers shall be used only to serve appliance loads, or other loads not designed to operate at 277 volts. Manufacturers shall make available to prospective building owners or their representatives data on the full-load efficiency of such transformers.

EVALUATION

Verify by inspection of the plans submitted for approval.

COMMENTARY

Higher service voltages mean lower losses in the distribution of electricity.

CRITERION

8.0.4 Voltage Drop -- In any building, the combined voltage drop in feeders and branch circuits shall not exceed 3 percent of the service voltage.

EVALUATION

The plans submitted for approval shall have a tabulation of feeders and branch circuit voltage drops. The voltage drop summation of the longest and the most heavily loaded feeder and branch circuits should not be more than 3 percent of the service voltage.

COMMENTARY

Articles 210-6(d) and 215-3 of the National Electric Code define the size of the feeders and branch circuits so that the total voltage drop does not exceed 5 percent of the service voltage. The energy lost in the distribution system principally goes into I^2R losses in the feeders, branch circuits, transformers and switch gear, and is converted into heat which is generally not credited to useful effect, and adds to the comfort cooling load.

The above criterion reduces the voltage drop loss by up to 2 percent, and to that extent, energy will be conserved.

CRITERION

8.0.5 Light Switching -- In any space requiring two or more branch
circuits for lighting, switching shall be provided for each circuit
or for portions of each circuit, so that a portion of the lighting system
adequate for custodial or maintenance purposes or for effective com-
plementary use of natural and artificial lighting may be operated
without switching on/off all of the lighting in that space.

EVALUATION

The plan examiner shall look at the diagrams to make sure that
there is enough switching provided. He should determine that there
is at least one switch in each room.

CRITERION

8.0.6 Electric Meters -- In any multi-tenant building, the electric
energy to each tenant shall be metered separately for energy consumed
in his portion of the building. It is recommended that each tenant also
be billed separately for the energy he uses. Condominiums shall be
included as multi-tenant buildings. Hotels, college dormitories, and
other transient facilities are excluded from the provisions of this
paragraph.

EVALUATION

Examine plans to determine that each tenant has his own meter.

COMMENTARY

There is some evidence that a significant reduction in energy
usage occurs when tenants pay directly for the energy they con-
sume.

CHAPTER 9

LIGHTING REQUIREMENTS

9.0 REQUIREMENT

In any space within a building, the permissible level of maintained illumination shall be based upon the use for which the space is intended.

CRITERIA

9.0.1 Task Lighting -- The design criteria for the level of illumination in the immediate area of a specific task shall be no greater than that recommended by the Illumination Engineering Society in the IES Lighting Handbook, 5th ed., for that task.

9.0.2 Local Lighting -- Task illumination shall be produced by luminaires arranged to illuminate the immediate task area, and such luminaires shall be individually switched. This requirement shall not apply where room occupancy is such that the averaged occupied space is 50 ft^2 or less per occupant.

9.0.3 General Lighting -- The general level of illumination in a space surrounding the task area shall be not more than 1/3 of the task level. Where more than one task level occurs in a space, the general level shall be not more than 1/3 of the average level of task illumination in the adjacent task spaces.

9.0.4 Noncritical General Lighting -- In the areas within corridors, stairways, toilets, lobbies, and the like, where no specific visual task occurs, the level of illumination shall be no more than 1/3 of the average level of general illumination in the adjacent task spaces, but not less than OSHA recommended levels for safety.

9.0.5 Lighting Calculations

9.0.5.1 Compliance with the requirements and criteria of 9.0 and 9.1 shall be determined by calculation of maintained illumination, following the procedure recommended by the Illuminating Engineering Society in the IES Lighting Handbook, 5th ed.

9.0.5.2 The following initial reflectances shall be used in calculation of maintained illumination:

1) Ceilings, 80%
2) Walls, 50%
3) Floors, 20%

COMMENTARY

Where higher reflectances are provided, increased lighting levels will be permitted in proportion. Where lower reflectances are provided, no increase in wattage will be permitted for the purposes of bringing lighting levels up to those specified above.

9.0.5.3 The following shall be used in calculating Light Loss Factors:

    1) Area atmosphere to be "clean"
    2) Time between cleaning, 12 months
    3) Lamp burnout factor = 1.0
    4) All recoverable factors = 1.0

9.0.5.4 Coefficients of utilization shall be no lower than those given in the IES Lighting Handbook, 5th ed., for the existing conditions and type of luminaires.

9.1 REQUIREMENT

Only efficient lamps shall be used for general illumination and local task illumination, except as provided below in 9.1.3 and 9.1.4.

CRITERION

9.1.1 Efficient Lamps -- Lamps shall be defined as those which produce at least 40 lumens per watt input, including ballast losses, at the rated initial output, defined herein as "efficient lamps". This definition is used in 9.1.4 as a basis for determining lighting load.

COMMENTARY

Some lamps in common use operate with a relative efficiency as low as 1/4 that of other commonly available lamps. The objective of the criteria of 9.1.1 is twofold:

1) To provide a basis for computing the total wattage allowed for lighting under 9.1.4.

2) To restrict the use of inefficient lamps to special usages (9.1.3) and in a trade-off mode with more efficient lamps as provided under 9.1.4.

CRITERIA

9.1.2 Other Lamps -- To the extent that lamps producing less than 40 lumens per watt are used, the general lighting in the space shall be reduced by an equal number of watts.

9.1.3 Exceptions -- The criteria of 9.1.1 and 9.1.2 shall not apply to the following:

1) Private residences, except for kitchens, bathrooms, and laundry areas.

2) Private apartments in apartment houses, except for kitchens and bathrooms in the apartments, and public spaces such as lobbies, halls, stairways, laundry and utility rooms, and basement areas generally.

3) Small spaces, such as closets, requiring only one lamp of not over 60 watts.

83

4) Auditoriums and stages where dimming is essential to the use
of the space.

5) Projectors.

6) Portable devices.

7) Luminaires for medical and dental diagnostic, surgical, or
therapeutic purposes.

8) Highlighting applications, such as localized lighting of work
stations, sculpture exhibits, art exhibits, and individual items of
display merchandise.

9) Specialized lighting applications (color matchings; where
electrical interference cannot be tolerated).

9.1.4 Lighting Alternatives -- The total watts used in a building for
interior lighting purposes shall be no more than that which would have
been required had all spaces been illuminated with efficient lamps,
efficient luminaires, and reflectances, as defined above. Performance
specifications of lamps and luminaires shall be that given in the fifth
edition of the IES Lighting Handbook.

9.2 REQUIREMENT

Use of luminaires providing for heat removal or heat recovery shall be
encouraged.

CRITERION

9.2.1 Heat Removed/Recovered from Luminaires -- Where the heat from lamps
is in part removed by a heat transfer medium which does not enter the
occupied spaces, each Btu so removed may be offset by 1/2 Btu of additional
permitted energy input to the lighting system for illumination purposes,
provided that at least 50% of energy so removed can be recovered for useful
heating purposes elsewhere or for reheat in humidity-control equipment, and
provided that the remainder of the energy removed is not transmitted as
additional load to the cooling system.

   EVALUATION

   The evaluator may determine from standard procedures when available,
   or manufacturers' recommendations when industry or national standards
   are not available, the total Btu exhausted from luminaires.

   COMMENTARY

   All energy used for lighting ends up as heat, and energy saved by
   removing this load from the air conditioning load should be rewarded.
   The criteria of 9.5 is not intended to encourage the use of more
   energy in lighting for the purpose of heating building space.

9.3 REQUIREMENT

The energy expended for exterior lighting shall be minimized by basing the maximum level of maintained illumination upon the use for which the space is intended and by using efficient light sources as defined in 9.1.1.

CRITERIA

9.3.1 Lighting Levels

9.3.1.1 Maintained levels of illumination for exterior lighting shall be no greater than that recommended by the Illuminating Engineering Society in the IES Lighting Handbook, 5th ed., for that area classification.

9.3.1.2 Signs and facade lighting, 500 watts, or 1% of total interior lighting load of the building, whichever is greater.

9.3.1.3 Continuous burning gas lamps shall not be used to provide illumination or decoration.

9.3.2 Lighting Calculations -- Calculation of illumination shall follow the procedure recommended by the Illuminating Engineering Society (IES) Lighting Handbook, fifth edition.

CHAPTER 10

ENERGY REQUIREMENTS FOR BUILDING
DESIGNS BASED ON DYNAMIC ANALYSIS

10.0   REQUIREMENT

Alternative building designs shall be accepted that can be shown to save
equivalent amounts of energy without following each and every detailed
requirement of Chapters 5 through 9 of this standard.

CRITERIA

10.0.1   Equivalent Annual Energy Consumption -- Under the provisions of
this chapter the designer may propose any design of building and energy-
saving systems for which the integrated annual energy use is equal to or
less than the corresponding annual energy use of a similar system designed
to meet the requirements of chapters 1-9 of this standard. Comparison of
the two designs shall be based on annual energy profiles of both systems
covering heating, ventilating, cooling, lighting, and service water
systems. The criteria for this comparison process are illustrated in
Figure 10-1.

10.0.2   Documentation -- Building owners or their representatives who
desire to use an alternative building design based on dynamic analysis
shall provide detailed technical data and analyses as necessary to
verify that the design complies with the requirements of this chapter.
This report shall include details of the annual energy consumption
analysis for the building service systems prepared by a registered
professional engineer or architect, recognized as an expert in the de-
sign of the type of structure and systems submitted.

10.0.3   Basis for Comparison -- The building and service system design
selected as a basis for the reference energy budget shall meet the re-
quirements of Chapters 1 through 9 of this document and shall be one that
is commonly employed for the proposed type of occupancy and geographical
location.

10.0.4   Commonality -- The comparative analysis for evaluation shall
include the building exterior envelope design, common climatic data,
common operational occupancies and schedules, common energy systems
characteristics, common efficiency assumptions, and comparable building
shape and height.

10.0.5   Analysis Procedure -- The energy consumption analysis for the
design forming the basis of comparison and for all energy-using systems
considered as alternatives under the provisions of this chapter shall
be conducted according to the following procedure:

10.0.5.1 The building heating and cooling load analysis that is used as
the basis for the energy consumption analysis shall be performed in ac-
cordance with the procedures recommended by the American Society of Heat-
ing, Refrigerating and Air Conditioning Engineers (ASHRAE) Task Group
On Energy Requirements in the document entitled "Procedures for Determining
Heating and Cooling Loads for Computerized Energy Calculation", or
equivalent.

10.0.5.2 The simulation of the building and its systems shall cover the
entire range of operation for a test year. Simulation of the HVAC system
shall be performed in accordance with the ASHRAE Task Group publication
entitled "Proposed Procedures for Simulating the Performance of Components
and Systems for Energy Calculation". Operational characteristics of the
building, including temperature and humidity levels, lighting schedule,
occupancy schedule, and schedule of outside air being introduced through
the ventilation system shall be included. The simulation of the compp-
onent equipment shall include operation at part-load as well as full-
load conditions. Manufacturers' data shall be used where available and
all thermal performance characteristics of the energy-significant com-
ponents as well as thermal characteristics of the building shall be
given in the report specified in 10.0.2.

10.0.5.3 The particular computer program or calculation procedure that
is used to estimate annual energy consumption shall be reviewed and
evaluated by the registered professional engineer or architect referenced
in 10.0.2. An analysis procedure which deviates from the criteria of
10.0.5.1 and/or 10.0.5.2 shall be allowed provided that it is approved.

COMMENTARY

These criteria allow maximum flexibility to the designer to provide
performance solutions without necessarily complying with the detailed
criteria for the building envelope, mechanical, electrical, lighting,
service water, or other systems within a building.

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OPTIONAL DESIGN APPROACH FOR
CONVENTIONAL ENERGY SOURCES USING DYNAMIC
ANALYSIS AND COMPARATIVE ENERGY BUDGETS

#4 TRADE-OFF ENVELOPE REQUIREMENTS
OPTIONAL

#5 TRADE-OFF BUILDING SERVICE SYSTEMS
OPTIONAL

#6 CALCULATE TOTAL ANNUAL ENERGY BUDGET
CHAPTER 10

COMPARE

DESIGN STEP
CRITERIA REFERENCE

LEGEND

#1 DESIGN ACCEPTABLE BUILDING ENVELOPE
CHAPTER 5

#3 CALCULATE TOTAL ANNUAL ENERGY BUDGET
CHAPTER 10

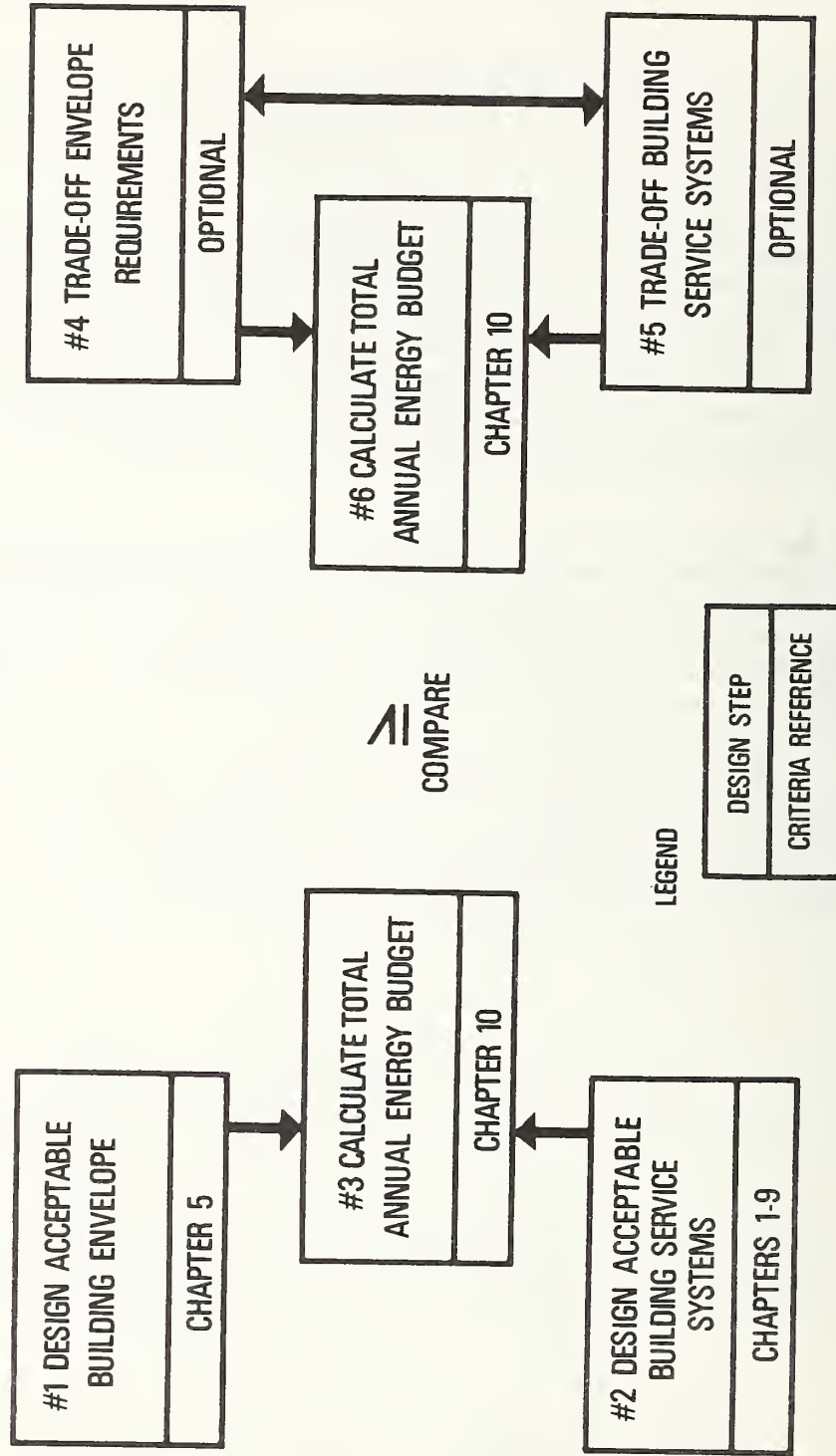| #2 DESIGN ACCEPTABLE BUILDING SERVICE SYSTEMS |
|---|
| CHAPTERS 1-9 |

Figure 10-1

CHAPTER 11

REQUIREMENTS FOR BUILDINGS UTILIZING
SOLAR OR WIND POWERED ENERGY SOURCES

11.0 REQUIREMENT

An energy bonus shall be granted to buildings designed to reduce usage of mineral or hydroelectric energy sources by using solar or wind powered energy sources to supply part of all of the building energy requirements.

CRITERIA

11.0.1 Energy Estimate -- The computed annual energy consumption of a building and its service systems when employing part or all solar or wind powered energy sources according to the Criteria of this chapter shall be allowed to exceed the reference energy budget obtained by computing the annual energy consumption of a system employing only mineral or hydroelectric energy sources by the amount of 50 percent of the energy obtained from solar or wind powered sources. The criteria for claiming such an energy bonus is given in this chapter and the steps illustrated in Figure 11-1. Windows shall not be considered a solar energy source for the purposes of this chapter. Use of windows to make more effective use of solar energy can be recognized under Chapter 10.

11.0.2 Documentation -- Building owners or their representatives desiring to claim the energy bonus that is permitted in 11.0.1 shall provide a report giving detailed technical data and analysis as necessary to verify that the design complies with the requirements of this chapter. This report shall include details of the energy consumption analysis for the building service systems prepared by a registered professional engineer or architect, recognized as an expert in the design of the type of structure and systems submitted.

11.0.3 Basis for Comparison -- The building and service systems design using mineral or hydroelectric energy source(s) and selected as a basis for the reference energy budget shall meet the requirements of Chapters 1 through 9 of this document and shall be one that is commonly employed in the proposed type of occupancy and geographical location.

11.0.4 Commonality -- In designing the service systems using part or all solar or wind energy sources, only those components of the building and service equipment that must be modified to utilize such energy may be different from those used to calculate the total annual energy budget. Common climatic data, common occupancies and use schedules, and common efficiency assumptions for identical components shall be used in the two cases.

11.0.5 Analysis Procedure -- The energy consumption analysis for both the mineral or hydroelectric and the solar or wind powered energy-using systems shall be conducted according to the following procedure.

11.0.5.1 The building heating and cooling load analysis that is used as the basis for the energy consumption analysis shall be performed in accordance with the procedures recommended by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Task Group on Energy Requirements in the document entitled "Procedures for Determining Heating and Cooling Loads for Computerized Energy Calculation," or equivalent.

11.0.5.2 The simulation of the building and its systems shall cover the entire range of operation for a test year. Simulation of the HVAC system shall be performed in accordance with the ASHRAE Task Group publication entitled "Proposed Procedures for Simulating the Performance of Components and Systems for Energy Calculation". Operational characteristics of the building, including temperature and humidity levels, lighting schedule, occupancy shcedule, and schedule of outside air being introduced through the ventilation system shall be included. The simulation of the component equipment shall include operation at part-load as well as full-load conditions. Manufacturers' data shall be used where available and all thermal performance characteristics of the energy-significant components as well as thermal characteristics of the building shall be given in the report specified in 11.0.2.

11.0.5.3 The particular computer program or calculation procedure that is used to estimate annual energy consumption shall be reviewed and evaluated by the registered professional engineer or architect referenced in 11.0.2. An analysis procedure which deviates from the criteria of 11.0.5.1 and/or 11.0.5.2 shall be allowed provided that it is approved by the organization using this document.

COMMENTARY

The intent of Chapter 11 is to encourage the development and use of solar or wind powered energy sources so as to conserve extracted energy sources and reduce pollution. For example, assume a design that meets the criteria of Chapters 1 through 9 and that has an annual consumption of energy from mineral sources of 100 units. The designer can elect to use the criteria of Chapter 11 instead of Chapters 1 through 9 and design his building to supply, say, 50 units of the energy requirement from solar energy sources. Using the formula in Figure 11-1, block #6, he will then be permitted to design his building and service systems to consume a total of 125 units of energy annually with 75 coming from mineral fuel and 50 units coming from solar energy. The net saving will be 25 units of mineral fuel and the building will be allowed a bonus of 25 units of energy over and above the reference energy budget of 100 units.

The rationale for Chapter 11 and the related definition of solar energy sources is as follows:

1) All forms of extracted energy sources commonly in use today are in short supply, will apparently remain so for the near future, and have finite limits of economic recovery and ultimate depletion.

2) The AEC has stated that nuclear electrical power generation cannot reasonably be expected to carry a major fraction of the electric energy load until after the turn of the century.

3) Limitations on the total quantity of thermally generated energy as we know it today will ultimately be determined by the effects of various forms of pollution, including thermal pollution. The effects of thermal and other forms of pollution are already measurably significant.

4) Conserving energy is an essential element of the Federal Government's goal to achieve energy self-sufficiency.

It follows that the Nation's finite energy sources and particularly those in short supply should be conserved and used in the most efficient manner available, and that extra incentives are neither needed nor should be used to stimulate the exploitation of energy sources which add pollution to the air or waterways.
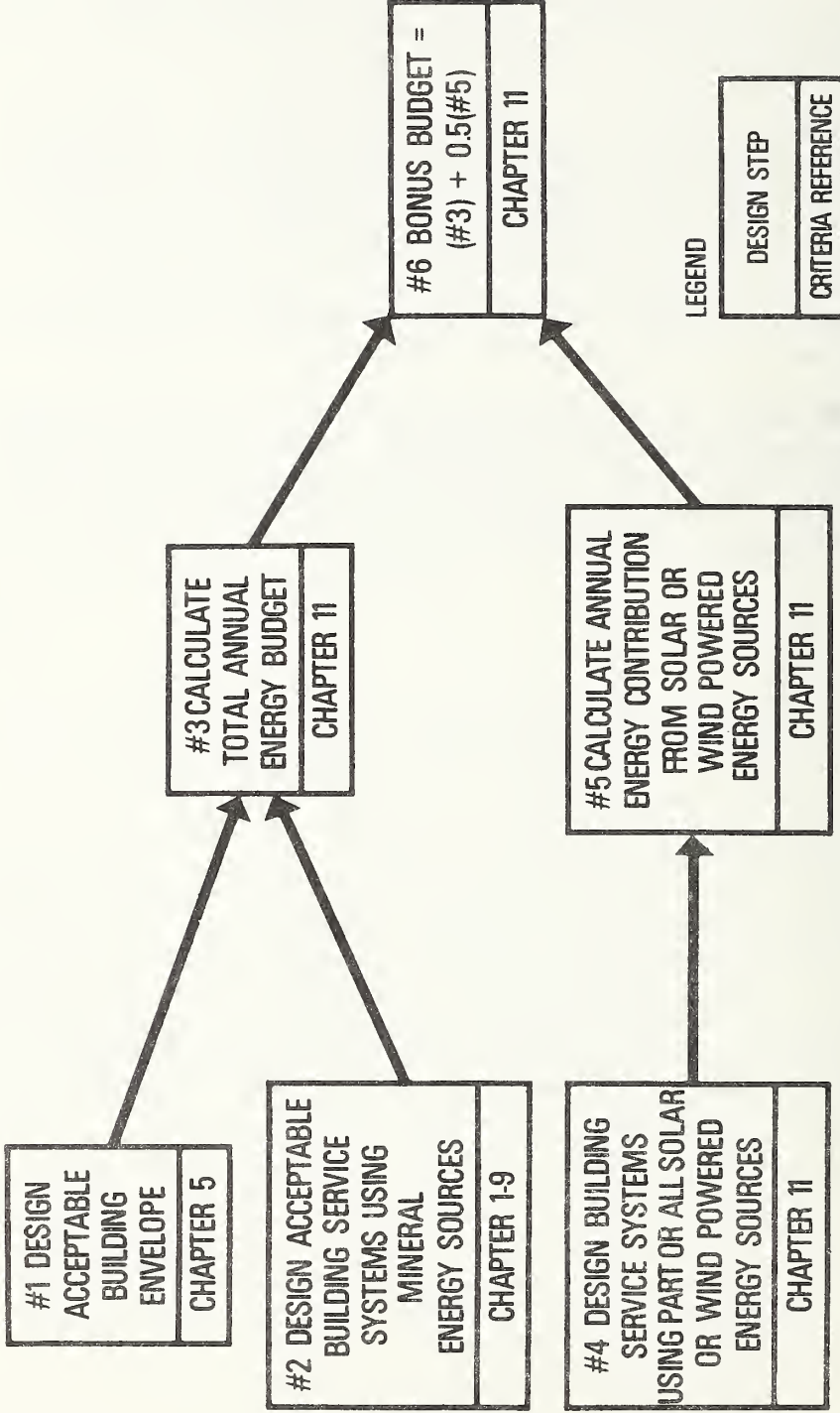
ENERGY BONUS FOR CONSERVING
MINERAL ENERGY SOURCES

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#1 DESIGN
ACCEPTABLE
BUILDING
ENVELOPE

CHAPTER 5

#2 DESIGN ACCEPTABLE
BUILDING SERVICE
SYSTEMS USING
MINERAL
ENERGY SOURCES

CHAPTER 1-9

#3 CALCULATE
TOTAL ANNUAL
ENERGY BUDGET

CHAPTER 11

#6 BONUS BUDGET =
(#3) + 0.5(#5)

CHAPTER 11

#4 DESIGN BUILDING
SERVICE SYSTEMS
USING PART OR ALL SOLAR
OR WIND POWERED
ENERGY SOURCES

CHAPTER 11

#5 CALCULATE ANNUAL
ENERGY CONTRIBUTION
FROM SOLAR OR
WIND POWERED
ENERGY SOURCES

CHAPTER 11

LEGEND

DESIGN STEP

CRITERIA REFERENCE

Figure 11-1

CONVERSION FACTORS TO METRIC (S.I.) UNITS

Physical Quantity	Symbol	To convert from	to	Multiply by
Length	x	inch	meter	$2.54^* \times 10^{-2}$
		foot	meter	$3.048^* \times 10^{-1}$
Area		$inch^2$	m^2	$6.4516^* \times 10^{-4}$
		$foot^2$	m^2	9.290×10^{-2}
Volume		$inch^3$	m^3	1.639×10^{-5}
		$foot^3$	m^3	2.832×10^{-2}
Temperature		Fahrenheit	Celsius	$t_c = (t_F - 32)/1.8$
Temperature difference		Fahrenheit	Kelvin	$K = (\Delta t_F)/1.8$
Pressure		inch Hg (60 F)	Pa	3.377×10^2
Mass		lbm	kg	4.536×10^{-1}
Mass/unit area	M	lbm/ft^2	kg/m^2	4.882
Moisture content rate		lbm/ft^2 week	$kg/m^2 s$	8.073×10^{-6}
Density	ρ	lbm/ft^3	kg/m^3	1.602×10^1
Thermal conductivity	k	$Btu/hr\ ft^2 (F/inch)$	W/mK	1.442×10^{-1}
U-value	U	$Btu/hr\ ft^2 F$	$W/m^2 K$	5.678
Thermal resistance	R	$F/Btu/hr\ ft^2)$	$K/(W/m^2)$	$1.761. \times 10^{-1}$
Heat Flow	q/A	$Btu/hr\ ft^2$	W/m^2	3.155
Heat flow		Btu/hr	W	2.931×10^{-1}
Heat flow		ton (of refrigeration	W	3.517×10^3
Water vapor:				
--permeability (perm-inch)	μ	$\dfrac{grain}{hr\ ft^2 (in.Hg/in.)}$	kg/Pa.s.m.	1.459×10^{-12}
--permeance (perm)	p,P	$\dfrac{grain}{hr\ ft^2 (in.Hg)}$	$kg/Pa.s.m^2$	5.745×10^{-11}
Illumination		foot candle	lm/m^2	1.076×10^1
Flow		gpm	m^3/s	6.309×10^{-5}
Flow		cfm	m^3/s	4.719×10^{-4}
Wind velocity		mph	knots	8.696×10^{-1}
Wind velocity		mph	m/s	4.470×10^{-1}
Pressure		lbf/ft^2	Pa	4.788×10^1
Pressure		psi (gage)	Pa (gage)	6.895×10^3
Cooling efficiency		Btu/hr kW		2.931×10^{-4}
Cooling efficiency		Btuh/watt		2.931×10^{-1}

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* Exact value: others are rounded to fourth place.

PROCEDURE FOR DETERMINING ECONOMIC EFFICIENCY

In order to avoid the possibility that any requirement of these criteria might be counterproductive in an economic efficiency sense, it may become necessary to determine whether a requirement is economically efficient. To determine economic efficiency, the present worth of life-cycle energy savings must be compared to the present worth of the extra life-cycle costs incurred to achieve the energy savings. This section describes one acceptable method for calculating the present worth of energy savings and extra costs, and it specifies a relationship between these two magnitudes in order for economic efficiency to be determined.

For the purpose of these calculations, the building life (L) and the real annual discount rate (D) must be assumed. The life-cycle energy savings, resulting from the use of a required subsystem rather than a specific alternative, consist of the estimated yearly difference in electrical and fossil fuel consumption valued at present prices, which grow, in real terms, at an annual rate of P. The extra life-cycle costs consist of additional initial costs, additional maintenance operations, and replacement costs through the life of the building. Real discount rates and real rates of fuel price increases (i.e., rates of change apart from general price increases) are used to eliminate the need to estimate the rate of general inflation.

A given requirement in the document should be considered economically efficient if the present worth of energy savings (B) is greater than the present worth of the extra costs (C). A requirement should be considered economically inefficient if the present worth of energy savings (B) is less than the present worth of the extra costs (C). The calculation of B and C is described as follows:

$$B = \frac{1 + P}{D - P} \cdot \left[1 - \left(\frac{1 + P}{1 + D}\right)^{L} \right] \cdot S \qquad D \neq P \qquad (1a)$$

$$B = L \cdot S \qquad\qquad\qquad D = P \qquad (1b)$$

where

> S = the annual value of energy saving by incorporating a subsystem or component required in the document rather than using a specific alternative.

$$S = P_1 \, s_1 + P_2 \, s_2, \text{ etc.},$$

where

> P_1 = the present unit price of fuel 1, and s_1 = the number of units of fuel 1 saved annually.

Simply stated, B is equivalent to the present value of a stream of dollar energy savings over L years which grow at the real rate of fuel price increase, P, while being discounted to present value at the real discount rate, D.

$$C = I + \left[\frac{1 - \dfrac{1}{(1 + D)^L}}{D} \right] (M + O) + \sum_{y=1}^{L} \frac{R_y}{(1 + D)^y} \qquad (2)$$

where

D = real annual discount rate in decimal form.

P = annual rate of change in the real price of energy in decimal form.

I = extra initial cost incurred by incoporating a subsystem or component required by these criteria rather than using a specific alternative.

L = building life in years.

M = extra annual maintenance cost at present prices.

O = extra annual operations cost at present prices.

R_y = extra replacement costs in year y at present prices.

I, M, O and R_y may be negative. A negative value indicates that the particular cost component of the required subsystem is lower than that for the alternative being considered. If this is the case, the negative sign should be retained in the computation.

In selecting specific values for D and L, lower values of L and higher values of D will reduce B, thereby increasing the chance that the requirement will appear to be economically inefficient. It is recommended that a building life of no less than 30 years be used (12 years for mobile homes) and a discount rate of no more than .08 be used.

As increasingly costly energy sources are utilized, e.g., North Sea and North Slope oil rather than Oklahoma oil, the real price of energy can be expected to rise during the life of the building (barring an innovation such as the commercial generation of electricity by fusion at favorable cost). Therefore, it appears overly conservative to say that P equals zero. As an attempt to capture the effect of rising real energy prices, it is suggested that P be assumed to equal .01. This assumption means that the nominal price of energy is expected to rise annually at a rate one percent greater than the general level of prices over the appropriate lifetime.

95

NEW INFORMATION NEEDED FOR ENERGY CONSERVATION CRITERIA

ENERGY ANALYSIS DATA

The amount of energy consumed by building service systems is strongly
affected by the dynamic interplay of structure heat transfer character-
istics and mechanical systems for heating and cooling, both of which are
usually changing with respect to time depending upon the outdoor weather
conditions and the use patterns of the building spaces such as lighting,
energy consuming equipment and occupancy.

Even with similar mechanical systems in similar types of building in the
same general locality, the energy consumption between buildings may differ
considerably depending upon the design of the central system and the
specific types of system components used.

Accurate evaluation of building energy consumption, therefore, requires
detailed mathematical simulation of the system dynamics. Such a simu-
lation technique has been illustrated in a document entitled, "Proposed
Procedures for Simulating the Performance of Components and Systems for
Energy Calculations", published by the American Society of Heating, Re-
frigerating and Air-Conditioning Engineers.

Although the methodology to perform dynamic simulation analysis is well
defined, the validity of such calculation is limited by the lack of
adequate technical information such as the following:

Part-Load Efficiency Data -- Most of the HVAC equipment manufacturers pub-
lish efficiency data for major energy consuming components in terms of
output capacity and input power requirement at a specified design point
so that consulting engineers can select equipment to meet the heating
and cooling load of the building under steady state design conditions.
The efficiencies of components are commonly available only at a specific
design point, often 100 percent of design rated load, which seldom occurs
during the course of building operation throughout the year. During most
of the year the equipment operates under part load conditions. Yet the
energy efficiency data for the part load condition are seldom available
from the manufacturer. In some cases such data are not easy to obtain
and may require considerable one-time expenditure. In order for energy
analysis to become an effective adjunct of building design, however,
part load efficiency data is essential.

Control Characteristics -- The dynamic response of a heating and cooling
system with respect to changing requirements in the space is influenced
by the manner in which the system and its equipment are controlled. If
the control is out of phase with the space heating and cooling needs,

much of the energy used to heat and cool the space will be wasted. This phenomena is especially acute for the terminal reheat system and double duct system whereby the primary energy is used to simultaneously heat and cool the supply fluid to attain the desirable condition. The parameters that describe the performance of the control function are usually expressed in such terminology as throttling range, time constant, transfer function and LaPlace transform, details of which are found in most control textbooks. Availability of this type of information for different types of controls would make it possible to estimate the energy consumption of system components as reflected in the drooping of the modulating control or the cycle frequency, percent-on time and anticipation characteristics of the on-off controls. However, very little information has been made available by the manufacturers as to these parameters, nor are comprehensive algorithms available to take these factors into account for the energy analysis.

Air Distribution To Multiple Zones From Central Fan-Plants-- The amount of chilled or heated air to be delivered to the various zones from a central fan plant is in many instances very much different from that predicted by zone heat balance equations. Present engineering practice for air distribution design is aimed at the sizing of the air duct, and not suitable for evaluating the air delivery performance under actual operating conditions. Moreover, a large amount of fan power is wasted by overpressurizing supply air and subsequent throttling of it through dampers. More comprehensive and accurate methodology for designing and evaluating the air distribution system, such as that based upon network analysis, is available and its use should be encouraged.

Standard Weather Data For The Energy Analysis -- Weather data required for the energy analysis is not the same as the steady state design weather data used for the selection of heating and cooling equipment and system design. The design weather data are basically specified as preventive measures so that occupants can be protected from the results of inadequate capacity of heating and cooling equipment. Such weather design criteria are not suitable for the dynamic evaluation of energy consumption by the equipment, since extreme weather conditions seldom prevail during the year. The weather data needed for energy analysis must satisfy the following requirements:

. Must contain coincidental values of temperature, humidity, wind data and solar radiation data including percent of sky cover by clouds.

. Must be conducive to dynamic analysis of building thermal performance and system responses.

. Must be readily obtainable and usable for each locality.

. Must be consistent.

Engineering Data For Nonconventional Systems -- Design and performance analyses data are needed for nonconventional systems, such as solar and/ or wind power utilization systems, engine driven heat pumps, and heat-operated refrigeration cycles (Rankine, absorption, adsorption and fuel-cell).

Simplified And Reliable Energy Calculation Procedures -- Although the energy calculation methods based upon the dynamic simulation of buildings and building service systems fulfill a need, they require considerable effort and a comprehensive computer program which may not be warranted in many applications of small or simple buildings. Simple energy estimate methods and versatility for evaluating different mechanical systems or innovative designs are necessary. What is needed is an energy analysis procedure more comprehensive than the degree day method yet less difficult to use than dynamic analysis. One such attempt was made recently at the National Bureau of Standards to estimate heating and cooling load(1). Approaches similar to this effort need to be further developed so that the energy consumption of less complicated buildings may be determined by a simple arithmetic manipulation of climatic factors, energy usage patterns and indoor conditions with respect to energy response factors, which will be predetermined for several typical buildings by the detailed dynamic analyses.

TESTING PROCEDURES

Most of the testing procedures published today for the HVAC equipment are for the rating or safety labeling/listing of equipment under specified design conditions. Due to standby losses (standing pilots, stack losses, compressor crankcase heaters, circulating pumps, etc.) energy converting equipment may operate with higher efficiency under the design test condition, than the part load conditions typical of day by day operation. In addition, conventional testing procedures are usually under steady loading conditions whereas the actual load is usually fluctuating. For the purpose of energy-based evaluation of building service systems and equipment, new testing procedures must be developed for evaluating efficiency performance under realistic operating conditions. General requirements for energy based testing may be stated as follows:

1. For the purpose of evaluating energy utilization efficiency, equipment shall be subjected to standardized, non-steady load conditions which represent the changing climatic and internal building load patterns common to the building.

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(1) Kusuda, T., Tsuchiya, T., Powell, F.J., "Prediction of Room Temperature by Using Equivalent Thermal Mass Response Factors", Proceedings for the 5th Symposium on Temperature, National Bureau of Standards, Wash., D. C. 1971.

2. Accurate instrumentation for determining integrated energy con-
    sumption as well as the peak power demand should be used.

3. Methodology to translate the test results to actual operating
    condition through mathematical simulation must be prescribed.

INFILTRATION

One of the greatest causes of building energy waste is due to unwanted
air leakage, which is usually affected by the way the buildings are con-
structed and by the outdoor weather conditions, particularly the temp-
erature and wind. Yet the present technology for estimating the heat
gain and heat loss due to infiltration is relatively weak as compared to
other modes of heat transfer such as conduction and solar radiation.

Methods of testing and evaluating building air infiltration under field
conditions are presently available, but such methods need to be further
developed and reduced to consensus standard procedures.