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Recommendations for Energy Conservation Standards and Guidelines for New Commercial Buildings

Volume I: Text of the

RECOMMENDATIONS FOR ENERGY CONSERVATIONS STANDARDS AND GUIDELINES FOR NEW COMMERCIAL BUILDINGS

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Recommendations for Energy
Conservation Standards and
Guidelines Standards and
Buildings

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1.0 PURPOSE

1.1 The purpose of this Standard is to provide design requirements or criteria that will improve the utilization of energy in new buildings.

1.2 The criteria contained in this Standard are directed toward the design of building envelopes, mechanical systems and equipment, service water heating, electrical and illumination systems and equipment for the purpose of more effectively using depletable energy resources and increasing consideration and use of nondepletable energy resources.

1.3 It is intended that this Standard be flexible in order that designers be encouraged to use innovative approaches and techniques to achieve effective utilization of energy. More effective use of energy may be achieved by the use of alternate design solutions, which follow the specific requirements of Sections 10 and/or 11.

1.4 This Standard is intended to be used in the design of new buildings. Compliance with its requirements should be determinable by evaluation and analysis of the design during the preconstruction stage.

1.5 It is not the intent, nor should the Standard be used, to abridge or supersede any safety, health or envirornental design requirements contained in legally adopted building construction codes.

PREFACE

The Energy Conservation for New Buildings Act of 1976, as amended, 42 U.S.C. Section 6831 et. seq. requires the U.S. Department of Energy to issue energy conservation standards for the design of new commercial and residential buildings. The standards will be mandatory only for the design of new federal buildings, and will serve as voluntary guidelines for the design of new non-federal buildings.

This report documents the development and testing of a set of recommendations that will serve as the basis for the Congressionally-mandated conservation standard for new commercial buildings. The recommendations have been developed and tested over the past 18 months by a multidisciplinary project team under the management of the U.S. Department of Energy and its prime contractor, Pacific Northwest Laboratory.

The report has been issued in four volumes consisting of 40 separate publications. The four volumes are briefly described below. A detailed view of the report structure is presented on the next page.

- Volume I contains the text of the recommendations for the conservation standard. Appendix A to Volume I compares (on a line-by-line basis) the recommendations with ASHRAE/IES Standard 90A-1980. This ASHRAE standard was the starting point for development of the recommendations.

- Volume II is a description of the standard development process and contains the rationale for the general approach and specific criteria contained within the recommendations. It is supported by appendices that document the project research conducted in support of the exterior envelope, HVAC systems and equipment, and lighting sections of the recommendations.

- Volume III is a description of the project's testing process and contains summaries of the energy and economic implications of the application of these recommendations to 10 test buildings across 7 climates. It is supported by appendices that document input data, assumptions, and computer codes employed in the testing process.

- Volume IV is composed of 30 separate books that contain detailed background information on the testing process and results. Three books document the testing process for each of the ten test buildings: one details building configuration and cost estimates, one presents representative energy (DOE-2.1B) analyses, and one presents life-cycle-cost estimates.

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2.0 SCOPE

2.1 This Standard sets forth requirements for the design of new buildings for human occupancy, as enumerated below, covering their exterior envelopes and selection of their HVAC, service water heating, auxiliary systems and equipment, and illuminating systems and equipment for effective use of energy.

2.1.1 This Standard covers new commercial buildings that provide facilities or shelter for public assembly, educational, business, mercantile, institutional, apartments and hotels/motels, as well as those portions of warehouse, factory and industrial occupancies that are used primarily for human occupancy and/or product storage. Commercial buildings shall be considered to include all buildings designed primarily for human occupancy other than detached one- and two-family dwellings and multi-family residential buildings of three stories or less. Residential buildings of greater than three stories including, but not limited to, multi-family dwellings, dormitories, hotels and motels shall be considered as commercial buildings.

2.1.2 Buildings or portions thereof whose peak design rate of energy usage is less than 3.5 Btu/h·ft^2 (11.0W/m^2) of gross floor area for all purposes and those which are neither heated nor cooled are excluded from the scope of this Standard.

2.1.3 Where specifically noted in the sections of this Standard, certain other buildings or elements thereof may be exempt when design data are not available or not applicable.

2.2 This Standard does not cover specific procedures for the operation, maintenance, and use of buildings.

3.0 DEFINITIONS

The following definitions are intended to be utilized in applying the criteria in this Standard. Where terms are not defined, it is intended their common dictionary definition be used.

<ins>accessible (as applied to equipment)</ins>. Admitting close approach because not guarded by locked doors, elevation or other effective means. (See <ins>readily accessible</ins>.)

<ins>area factor</ins>. See 4.3.1.2 for definition.

<ins>air conditioning, comfort</ins>. The process of treating air to control simultaneously its temperature, humidity, cleanliness and distribution to meet the comfort requirements of the occupants of the conditioned space.

<ins>air transport factor (ATF)</ins>. The ratio of the rate of useful sensible heat removal from the conditioned space to the energy input to the supply and return fan motor(s), expressed in consistent units and under the designated operating conditions.

<ins>automatic</ins>. Self-acting, operating by its own mechanism when actuated by some impersonal influence, as for example, a change in current strength, pressure, temperature or mechanical configuration. (See <ins>manual</ins>.)

boiler capacity. The rate of heat output in Btu/h (W) measured at the boiler outlet, at the design inlet and outlet conditions and rated fuel/energy input.

British thermal unit (Btu). Approximately the amount of heat required to raise the temperature of one pound of water by one Fahrenheit degree, at 60 F. International Steam Table Btu x 1.055 = kJ. (See energy.)

building envelope. The elements of a building that enclose conditioned spaces through which thermal energy may be transferred to or from the exterior or to or from spaces exempted by the provisions of 2.1.2. (See also Section 5).

C = thermal conductance. The thermal transmission in unit time through unit area of a particular body or assembly having defined surfaces, when unit average temperature is established between the surfaces; $Btu/ft^2 \cdot h \cdot F$ ($W/m^2 \cdot °C$).

COP. See coefficient of performance.

coefficient of performance (COP). See the following criteria for appropriate definitions:

Electrically Operated HVAC System Equipment--Cooling	7.3.3
Applied HVAC System Components--Cooling	7.4.1
Heat Operated HVAC System Equipment--Cooling	Table 7.7
Electrically Operated HVAC System Equipment--Heating	7.7.3

coefficient of utilization (CU). The ratio of the luminous flux (lumens) from a luminaire received on the work plane to the lumens emitted by the luminaire's lamps alone.

comfort envelope. The area on a psychrometric chart enclosing all conditions described in ANSI/ASHRAE Standard 55-81, Figure 1, as being comfortable.

conditioned floor area. The horizontal projection of that portion of interior space contained within exterior walls and conditioned directly or indirectly by an energy-using system.

conditioned space. Space within a building that is provided through design with the capacity to maintain a space condition falling within the comfort envelope set forth in ANSI/ASHRAE Standard 55-81.

degree day, cooling. A unit, based upon temperature difference and time, used in estimating energy consumption and specifying nominal cooling load of a building. For any one day, when the mean temperature is more than a specified base temperature in degrees Fahrenheit (Celsius), there are as many degree days as degree Fahrenheit (Celsius) difference in temperature between the mean temperature for the day and the specified base temperature.

degree day, heating. A unit, based upon temperature difference and time, used in estimating energy consumption and specifying nominal heating load of a building. For any one day, when the mean temperature is less than a specified base temperature efficiency, HVAC system. The ratio of the useful energy output (at the point of use) to the energy input for a designated time period, expressed in percent.

energy. The capacity for doing work; taking a number of forms which may be transformed from one into another, such as thermal (heat), mechanical (work), electrical, and chemical; in customary units, measured in kilowatt hours (kWh) or British thermal units (Btu); in SI units, measured in joules (J), where 1 joule = 1 watt-second.

energy efficiency ratio (EER). The ratio of net equipment cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions. When SI units are used this ratio becomes equal to COP. (See coefficient of performance.)

energy, recovered. (See recovered energy.)

enthalpy. A thermodynamic property of a substance defined as the sum of its internal energy plus the quantity Pv/J: where P = pressure of the substance, v = its volume, and J = the mechanical equivalent of heat; formerly called total heat and heat content.

external shading coefficient (S_E). The shading coefficient due to external shading devices.

gross floor area. The sum of the areas of the several floors of the building, including basements, mezzanine and intermediatefloored tiers and penthouses of headroom height, measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but excluding:

- o Covered walkways, open roofed-over areas, porches and similar spaces.
- o Pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

gross wall area. See 5.2.3 for definition.

HVAC. Heating, ventilating and air conditioning.

HVAC system. A system that provides either collectively or individually the processes of comfort heating, ventilating, and/or air conditioning within or associated with a building.

HVAC system component. (See 7.1.2.2 and HVAC system equipment.)

HVAC system equipment. (See 7.1.2.1) The word "equipment," used without modifying adjective, may, in accordance with common industry usage, apply either to HVAC system equipment or HVAC system components.

humidistat. A regulatory device, actuated by changes in humidity, used for automatic control of relative humidity.

illuminance. The density of the luminous flux incident on a surface; it is the quotient of the luminous flux by the area of the surface when the latter is uniformly illuminated.

infiltration. The uncontrolled inward air leakage through cracks and interstices in any building element and around windows and doors of a building, caused by the pressure effects of wind and/or the effect of differences in the indoor and outdoor air density.

light loss factor (LLF). A factor used in calculating the level of illumination after a given period of time and under given conditions. It takes into account temperature and voltage variations, dirt accumulation on luminaire and room surfaces, lamp depreciation, maintenance procedures and atmospheric conditions.

luminaire. A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

manual. Capable of being operated by personal intervention (adjective). (See automatic.)

marked rating. The design load operating conditions of a device as shown by the manufacturer on the nameplate or otherwise marked on the device.

non-depletable energy sources. Sources of energy (excluding minerals) derived from: incoming solar radiation, including natural daylighting and photosynthetic processes; phenomena resulting therefrom including wind, waves and tides, lake or pond thermal differences; and energy derived from the internal heat of the earth, including nocturnal thermal exchanges. (See solar energy source).

outdoor air. Air taken from the outdoors and, therefore, not previously circulated through the system.

packaged terminal air-conditioner. A factory-selected combination of heating and cooling components, assemblies or sections, intended to serve a room or zone.

packaged terminal heat pump. A factory-selected combination of heating and cooling components, assemblies or sections, intended for application in an individual room or zone.

power. In connection with machines, power is the time rate of doing work. In connection with the transmission of energy of all types, power refers to the rate at which energy is transmitted. In customary units, it is measured in watts (W) or British thermal units per hour (Btu/h); in SI Units it is measured in joules per second (J/s) or in watts (W).

public facility restroom. A restroom used by the transient public on a regular (rather than casual) basis. Examples include restrooms in service stations, airports, train terminals and convention halls. Restrooms incorporated with private guest rooms in hotels, motels or dormitories, and restroom facilities intended for the use of employees and not usually used by the general public, are not considered public facility restrooms. (See 8.6.2)

R = Thermal resistance. The reciprocal of thermal conductance; $hr \cdot ft^2 \cdot F/Btu$ or $(m^2 \cdot °C/W)$.

__readily accessible__. Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. (See __accessible__.)

__recooling__. The removal of heat by sensible cooling of the supply air (directly or indirectly) that has been previously heated above the temperature to which the air is to be supplied to the conditioned space for proper control of the temperature of that space.

__recovered energy__. Energy utilized that would otherwise be wasted (i.e. not contribute to a desired end use) from an energy utilization system.

__reheat__. The application of sensible heat to supply air that has been previously cooled below the temperature of the conditioned space by either mechanical refrigeration or the introduction of outdoor air to provide cooling.

__reset__. Adjustment of the set point of a control instrument to a higher or lower value automatically or manually.

__room air conditioner__. An encased assembly designed as a unit primarily for mounting in a window or through a wall, or as a console. It is designed primarily to provide free delivery of conditioned air to an enclosed space, room or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulating and cleaning air, and may also include means for ventilating and heating.

Seasonal Energy Efficiency Ratio (SEER). The total cooling of a central air conditioner in Btu's during its normal annual usage period for cooling divided by the total electric energy input in watt-hours during the same period.

service systems. All energy-using systems in a building that are operated to provide services for the occupants of processes housed therein, including HVAC, service water heating, illumination, transportation, cooking or food preparation, laundering or similar functions.

service water heating. Supply of hot water for domestic or commercial purposes other than comfort heating.

service water heating demand. The maximum design rate of energy withdrawal from a service water heating system in a designated period of time (usually an hour or a day).

shading coefficient (S_C).

$$S_C = \frac{\text{Solar Heat Gain of Fenestration}}{\text{Solar Heat Gain of Double Strength Glass}}$$

Note: To be compared under the same conditions.

shall. Where shall is used with a specific provision, that provision is mandatory if compliance with the Standard is claimed.

should. Term used to indicate provisions which are not mandatory but which are desirable as good practice.

solar energy source. Source of natural daylighting and of thermal, chemical or electrical energy derived directly from conversion of incident solar radiation. (See non-depletable energy sources).

system. A combination of equipment and/or controls, accessories, interconnecting means, and terminal elements by which energy is transformed so as to perform a specific function, such as HVAC, service water heating or illumination.

terminal element. The means by which the transformed energy from a system is finally delivered; i.e., registers, diffusers, lighting fixtures, faucets, etc.

thermostat. An automatic control device actuated by temperature and designed to be responsive to temperature.

U = thermal transmittance. The coefficient of heat transmission (air to air). It is the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films in $Btu/h \cdot ft^2 \cdot F$ ($W/m^2 \cdot {}^\circ C$). The U value applies to combinations of different materials used in series along the heat flow path, single materials that comprise a building section, cavity air spaces, and surface air films on both sides of a building element.

U_o = thermal transmittance, overall. The overall (average) heat transmission of a gross area of the exterior building envelope in Btu/h·ft^2·F (W/m^2·°C). The U_o value applies to the combined effect of the time rate of heat flows through the various parallel paths, such as windows, doors, and opaque construction areas, comprising the gross area of one or more exterior building components, such as walls, floors, or roof/ceiling.

unitary cooling and heating equipment. One or more factory-made assemblies that 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 separate assemblies shall be designed to be used together.

unitary heat pump. One or more factory-made assemblies that normally include an indoor conditioning coil, compressor(s) and outdoor coil or refrigerant-to-water heat exchanger, including means to provide both heating and cooling functions. When such equipment is provided in more than one assembly, the separate assemblies shall be designed to be used together.

ventilation. The process of supplying or removing air by natural or mechanical means to or from any space. Such air may or may not have been conditioned.

ventilation air. That portion of supply air that comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space. (See Section 6 of this Standard. See outdoor air.)

Water-chilling package of absorption. A factory designed and prefabricated assembly (not necessarily shipped as a single package) of one or more condensers; evaporators (water coolers); absorbers; and generators; with interconnections and accessories, used for chilling water.

Water-chilling package, centrifugal or rotary. A factory-designed and prefabricated assembly (not necessarily shipped as one package) of one or more centrifugal or rotary compressors; condensers; and water-coolers (evaporators); with interconnections and accessories, used for chilling water.

Water-chilling package, reciprocating. A factory designed and prefabricated assembly, self-contained or condenserless, of one or more reciprocating compressors; condensers (self-contained only); water coolers (evaporator); and interconnections and accessories; used for chilling water. The condenser may be air-, evaporatively-, or water-cooled.

watt (W). SI unit of power equal to one joule per second (J/s). Also, the power delivered by one volt with one ampere flowing (unity power factor). (See power.)

Zone. A space or group of spaces within a building with heating and/or cooling requirements sufficiently similar so that comfort conditions can be maintained throughout by a single controlling device.

4.0 ILLUMINATION SYSTEMS

The Lighting Section of this document proved to be difficult to compile. The difficulty exists because there is no quantitative metric for lighting quality, so no evaluative procedure exists to prove that a given power density will produce an acceptable lighting installation. The power density portion of this document is the result of computer research and energy analysis. The listed densities and the methodology used to achieve them has not been empirically tested. The careful preceding notation is made because the power allocations listed are a matter of dispute among lighting design professionals; therefore, any use of them for practice should be done with caution.

4.1 Scope

The procedure outlined herein provides power and control criteria for designing illumination systems in new buildings.

4.1.1 The rooms, spaces and areas covered by this procedure include:

(1) building interiors.

(2) building exteriors including open-air roofed areas, porches, entrances, exits, loading areas, parking areas, driveways, and similar spaces associated with the buildings where lighting is required.

(3) building facade and exterior supplementary lighting.

4.1.2 Rooms, spaces, areas and equipment exempted from this procedure include:

(1) outdoor processing, manufacturing, and storage facilities and activities;

(2) lighting power for theatrical productions, entertainment facilities, and audiovisual presentations where lighting is an essential technical element for the function performed;

(3) luminaries for medical and dental purposes;

(4) outdoor athletic facilities;

(5) special lighting required for art exhibits or displays in galleries, museums and monuments;

(6) residential living spaces within each of the following: apartments, condominiums, hospitals, health care facilities, hotels, motels, and other permanent and transient living spaces;

(7) all rooms of 50 square feet (4.65 m^2) or less enclosed by floor to ceiling partitions.

4.1.3 The procedure described herein is not to be used as a lighting design procedure. Its purpose is to establish a methodology for determining the upper power limit and minimum control systems for lighting systems, and to provide the appropriate inputs to the exterior envelope design criteria of Section 5. Once the lighting power limit and control systems have been determined, the designer should strive to design a lighting system that will provide an effective and pleasing visual environment in accordance with the use of the space, without exceeding the power limit, or reducing the level of control.

4.1.4 Where appropriate the designer is encouraged to use less power than the limit allows, and less energy overall, by:

(1) using task lighting;

(2) using daylighting, daylighting controls and room-occupancy-monitor control systems;

(3) using more efficient lamps and luminaires;

(4) using luminaires with heat removal and heat recovery capabilities;

(5) using systems that provide more light on tasks, i.e., specifying fixtures with higher Coefficients of Utilization (CU).

(6) Reducing light losses, i.e., providing system designs with better Light Loss Factors (LLF).

4.2 General

This procedure requires the listing of the total area of all interior rooms with similar tasks or activities for determining the lighting power budgets for activity areas. The summation of these budgets shall constitute the lighting power limit for the building interior. Separate lighting power limits shall be determined for exterior activity areas and for facade and exterior supplementary lighting.

When sufficient information is not known about the specific use of an interior room or external activity area, power budgets are to be based upon the apparent intended use of the room or activity area.

4.3 Lighting Power Limit for Building Interiors

The lighting power limit for the building interior is determined by totaling the activity area lighting power budgets calculated in accordance with 4.3.1. Form 4-1 provides a suggested format for summarizing room area data, determining activity areas and budgets, and calculating the lighting power limit.

4.3.1 Activity Area Budget. The lighting power budget for an activity area is determined by the following equation:

$$Pa = Aa \times PD \times AF$$

Where:

Pa = power budget for the activity area in watts.

Aa = activity area; the sum of the room areas in square feet (square meters) associated with a particular building activity and the same ceiling height. Activities are listed in Table 4.1. Areas are calculated on a room interior dimension basis.

PD = the upper limit of lighting power for the activity in watts per square foot (watts per square meter) from Table 4.1.

AF = area factor from Table 4.2 for the average area of all rooms with the same ceiling height associated with the activity. (Average room area is calculated by dividing the total area dedicated to an activity by the number of rooms characterized by that activity.)

4.3.1.1 The power density (PD) is that which will provide sufficient power to satisfy the lighting requirements of the listed activities of the room. Power density values for specific activities are given in Table 4.1.

In multifunction rooms (such as hotel banquet/meeting rooms) where multiple illumination systems are installed for essentially independent operation, the power density for the activity shall be 1.5 times the power density associated with the activity having the highest power density.

In rooms with multiple simultaneous activities (such as a room with dedicated office and drafting activities), each activity area shall be considered a separate room for the purpose of determining the interior power limit.

Where specific building activities are not shown in Table 4.1, the designer shall select activities closest to those provided in the table.

4.3.1.2 The area factor (AF) is a multiplying factor that adjusts the power density for each activity to account for the effects of room configuration on lighting efficiency. Area factors are given in Table 4.2 and shall be determined for each activity area using the average area for all rooms with the same ceiling height associated with a specific activity.

4.4 Lighting Power Limit for Building Exteriors

The lighting power limit for the building exterior is determined by totaling the activity area lighting power budgets derived from Table 4.3.

4.5 Lighting Power Limit for Building Facade and Exterior Supplementary Lighting

The lighting power limit for building facade and exterior supplementary lighting shall be set equal to 5 percent of the total building interior lighting power limit.

4.6 Controls for Building Interiors

4.6.1 Each room enclosed by ceiling-height partitions shall have independent control of the lighting within that area. This control shall be readily accessible to personnel occupying that area.

Exception: Automatic controls or those for special purpose application that require trained operators or those that would pose safety problems or security hazards.

4.6.2 Where spaces are served by more than one lighting circuit, each individual lighting circuit shall be controlled by a separate control device accessible from within the space.

4.6.3 Any area over 400 square feet (37.17 m^2) and having a general lighting power density greater than 1.0 watt per square foot (10.76 w/m^2), should be controlled so as to be able to reduce any general lighting by at least approximately one-half in a uniform pattern. The intent of this provision is to allow reduced lighting during periods of reduced lighting demand.

4.6.4 In all rooms where use can be made of daylight, lighting systems shall be designed so that luminaires in portions of the room where daylight is available can be controlled separately from the rest of the room. At a minimum, the row of luminaires nearest the source of daylight shall comply.

In general, a zone depth equal to approximately two times the floor-to-head-of-window height from all windowed walls should be considered for daylighting control.

4.6.5 Four-lamp and three-lamp flourescent luminaires with multiple ballasts should have at least two separate control devices where appropriate.

4.7 Controls for Building Exteriors

Facade lighting and other exterior area lighting shall be automatically (timer or photoelectric cell) switched for non-operation when daylighting is available to meet design criteria.

Exceptions: Safety, security and sign lighting.

4.8 Illumination System Performance

The lighting systems designed for the rooms and activity areas should be analyzed to ensure that the systems, as designed, meet the illuminance quantity and quality criteria required to support the room functions.

4.9 Compliance

4.9.1 Compliance with the illumination systems design procedure is achieved when:

(1) Total dedicated interior power is less than or equal to the building interior lighting power limit computed by the procedure in Section 4.3.

(2) Total dedicated exterior power is less than or equal to the building exterior lighting power limit computed by the procedure in Section 4.4.

(3) Total dedicated facade and exterior supplementary power is less than or equal to the building facade and supplementary lighting power limit computed by the procedure in Section 4.5.

(4) Building lighting controls are designed in accordance with Sections 4.6.1, 4.6.2, 4.6.4 and 4.7.

Power limit compliance is not required on a room-by-room or exterior area-by-area basis.

4.9.2 For the purposes of allowing additional lighting to supplement areas using daylighting and for calculating compliance in rooms using automatic daylighting controls, the dedicated power of the controlled lighting fixtures may be computed at 0.8 times their rated wattage.

4.9.3 For the purposes of calculating compliance in rooms using occupancy sensors for lighting controls and not addressed under 4.9.2, the dedicated power of the controlled lighting fixtures may be computed at 0.9 times their rated wattage.

4.9.4 The total interior connected load shall be employed in the appropriate equations for exterior envelope compliance in Section 5.

TABLE 4.1
POWER DENSITIES FOR INTERIOR ACTIVITY AREAS

	PD Watts per Square Foot	PD Watts per Square Meter
Common Areas		
Boiler Room	.6	6.46
Conference Room	1.0	10.76
Corridor	.5	5.38
Dining (Fast Service)	2.1	22.60
Dining (Leisure)	1.6	17.22
Electrical Equipment Room	.5	5.38
General Assembly (Auditorium)	.8	8.61
Kitchen	1.3	14.00
Laboratories	2.4	25.83
Library Room	1.7	18.30
Lobby, Reception, Waiting	.8	8.61
Locker Room and Shower	.5	5.38
Mail Room	2.1	22.60
Material Handling (Bulk)	.6	6.46
Mechanical Equipment Room	.5	5.38
Stairs	.5	5.38
Storerooms or Warehouse		
Inactive	.2	2.15
Active Bulky	.4	4.31
Active Medium	.5	5.38
Switchboard and Control Room	1.3	14.00
Toilet and Washroom	.6	6.46
Utility Room, General	.4	4.31
Office		
Accounting	2.4	25.83
Drafting	3.5	37.67
Filing (Active)	1.5	16.15
Filing (Inactive)	.6	6.46
Graphic Arts	2.3	24.76
Office Machine Operation		
Computer Machinery	1.3	14.00
Duplicating Machines	.6	6.46
EDP I/O Terminal (Internally Illuminated)	.6	6.46
EDP I/O Terminal (Room Illuminated)	1.3	14.00
Typing and Reading	1.7	18.30

TABLE 4.1
POWER DENSITIES FOR INTERIOR ACTIVITY AREAS

	PD Watts per Square Foot	PD Watts per Square Meter
<u>Commercial and Institutional</u>		
Armories		
Drill	.5	5.38
Exhibitions	.6	6.46
Seating Area	.4	4.31
Art Galleries	1.2	12.92
Bakeries		
Hand Decorating	2.6	27.99
Mixing and Filling	1.0	10.76
Banks		
Lobby, General	1.7	18.30
Posting and Keypunch	3.5	37.67
Tellers Stations	3.5	37.67
Bar (Lounge)	.8	8.61
Barber Shops and Beauty Parlors	2.9	31.22
Church and Synagogues, Main Worship Area	1.7	18.30
Cleaning and Pressing		
General Processing	1.1	11.84
Pressing	3.3	35.52
Repair and Alteration, Inspection & Spotting	5.8	62.43
Club and Lodge Rooms	.8	8.61
Courtrooms	.7	7.53
Depots, Air Terminals and Stations		
Baggage Checkroom	1.0	10.76
Concourse (Main Thruway)	.6	6.46
Platforms	.5	5.38
Ticket Counter	1.7	18.30
Waiting and Lounge Area	.6	6.46
Hotels		
Bathrooms (Public)	1.0	10.76
Entrance Foyer	.8	8.61
Lobby, General	.8	8.61
Laundries		
Fine Hand Ironing	2.1	22.60
Ironing, Weighing, Listing, Marking	1.0	10.76
Machine & Press Finishing, Sorting	1.3	14.00
Washing	.6	6.46

TABLE 4.1
POWER DENSITIES FOR INTERIOR ACTIVITY AREAS

	PD Watts per Square Foot	PD Watts per Square Meter
Commercial and Institutional		
Library		
Audio Listening Areas, General	.6	6.46
Audiovisual Areas	1.3	14.00
Book Stacks (Active)	.7	7.53
Book Stacks (Inactive)	.4	4.31
Book Repair and Binding	1.4	15.07
Card Files	2.4	25.83
Cataloging	1.7	18.30
Microfilm Areas	1.7	18.30
Reading Areas	1.7	18.30
Municipal Building--Fire & Police		
Fire Engine Room	.6	6.46
Fireman's Dormitory	1.4	15.07
Identification Records	3.5	37.67
Jail Cells	.6	6.46
Recreation Room	.7	7.53
Nursing Homes		
Administrative & Lobby Areas	1.1	11.84
Chapel or Quiet Areas, General	.7	7.53
Nurses' Station	1.1	11.84
Occupational Therapy	1.0	10.76
Pharmacy Area, General	1.2	12.92
Physical Therapy	1.4	15.07
Recreation Area	1.1	11.84
Post Offices		
Lobby	.6	6.46
Sorting, Mailing, etc.	2.1	22.60
Printing		
Composing	3.0	32.29
Electrotyping	1.8	19.38
Photoengraving	1.8	19.38
Schools		
Art	2.3	24.76
Classrooms	1.7	18.30
Dormitories	1.1	11.84
Drafting	2.4	25.83
Home Economics	1.1	11.84
Laboratories	2.1	22.60
Lecture	1.7	18.30
Music	1.3	14.00
Sewing	3.0	32.29
Shops	2.1	22.60
Study Halls or Typing	1.7	18.30

TABLE 4.1
POWER DENSITIES FOR INTERIOR ACTIVITY AREAS

	PD Watts per Square Foot	PD Watts per Square Meter
Commercial and Institutional		
Service Stations, Auto	.6	6.46
Stores		
Alteration and Fitting	4.3	46.28
Circulation	.7	7.53
Merchandise	3.2	34.45
Sales Transaction	1.4	15.07
Show Windows	6.5	69.97
Stockrooms	.6	6.46
Wrapping and Packing	1.0	10.76
Theaters and Motion Picture Houses	.8	8.61
Upholstering--Automobile, Coach, Furniture	2.6	27.99
Sports		
Seating Area All Sports	.4	4.31
Badminton		
Club	.5	5.38
Recreational	.4	4.31
Tournament	.6	6.46
Basketball		
College and Professional	1.1	11.84
College and Intramural & High School	.6	6.46
Bowling		
Approach Area	.4	4.31
Lanes	.5	5.38
Boxing or Wrestling (Ring)		
Amateur	1.9	20.45
Championship or Professional	3.8	40.90
Gymnasiums (Refer to individual sports listed)		
Exhibitions, Matches	1.1	11.84
General Exercising and Recreation	0.6	6.46
Handball		
Club	0.6	6.46
Recreational	0.5	5.38
Tournament	1.1	11.84
Hockey, Ice		
Amateur	1.1	11.84
College or Professional	2.1	22.60
Recreational	0.5	5.38

TABLE 4.1
POWER DENSITIES FOR INTERIOR ACTIVITY AREAS

	PD Watts per Square Foot	PD Watts per Square Meter
Commercial and Institutional		
Sports cont'd		
Skating Rinks	0.4	4.31
Swimming		
Exhibitions	1.0	10.76
Recreational	0.6	6.46
Tennis		
Professional (Class I)	2.1	22.60
Club (Class II)	1.4	15.07
Recreational (Class III)	1.1	11.84
Tennis, Table		
Club	0.6	6.46
Recreational	0.5	5.38
Tournament	1.1	11.84
Volleyball	0.5	5.38

TABLE 4.2
AREA FACTOR

Area (Sq. Ft.)	Ceiling Height (ft)									
	8	8.5	9	10	11	12	14	16	18	20
50	2.00									
60	1.90	2.00								
70	1.80	1.92	2.00							
80	1.72	1.82	1.94							
90	1.66	1.75	1.85	2.00						
100	1.61	1.69	1.79	1.98						
110	1.56	1.64	1.73	1.91						
120	1.53	1.60	1.68	1.85	2.00					
130	1.50	1.57	1.64	1.80	1.97					
140	1.47	1.54	1.61	1.76	1.92					
150	1.44	1.51	1.57	1.72	1.87	2.00				
160	1.42	1.48	1.55	1.68	1.83	1.99				
170	1.40	1.46	1.52	1.65	1.79	1.94				
180	1.39	1.44	1.50	1.62	1.75	1.90				
190	1.37	1.42	1.48	1.60	1.72	1.86				
200	1.36	1.41	1.46	1.57	1.70	1.83				
220	1.33	1.38	1.43	1.53	1.65	1.77	2.00			
240	1.31	1.35	1.40	1.50	1.60	1.72	1.97			
260	1.29	1.33	1.38	1.47	1.57	1.67	1.91			
280	1.27	1.31	1.36	1.44	1.54	1.64	1.86			
300	1.26	1.30	1.34	1.42	1.51	1.60	1.81	2.00		
350	1.23	1.26	1.30	1.37	1.45	1.54	1.72	1.93		
400	1.20	1.23	1.27	1.34	1.41	1.48	1.65	1.83	2.00	
450	1.18	1.21	1.24	1.31	1.37	1.44	1.59	1.76	1.94	
500	1.17	1.19	1.22	1.28	1.34	1.41	1.55	1.70	1.87	2.00
550	1.15	1.18	1.21	1.26	1.32	1.38	1.51	1.65	1.81	1.98
600	1.14	1.16	1.19	1.24	1.30	1.35	1.48	1.61	1.75	1.91
700	1.12	1.14	1.17	1.21	1.26	1.31	1.42	1.54	1.67	1.81
800	1.10	1.13	1.15	1.19	1.24	1.28	1.38	1.49	1.60	1.73
900	1.09	1.11	1.13	1.17	1.21	1.26	1.35	1.45	1.55	1.66
1,000	1.08	1.10	1.12	1.16	1.19	1.24	1.32	1.41	1.51	1.61
1,500	1.05	1.06	1.07	1.10	1.13	1.17	1.23	1.30	1.37	1.45
2,000	1.02	1.04	1.05	1.07	1.10	1.13	1.18	1.24	1.30	1.36
2,500	1.01	1.02	1.03	1.05	1.08	1.10	1.15	1.20	1.25	1.30
3,000	1.00	1.01	1.02	1.04	1.06	1.08	1.12	1.17	1.21	1.26
4,000		1.00	1.00	1.02	1.04	1.05	1.09	1.13	1.17	1.20
5,000				1.01	1.02	1.04	1.07	1.10	1.13	1.17
6,000				1.00	1.01	1.02	1.05	1.08	1.11	1.14
7,000					1.00	1.01	1.04	1.07	1.09	1.12
8,000						1.01	1.03	1.06	1.08	1.11
9,000						1.00	1.02	1.05	1.07	1.09
10,000							1.02	1.04	1.06	1.08
20,000							1.00	1.00	1.01	1.03
30,000									1.00	1.00

TABLE 4.3
POWER DENSITIES FOR EXTERIOR ACTIVITY AREAS

	PD Watts per Linear Foot	PD Watts per Linear Meter
Entrances without Canopy	30.0	98.43
Exits, with or without Canopy	20.0	65.62
Loading Doors	20.0	65.62
Driveways		
Private (based on 2 land width)	2.0	6.56
Public (based on 2 lane width)	3.0	9.84
	PD watts per square foot	**PD watts per square foot**
Loading Areas	0.3	3.23
Entrances with Canopy		
Decorative (retail, hotel, theater, etc.)	10.0	107.64
Utilitarian (hospital, office, industrial, etc.)	4.0	43.06
	PD watts per space	
Parking Lots (Open)		
Private	20.0	
Public	30.0	

FORM 4-1

DATA LISTING TO DETERMINE LIGHTING POWER LIMIT

				POWER		
A	B	C	D	E	F	G
Activity Description (Table 4.1) Room Height ____ft.	Room Name or Number	No. of Iden. Rooms	Room Area sq.ft.	Area Factor (Table 4.2)	Power Density (Table 4.1) w/sq.ft.	Power Budget watts C11xE12xF12
	1.					
	2.					
	3.					
	4.					
	5.					
	6.					
	7.					
	8.					
	9.					
	10.					
TOTALS	11.					
AVERAGE	12.					

				POWER		
A	B	C	D	E	F	G
Activity Description (Table 4.1) Room Height ____ft.	Room Name or Number	No. of Iden. Rooms	Room Area sq.ft.	Area Factor (Table 4.2)	Power Density (Table 4.1) w/sq.ft.	Power Budget watts C11xE12xF12
	1.					
	2.					
	3.					
	4.					
	5.					
	6.					
	7.					
	8.					
	9.					
	10.					
TOTALS	11.					
AVERAGE	12.					

				POWER		
A	B	C	D	E	F	G
Activity Description (Table 4.1) Room Height ____ft.	Room Name or Number	No. of Iden. Rooms	Room Area sq.ft.	Area Factor (Table 4.2)	Power Density (Table 4.1) w/sq.ft.	Power Budget watts C11xE12xF12
	1.					
	2.					
	3.					
	4.					
	5.					
	6.					
	7.					
	8.					
	9.					
	10.					
TOTALS	11.					
AVERAGE	12.					

5.0 EXTERIOR ENVELOPE REQUIREMENTS

5.1 Scope

The criteria of this section establishes the minimum thermal requirements of the exterior envelope for new commercial buildings. The equations, charts (which may be interpolated as necessary), and tables in this section are intended only for use in defining these criteria. These criteria explicitly consider a number of factors important in appropriate thermal envelope design across a range of commercial building functions and climates. The factors considered are building configuration and size, orientation, fenestration, shading, thermal mass, daylighting, and lighting. In cases where a system analysis approach to building design is required, for example when applying a passive strategy not covered by this section, the requirements of 10 and/or 11 of this Standard shall apply.

5.2 General

5.2.1 The intent of this section is to provide minimum requirements for commercial building envelope construction in the interests of energy conservation. These requirements are not intended to be, nor should they be construed as, optimized energy-conserving practices.

5.2.2 All buildings that are to be heated and/or mechanically cooled shall be designed so as to meet the heating criteria of Section 5.3.1, the annual and peak cooling criteria of Section 5.3.2, and the air leakage criteria of Section 5.5.

5.2.2.1 In determining compliance with the thermal performance criteria of Section 5.3, the appropriate thermal property and heat transfer data contained in the ASHRAE Handbook, 1981 Fundamentals Volume, shall be used. Measured thermal performance data for building envelope sections or components resulting from laboratory or field tests or from documented engineering analyses, may be used in addition to, or in place of, the thermal property data in the ASHRAE Handbook.

5.2.2.2 The following dry bulb temperatures shall be used as appropriate in selecting thermal property data and in demonstrating compliance with the thermal performance criteria of Section 5.3.

	Indoor		Outdoor
	F	°C	(from ASHRAE 1981 Handbook, Fundamentals)
Heating	70	21.0	97-1/2%
Cooling	78	25.5	2-1/2%

5.2.3 The gross area of exterior walls is measured on the exterior for walls which enclose a heated and/or mechanically cooled space. The gross area of exterior walls consists of all opaque wall areas (including between floor-spandrels, peripheral edges of floors, including interstitial areas, etc.) window areas (including sash), and door areas.

5.2.4 The gross area of a roof assembly consists of the total exterior surface of the roof assembly exposed to outdoor air and enclosing heated and/or mechanically cooled space. The roof assembly shall be considered to include all roof/ceiling components through which heat may flow between indoor and outdoor environments (including skylights and clerestory surfaces).

5.2.4.1 When return air ceiling plenums are employed, the roof/ceiling assembly shall:

a. for thermal transmittance purposes, not include the resistance of the ceiling proper nor of the plenum space as part of the total resistance of the assembly, and

b. for gross area purposes, be based upon the interior face of the upper plenum surface.

5.2.5 The design of buildings for energy conservation may increase the water vapor pressure differentials between the interior and exterior environments. Vapor retarders, ventilation, and interior humidity control may be required to maintain the thermal and moisture integrity of the envelope.

5.3 Criteria for Commercial Building Envelopes

5.3.1 Heating Criteria. The heating criteria shall establish the maximum allowable thermal transmittance of all building envelope components. Criteria are presented for roofs, walls, floors and slabs-on-grade. Compliance with these requirements may not, in some cases, yield the most energy efficient building. For buildings with high internal heat gains and/or unusual schedules for operation, it is suggested that consideration be given to utilizing the provisions of Section 10 in order to justify alternative designs to provide improved thermal performance.

5.3.1.1 Roof Criterion. Any building that is heated shall have a combined thermal transmittance value (U_o value) for the gross area of the roof assembly not exceeding that shown in Figure 5.1. Equation 1 shall be used to determine acceptable combinations to meet the required U_o values of Figure 5.1.

$$U_o = \frac{U_R A_R + U_S A_S}{A_o} \quad \text{...EQUATION 1}$$

Where:

U_o = the average thermal transmittance of the gross roof/ceiling area, Btu/ft^2·h·F (W/m^2·°C)

A_o = the gross area of the roof/ceiling assembly, ft^2 (m^2) (See 5.2.4)

U_R = the thermal transmittance of all elements of the opaque roof/ceiling area, Btu/ft^2·h·F (W/m^2·°C)

A_R' = opaque roof/ceiling assembly area, ft^2 (m^2)

U_S = the thermal transmittance of all skylight and other non-opaque elements in the roof/ceiling assembly, $Btu/ft^2 \cdot h \cdot F$ ($W/m^2 \cdot °C$)

A_S = skylight area (including frame), ft^2 (m^2)

NOTE: Where more than one type of roof/ceiling and/or skylight or other non-opaque materials are used, the U x A term for that exposure shall be expanded into its subelements as follows:

$$U_{R1} A_{R1} + U_{R2} A_{R2} + \ldots, \text{ etc.}$$

<u>Exceptions</u>: Where skylights are used in conjunction with automatic daylighting controls and meet all of the following conditions:

a. The opaque roof area does not exceed the values shown in Figure 5.1.

b. Skylight area (including framing) as a percentage of roof area does not exceed the following:

Installed Lighting Capacity of Area Served by the Skylights in w/ft^2	Maximum Skylight Area (percent of roof area)
Less than 1.0	2%
From 1.0 to less than 2.0	5%
From 2.0 to 3.0	8%
Greater than 3.0	10%

c. All lighting fixtures associated with the installed lighting capacity in (b) above are automatically controlled by daylighting as provided in Section 4.6.4.

d. Skylight curbs have a U_o value no greater than 0.21.

e. The infiltration coefficient of the skylights does not exceed 0.05 $Btu/ft^2 \cdot h \cdot F$.

5.3.1.1.1 Roof assemblies with monitors, atria or similar devices which are not capable of being evaluated under Section 5.3.1.1 shall be evaluated using the criteria in Section 11 of the standard.

5.3.1.1.2 The effects of roof absorptivity/reflectivity and strategies for external shading of roof surfaces should be considered.

5.3.1.2 Wall Heating Criterion. The heating criterion for the wall components of the building envelope is intended to provide flexibility in designing wall sections which comply with the intent of this standard. The wall heating criterion is specified by Figure 5.3 and is based on the thermal performance of all the wall components taken together.

5.3.1.2.1 The annual wall heating criterion for a building is determined from Figure 5.3 by using the following building and climate characteristics: 1) the average lighting power density for the interior of the building, as determined by Section 4.4.1; 2) the glazed fraction of the exterior wall area that is exposed to outside air; 3) the ratio of the total exposed exterior wall area to the total gross floor area of the building; and 4) annual heating degree hours at a 55F base.

5.3.1.2.2 Demonstration of compliance with the criterion of Figure 5.3 requires consideration of each wall component and its orientation. Equation 2, which is summed over orientation, shall be used to determine if a proposed design will yield a compliance value less than the applicable annual wall heating criterion.

$$H = \sum\left[\left((F_C U_O H_1) + (F_S S_C S_{EH} H_2) + (F_C L_P H_3)(1 - R_C K_H)\right) M_{TH}\right] \quad \text{...EQUATION 2}$$

conduction — *solar* — *lighting*

summed over all orientations ($\sum$)

Where for each orientation:

F_C = the fraction of the wall area for the orientation to the total exterior wall area

U_O = the average thermal transmittance of the gross wall area, $Btu/ft^2 \cdot h \cdot F$

H_1 = the transmission coefficient from Figure 5.4

F_S = the fraction of the fenestration area of the total exterior wall area

S_C = the shading coefficient of the glazing

S_{EH} = the external shading factor from Figure 5.4, for horizontal shading devices

H_2 = the solar coefficient from Figure 5.4

L_p = the average lighting power for the building W/ft^2, as determined in Section 4.4.1

H_3 = the lighting coefficient from Figure 5.4

R_c = the fraction of the lighting system automatically controlled for daylighting

K_H = the daylighting factor from Figure 5.4 (See 5.3.1.2.3)

M_{TH} = the mass factor from Figure 5.5 (See 5.3.1.2.4)

H = the annual wall heating compliance value for the entire building

Worksheet 1 in Attachment A to Section 5 may be used directly for the calculations required in Equation 2.

5.3.1.2.3 A daylighting factor K_H of less than 1.0 shall be applied when credit for daylighting is claimed under Section 4.9.2, otherwise K_H shall be set equal to 1.0.

5.3.1.2.4 A wall mass factor M_{TH} from Figure 5.5 may be used to adjust for the effects of mass in the exterior walls when insulation is external to the wall mass. Where the wall mass is external to insulation or is not at least 3 in. (7.62 cm.) solid concrete, or 6 in. (15.24 cm.) concrete block or equivalent, then M_{TH} shall be set equal to 1.0.

5.3.1.3 Walls Adjacent to Unconditioned Spaces. Walls enclosing conditioned space exposed to interior unconditioned spaces shall have a U_O value not exceeding that shown in Figure 5.2.

5.3.1.4 Floors Over Unconditioned Spaces. For floors of conditioned spaces over unconditioned areas, the U_O value shall not exceed the values shown in Figure 5.1.

5.3.1.5 Slab-on-Grade Floors. For slab-on-grade floors, the thermal resistance of the insulation around the perimeter of the floor shall be as shown in Figure 5.6. The insulation shall extend either downward from the top of the slab or downward to the bottom of the slab then horizontally beneath the slab for the minimum total distance given in Figure 5.6. There are no insulation requirements for heated slabs in locations having less than 1000 Fahrenheit degree days (550 Celsius heating degree days), or for unheated slabs in locations having less than 2000 Fahrenheit degree days (1100 Celsius heating degree days).

5.3.1.6 Below Grade Walls. Walls below grade enclosing conditioned spaces shall be insulated equivalent to unheated slabs as shown in Figure 5.6.

5.3.2 Cooling Criteria. The cooling criteria, annual and peak, shall establish the maximum allowable solar transmission and shading coefficients for all fenestrations. In addition criteria are presented for roofs and floors. Compliance with the specified cooling criteria may not, in some cases, yield the most energy efficient building. For buildings of unusual design it is suggested that consideration be given to utilization of the provisions of Sections 10 and 11 to justify alternative designs providing improved thermal performance.

5.3.2.1 Wall Cooling Criteria. The wall cooling criteria are designed to provide flexibility in the design of complying wall sections. The wall cooling criteria are specified by Figures 5.7 and 5.10 and are based on consideration of the thermal performance of all the wall components taken together.

5.3.2.1.1 The annual wall cooling criterion for a building is determined from Figure 5.7 by using the following building and location characteristics: 1) the average lighting power density for the interior of the building; 2) the glazed fraction of the exterior wall area that is exposed to outside air; and 3) the degrees north latitude.

5.3.2.1.2 Demonstration of compliance with the criterion of Figure 5.7 requires consideration of each wall component and its orientation. Equation 3, which is summed over orientation, shall be used to determine if a proposed design will yield a compliance value less than the applicable annual wall cooling criterion.

$$C_A = \sum \left[\left((F_C U_O C_1) + (F_S S_C S_{EC} C_2) + (F_C L_P C_3)(1 - R_C K_C) \right) M_{TC} \right] \quad \text{...EQUATION 3}$$

conduction — *solar* — *lighting*

summed over all orientations

Where for each orientation:

F_C = the fraction of the wall area for the orientation to the total exterior wall area

U_O = the average thermal transmittance of the gross wall area, $Btu/ft^2 \cdot h \cdot F$

C_1 = the transmission coefficient from Figure 5.8

F_S = the fraction of the glazed area for the orientation to the total exterior wall area

S_C = the shading coefficient of the glazing

S_{EC} = the external shading factor from Figure 5.8, for horizontal shading devices

C_2 = the solar gain coefficient from Figure 5.8

L_p = the average lighting power for the building W/ft^2, as determined in Section 4.4.1.

C_3 = the lighting coefficient from Figure 5.8

R_c = the fraction of the lighting system automatically controlled for daylighting

K_c = the daylighting factor from Figure 5.8 (See 5.3.2.1.5)

M_{TC} = the mass factor from Figure 5.9 (See 5.3.2.1.7)

C_A = the annual wall cooling compliance value for the entire building

Worksheet 2 in Attachment A to Section 5 may be used directly for the calculations required by Equation 3.

5.3.2.1.3 The peak wall cooling criterion for a building is determined from Figure 5.10 by using the following building and climate characteristics: 1) the average lighting power density for the interior of the building; 2) the glazed fraction of the exterior wall area that is exposed to outside area; and 3) the 5 percent summer design temperature.

5.3.2.1.4 Demonstration of compliance with the criterion of Figure 5.10 requires consideration of each wall component and its orientation. Equation 4, which is summed over orientation, shall be used to determine if a proposed design will yield a compliance value less than the applicable peak wall cooling criterion.

$$C_P = \sum \left[\left((F_C U_O P_1) + (F_S S_C S_{EP} P_2) + (F_C L_P P_3)(1 - R_C K_P) \right) M_{TP} \right] \quad \text{..EQUATION 4}$$

conduction *solar* *lighting*

summed over all orientations

Where for each orientation:

F_C = the fraction of the wall area for the orientation to the total exterior wall area

U_O = the average thermal transmittance of the gross wall area, $Btu/ft^2 \cdot h \cdot F$

P_1 = the transmission coefficient from Figure 5.11

F_S = the fraction of the glazed area for the orientation to the total exterior wall area

S_C = the shading coefficient of the glazing

S_{EP} = the external shading factor from Figure 5.11, for horizontal shading devices

P_2 = the solar gain coefficient from Figure 5.11

L_P = the average lighting power for the building W/ft^2, as determined in Section 4.4.1

P_3 = the lighting coefficient from Figure 5.11

P_3 = the lighting coefficient from Figure 5.11

R_c = the fraction of the lighting system automatically controlled for daylighting

K_p = the daylighting factor from Figure 5.11 (See 5.3.2.1.5)

M_{TP} = the mass factor from Figure 5.12 (See 5.3.2.1.7)

C_p = the peak wall cooling compliance value for the entire building

Worksheet 3 in Attachment A to Section 5 may be used directly for the calculations required by Equation 4.

5.3.2.1.5 Daylighting factors K_c (Figure 5.8) and K_p (Figure 5.11) of less than 1.0 shall be applied only when the lighting in the space served by daylighting is controlled automatically as specified in Section 4.6.4 and the window size and placement meet the criteria of Section 5.3.2.1.6, otherwise K_c and K_p shall be set equal to 1.0.

5.3.2.1.6 Credit for daylighting shall be determined only on the basis of the Daylighting Aperature Ratio (DAR). The DAR is defined as that percentage of gross wall area between the work plane and the ceiling which is glazed. For daylighting credit the top boundary of the glazing shall be as near the ceiling as practical.

5.3.2.1.7 Wall mass correction factors M_{TC} obtained from Figure 5.9 and M_{TP} obtained from Figure 5.12 may be used to adjust for the effects of mass in the exterior walls in those cases where the insulation is external to the wall mass. Where the wall mass is external to insulation or is not at least 3 in. (7.62 cm.) solid concrete, or at least 6 in. (15.24 cm.) concrete block or equivalent, then M_{TC} and M_{TP} shall be set equal to 1.0.

5.3.2.2 Roof Criterion. A building that is mechanically cooled shall have a combined thermal transmittance (U_O value) not exceeding that specified by 5.3.1.1.

5.3.2.3 Floor Over Unconditioned Spaces. For floors of conditioned spaces over unconditioned areas, the thermal transmittance shall not exceed that specified by 5.3.1.1.

5.4 Natural Ventilation

Consideration should be given to providing for natural ventilation in appropriate building locations to supplement HVAC systems operation. (See also Section 6.6.)

5.5 Air Leakage

5.5.1 The requirements of this section are limited to those locations separating exterior ambient conditions from interior building conditioned air space and are not applicable to the separation of interior conditioned spaces from each other.

5.5.2 Compliance with the criteria for air leakage through building components shall be determined by ANSI/ASTM E 283-73, Standard Method of Test for Rate of Air Leakage through Exterior Windows, Curtain Walls and Doors, at a pressure differential of 1.57 lb/ft^2 (75 Pa) which is equivalent to the effect of a 25 mph (11.1 m/s) wind.

5.5.3 Requirements

5.5.3.1 Windows: Windows shall be designed to limit air leakage; the air leakage rate shall not exceed 0.32 ft^3/min per foot ($5 \times 10^{-4} m^3/s$ per meter) of sash crack. (See 5.5.1.)

5.5.3.2 Entrance Swinging and Sliding Doors for Use in Residential Spaces: Swinging and sliding doors used for entrance or exit from residential living units shall be designed to limit air leakage; the air infiltration rate shall not exceed 0.5 ft^3/min per square foot (2.54×10^{-3} m^3/s per square meter) of door area or equivalent air infiltration.

5.5.3.3 Swinging, Revolving or Sliding Doors: Where these types of doors are used they shall be designed to limit air leakage; the air infiltration rate shall not exceed 11 ft^3/min per linear foot (1.70×10^{-2} m^3/s per linear meter) of door crack. If other types of coverings are used for door openings, they shall be designed not to exceed the same air leakage rate.

5.5.4 Caulking and Sealants: Exterior joints in the building envelope that are sources of air leakage such as those around window and door frames, between wall cavities and window or door frames, between wall and foundation, between wall and roof, through wall panels at penetrations or utility services through walls, floors and roofs, shall be caulked, gasketed, weatherstripped, or otherwise sealed.

FIGURE 5.1
Thermal Transmittance of Roof Sections
and Floors over Unconditioned Spaces

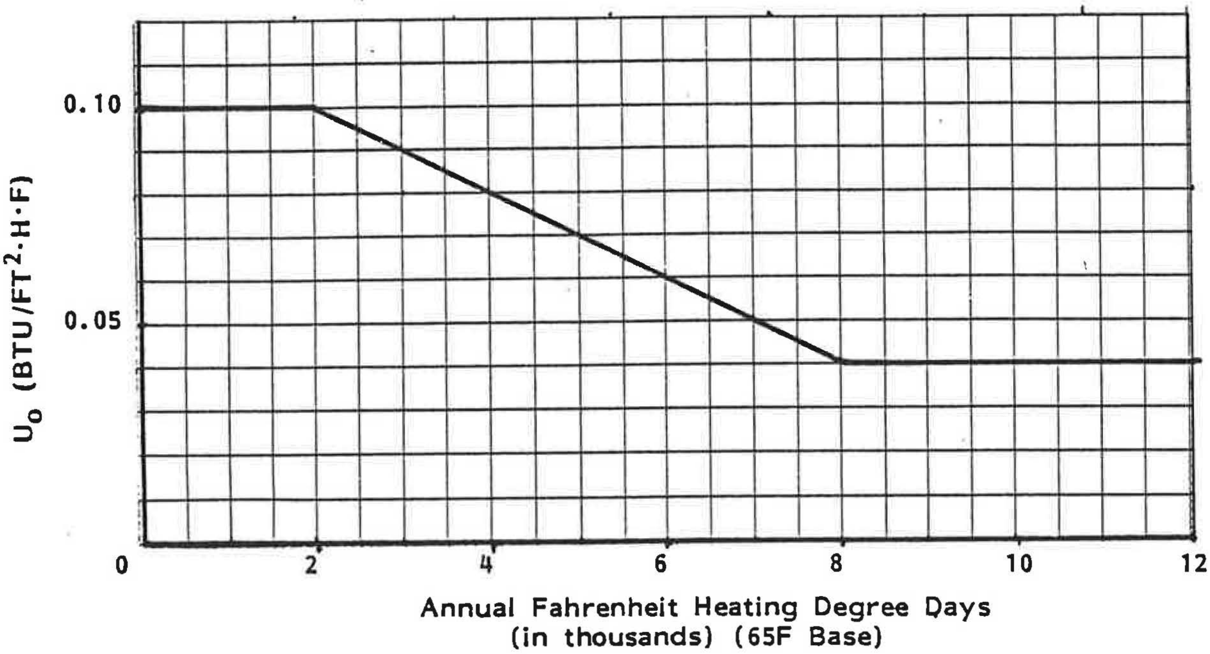


FIGURE 5.2

Thermal Transmittance of Interior Walls
Adjacent to Unconditioned Spaces

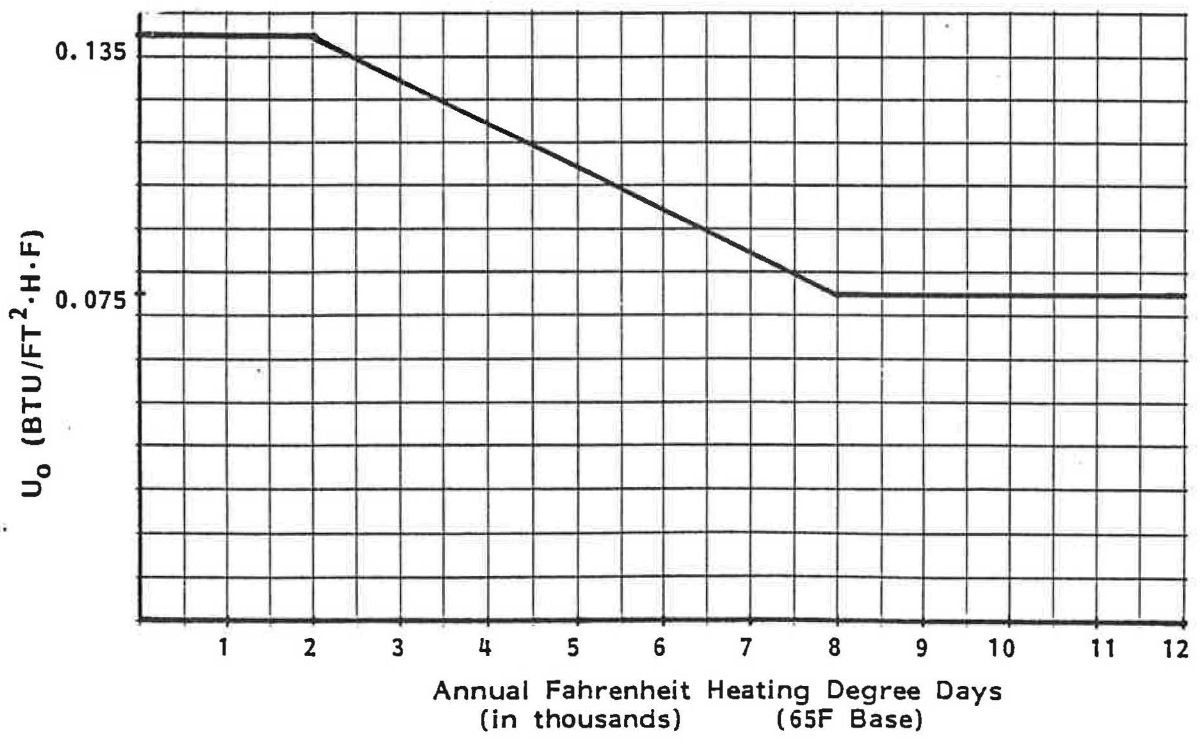
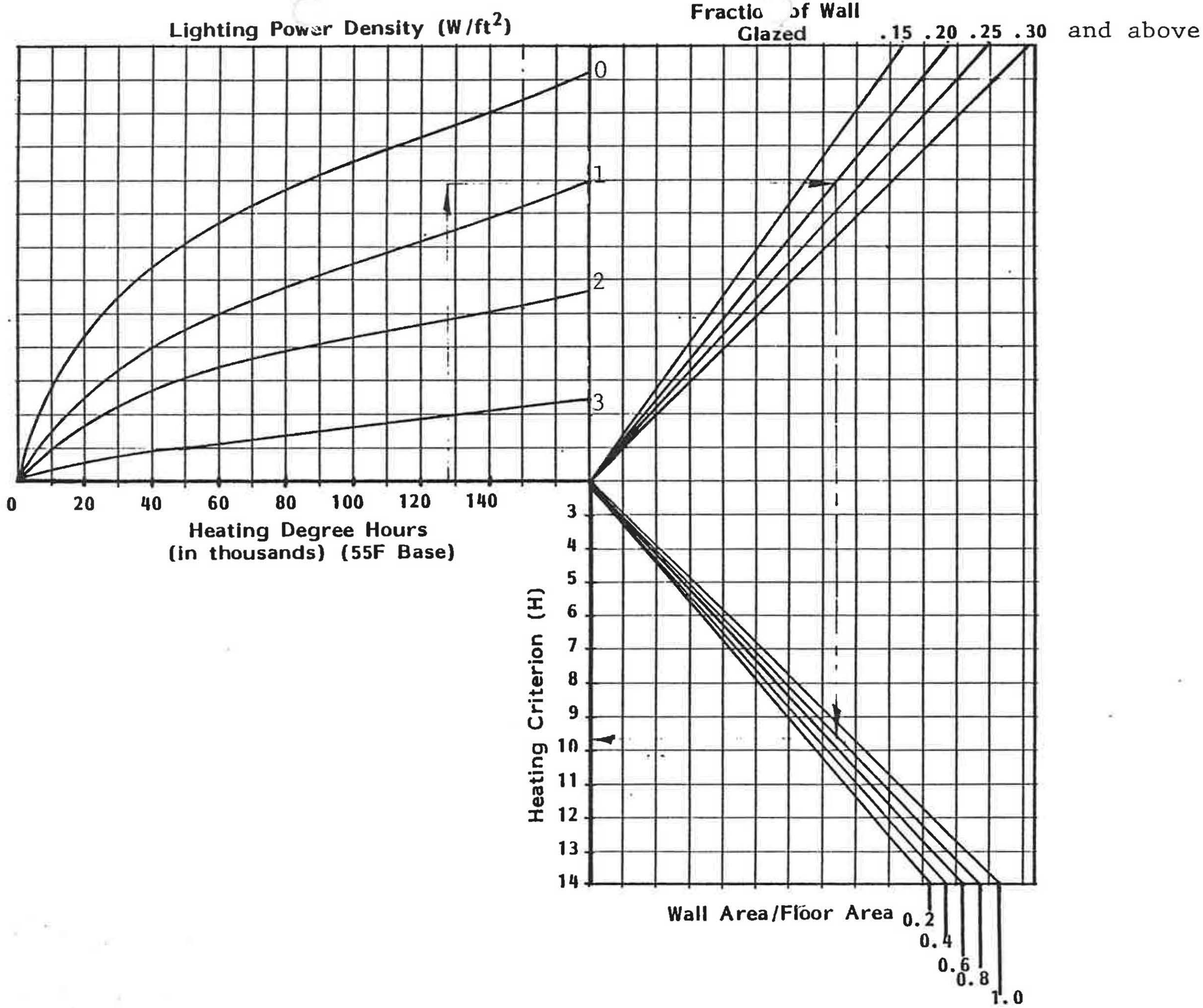


FIGURE 5.3
Wall Heating Criterion



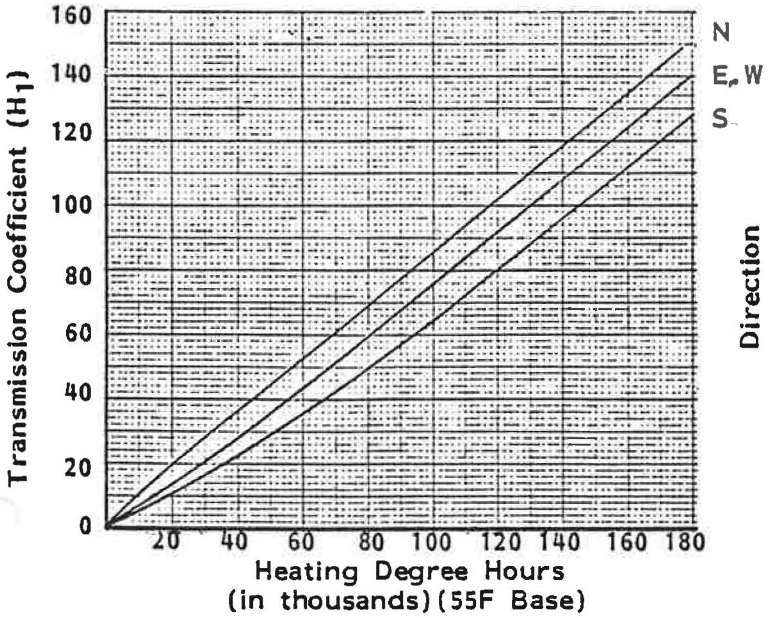


FIGURE 5.4

Coefficients for Determining Compliance with the Wall Heating Criterion

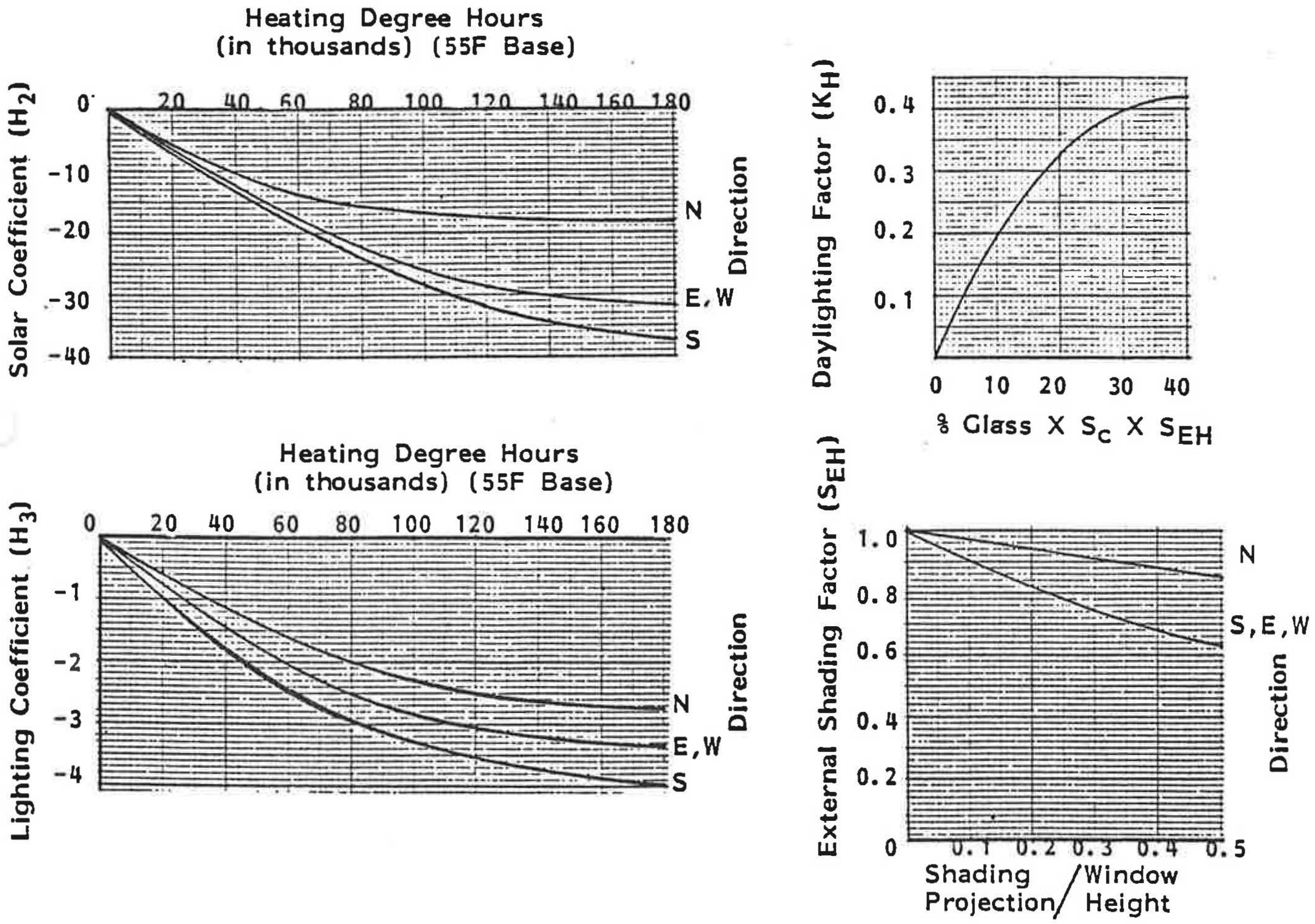


FIGURE 5.5

Mass Factors for Wall Heating (M_{TH})

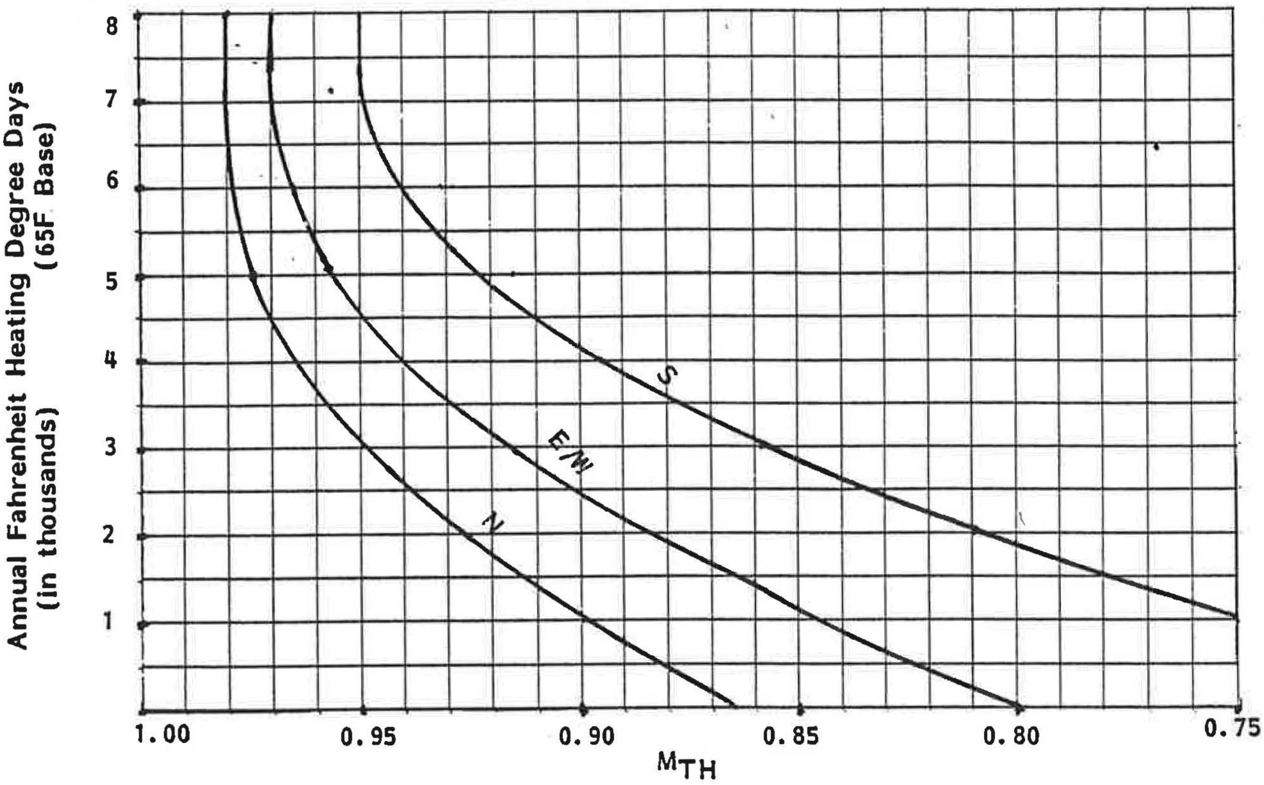


FIGURE 5.6

R Values - Slab on Grade

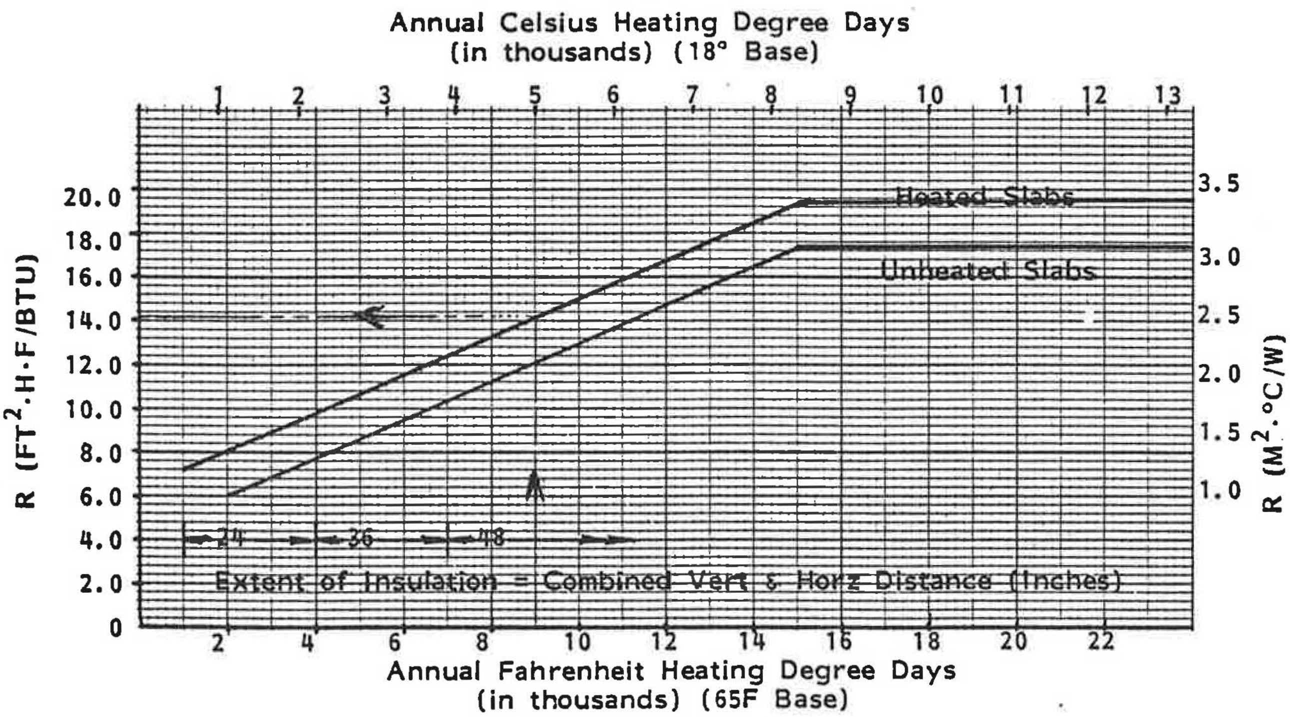
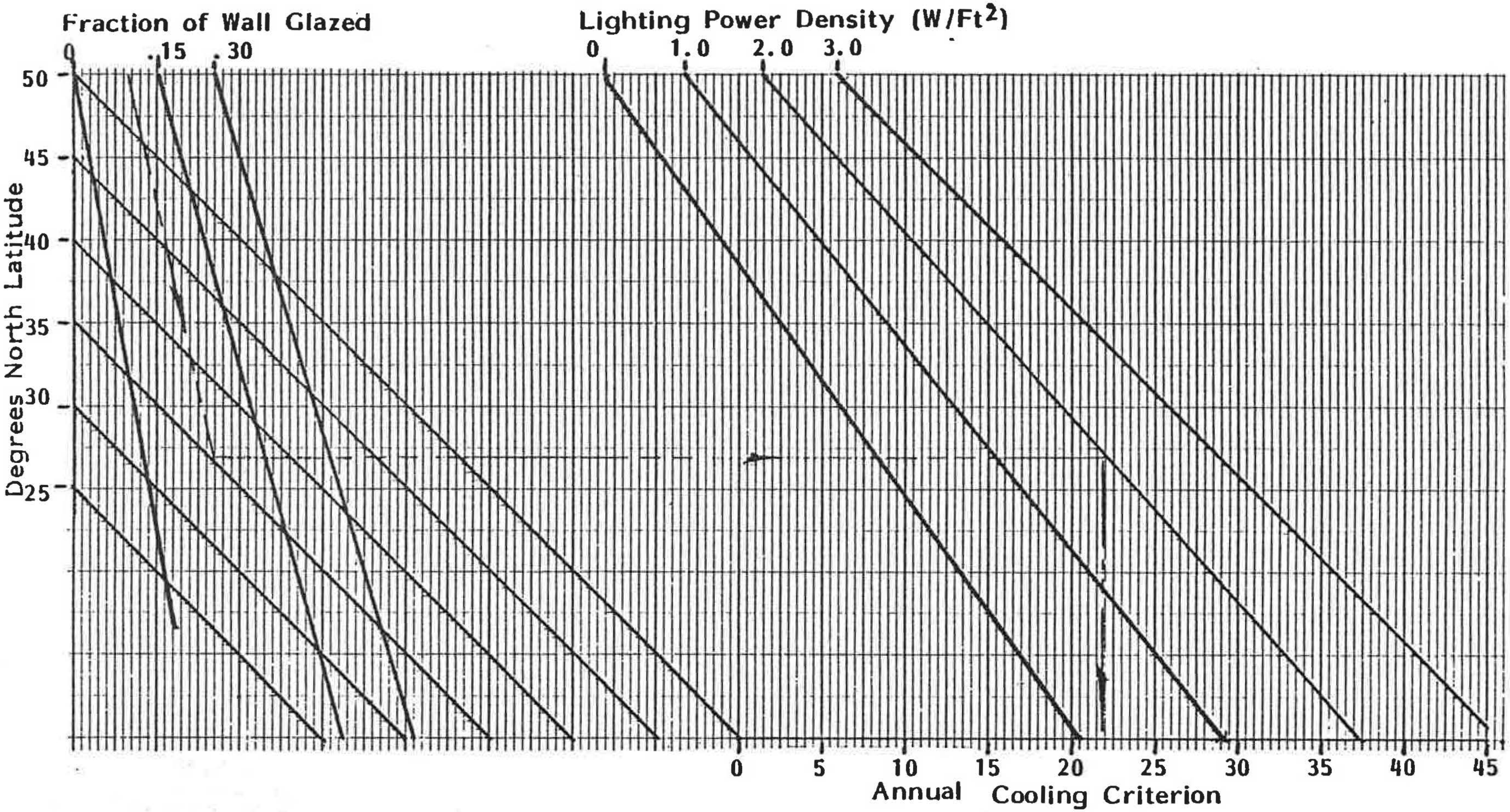


FIGURE 5.7

Wall Annual Cooling Criterion



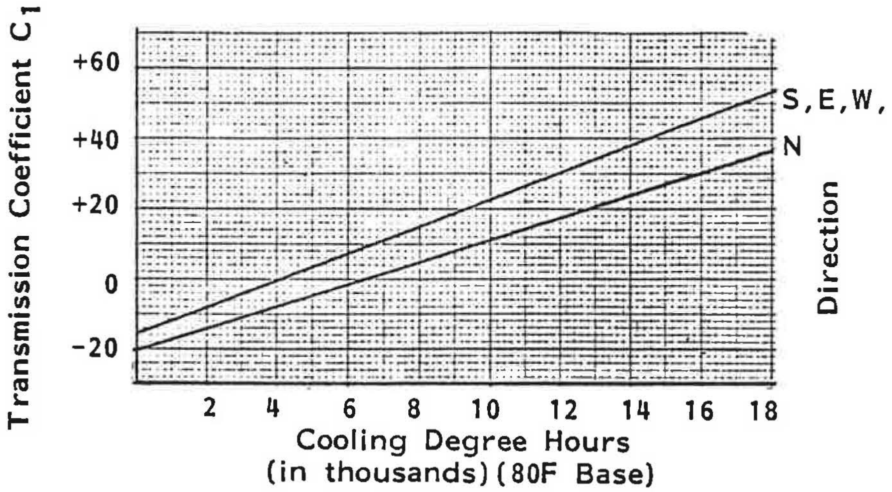
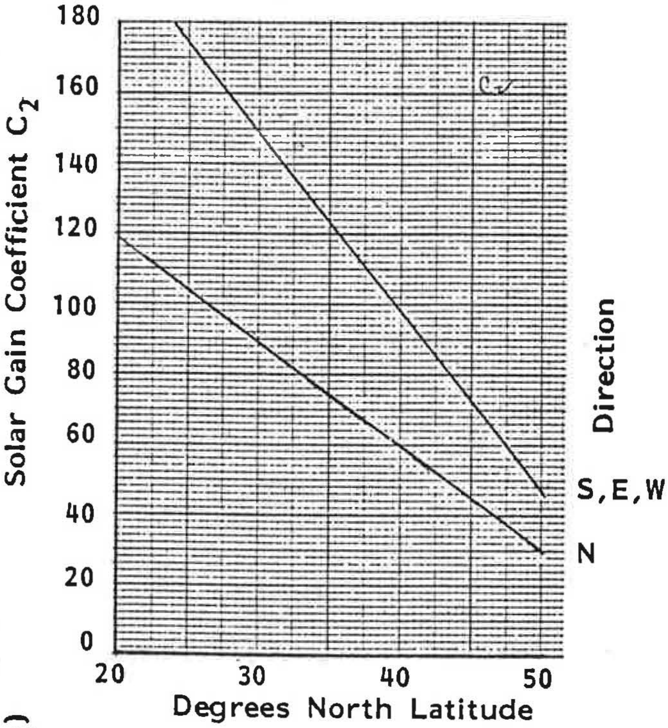
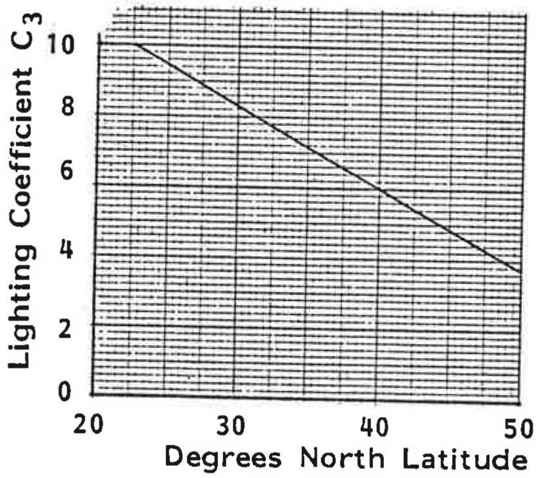
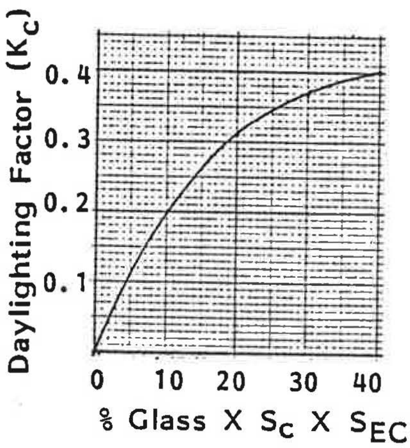


FIGURE 5.8
Coefficients for Determining Compliance with the Wall Annual Cooling Criterion







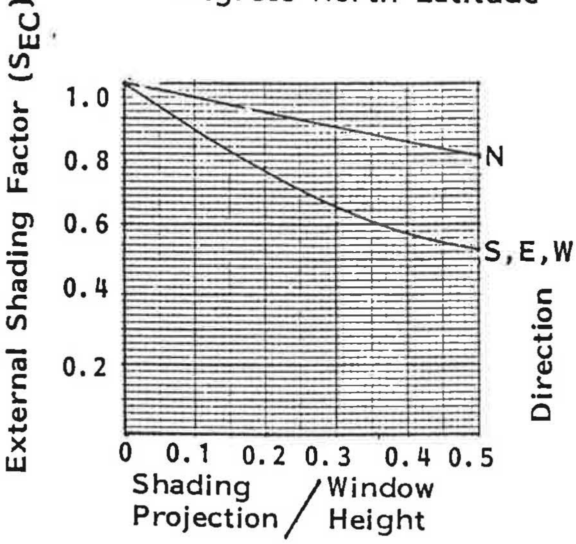


FIGURE 5.9

Mass Factors for Annual Cooling (M_{TC})

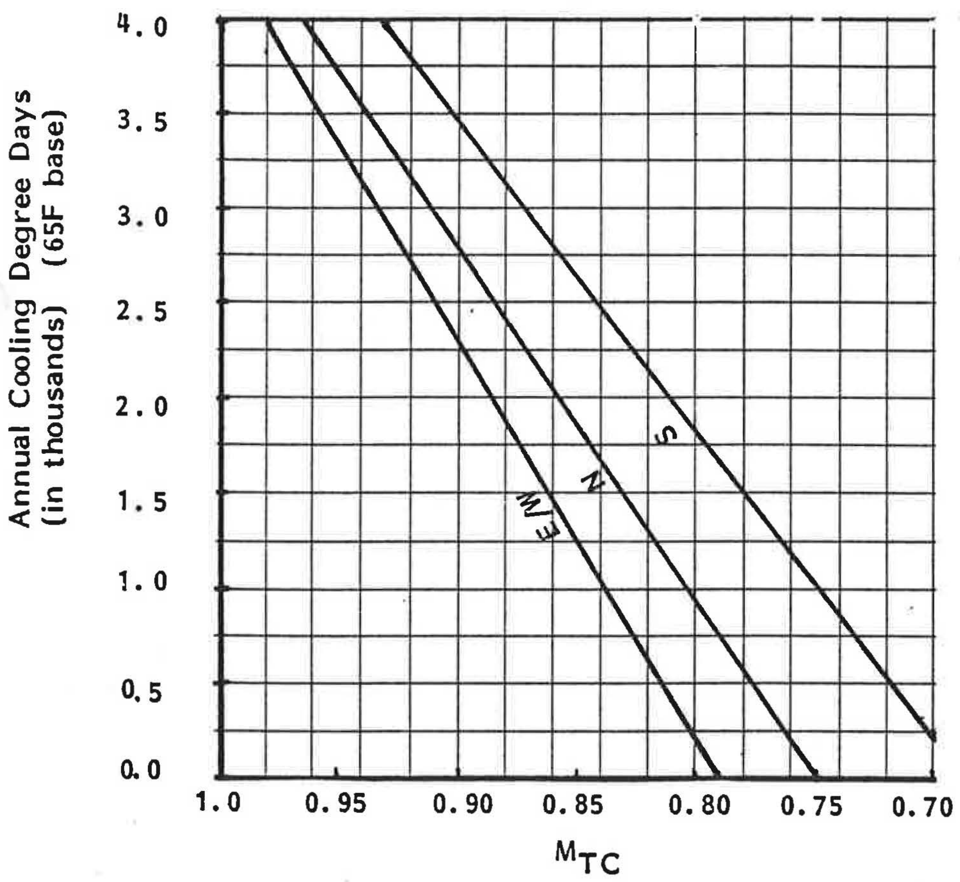
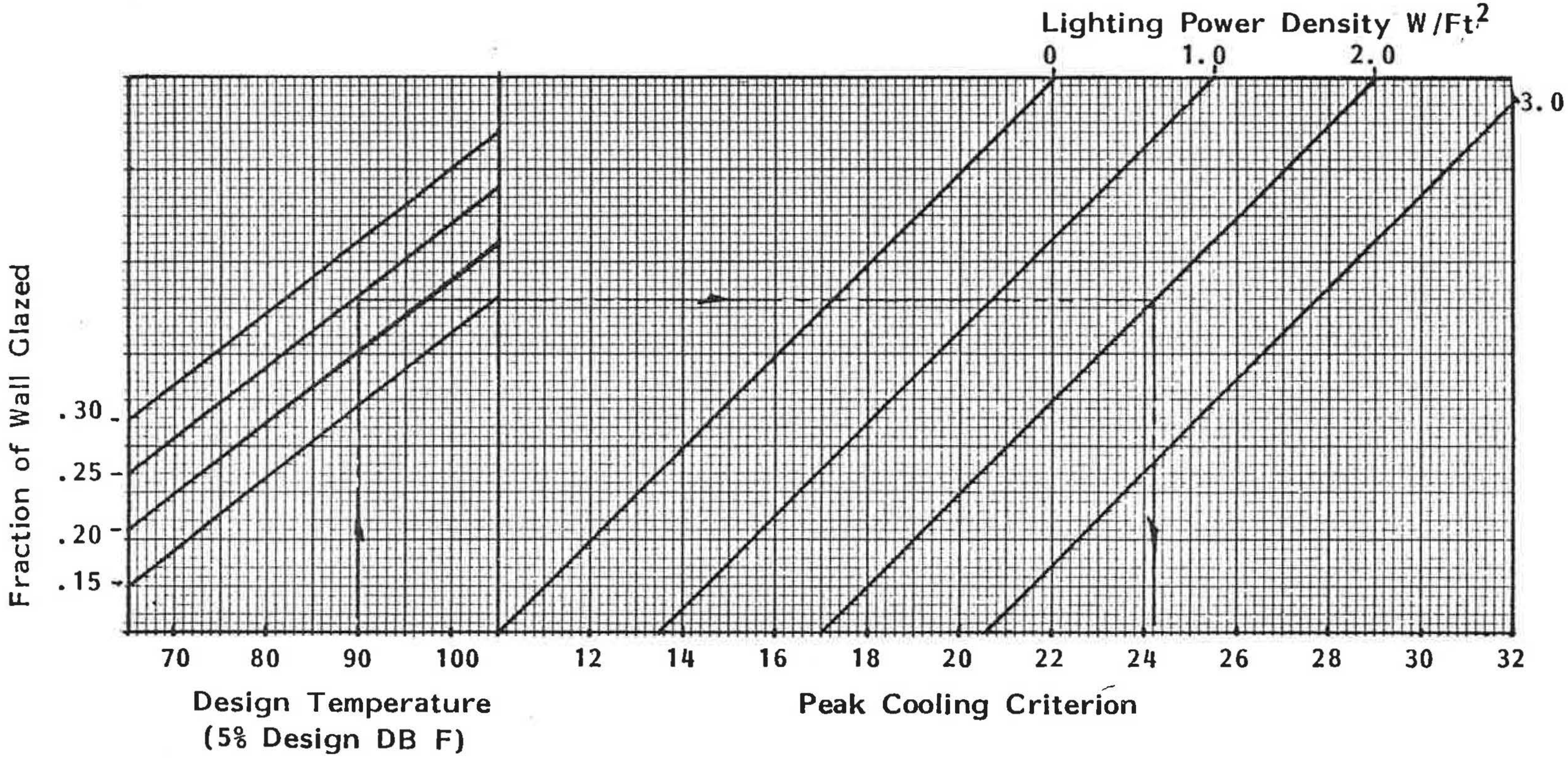


FIGURE 5.10

Peak Cooling Criterion



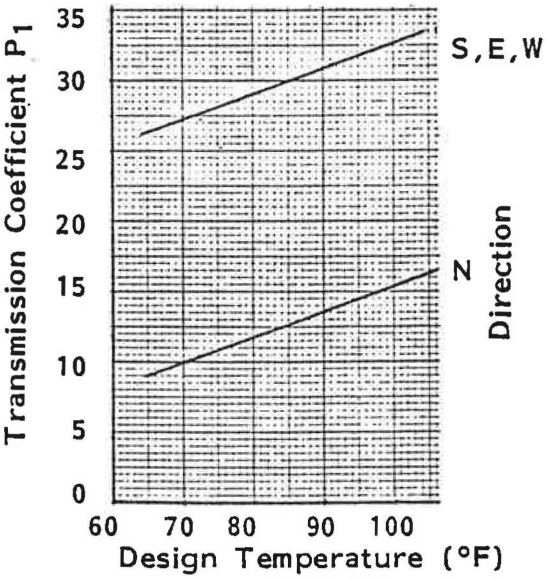
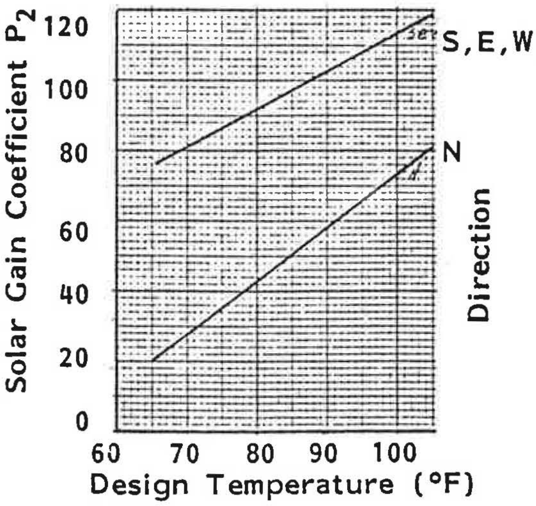
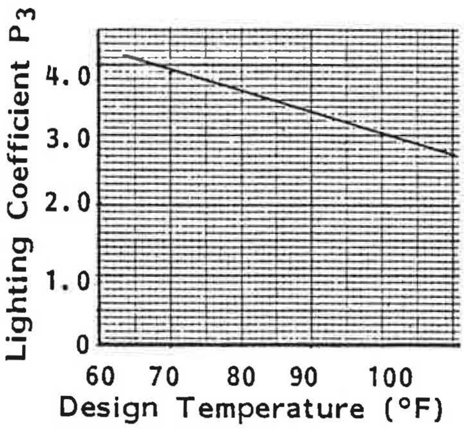
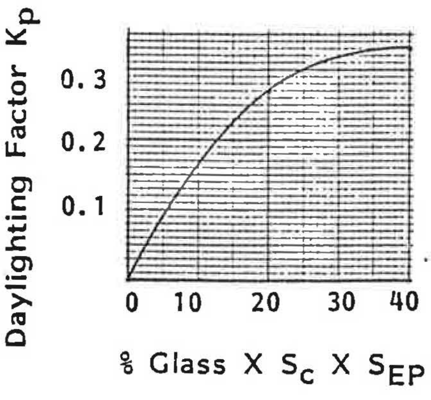


FIGURE 5.11

Coefficients for Determining Compliance with the Peak Cooling Criterion







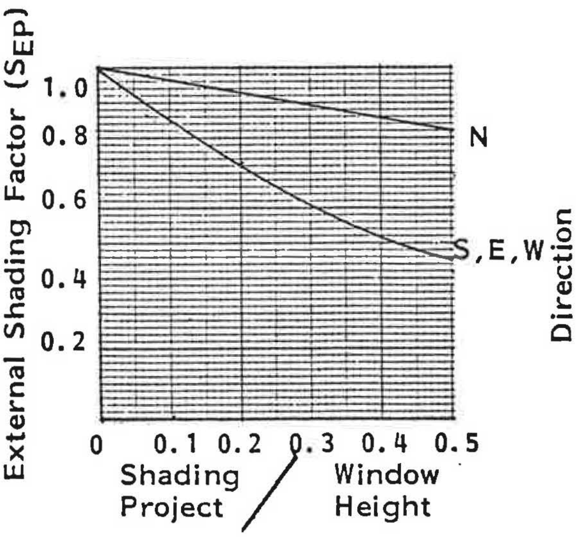
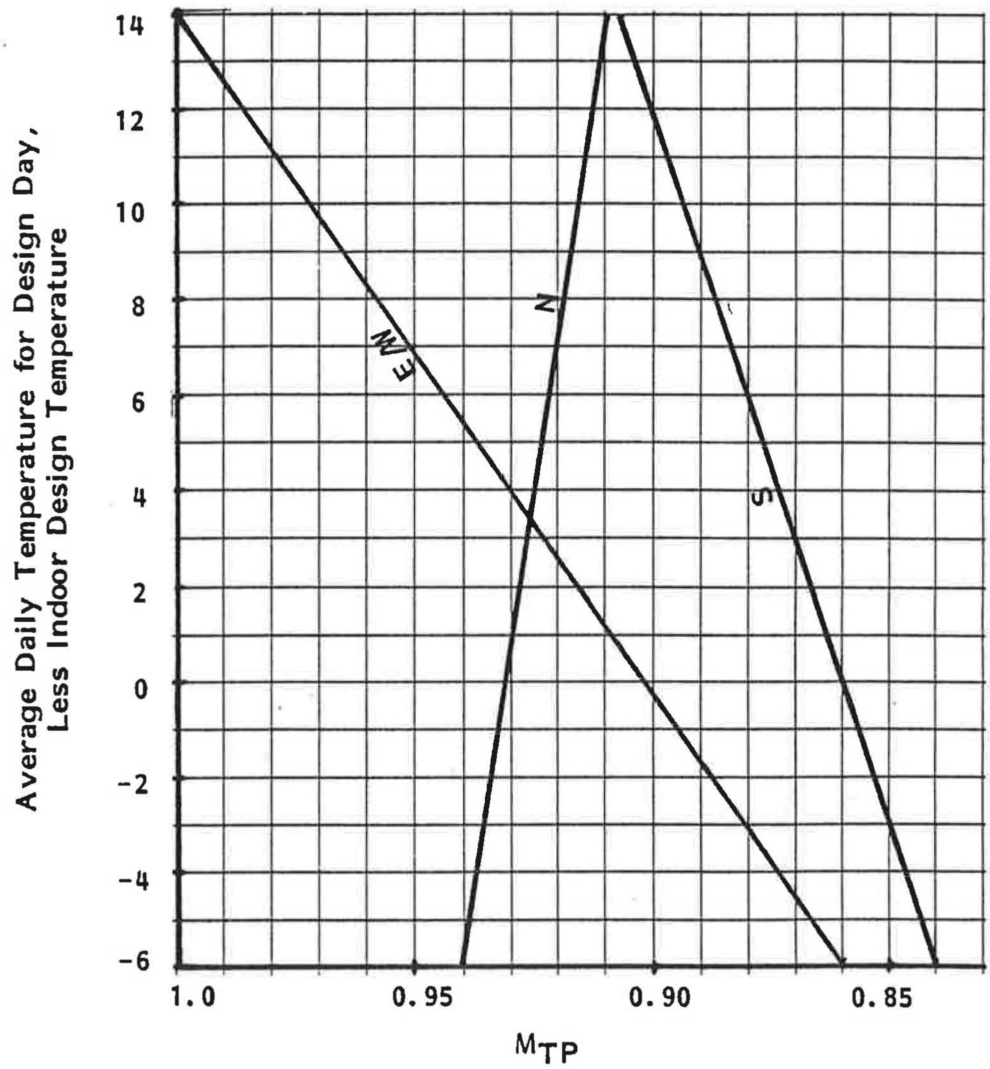


FIGURE 5.12

Mass Factors for Peak Cooling (M_{TP})



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Recommendations for Energy Conservation Standards and Guidelines for New Commercial Buildings

Volume I: Text of the Recommendations

October 1983

Prepared for:
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ATTACHMENT A TO SECTION 5

GUIDELINES FOR USE IN CALCULATING COMPLIANCE VALUES FOR WALLS

The annual wall heating, annual wall cooling and peak wall cooling criteria are specified in Sections 5.3.1.2.1, 5.3.2.1.1, and 5.3.2.1.3 of the Standard respectively. Building compliance is determined based on the building design using Equations 2, 3 and 4 in Section 5 of the Standard. The worksheets provided herein may be used directly for the calculations required by these equations and to document the compliance values for the building.

Worksheet 1 may be used to calculate the annual wall heating compliance value in accordance with Section 5.3.1.2.2 of the Standard.

Worksheet 2 may be used to calculate the annual wall cooling compliance value in accordance with Section 5.3.2.1.2 of the Standard.

Worksheet 3 may be used to calculate the peak wall cooling compliance value in accordance with Section 5.3.2.1.4 of the Standard.

In utilizing these worksheets to calculate the compliance values, it should be noted that much of the same building data will be used in all three worksheets. For this reason, it is recommended that the worksheets be completed concurrently when evaluating a particular building design.

Following the worksheets a brief description of the process necessary to complete the worksheets is presented.

WORKSHEET 1
WALL HEATING COMPLIANCE

Building:______________________ City:______________________
Heating Degree Hours (55F Base):______________ Date:______________________

Conduction	Orientation	(1) Surface Area (ft^2)	(3) Fraction of Total F_c	(4) U_o	(5) H_1 (Fig 5.4)	(6) = (3)(4)(5) Conduction
1						
2						
3						
4						
5						
6						
Total		(2)	1.00			(7)

Solar	Orientation	(8) Window Area (ft^2)	(9) = (8) ÷ (2) Fraction of Total Fs	(10) Shading Coef. Sc	(11) S_{EH} (Fig. 5.4)	(12) H_2 (Fig. 5.4)	(13) = (9)(10)(11)(12) Solar Gain
1							
2							
3							
4							
5							
6							
Total							(14)

Light	Orientation	(1) Surface Area (ft^2)	(3) Fraction of Total F_c	(15) Power Limit w/ft^2 L_p	(16) Fraction Contr R_c	(17) Daylight Factor K_H (Fig.5.4)	(18) = 1-[(17)·(16)] Daylight Modifier $(1-R_c \cdot K_H)$	(19) H_3 (Fig. 5.4)	(20) = (3)(15)(18)(19) Lighting Gain
1									
2									
3									
4									
5									
6									
Total		(2)	1.00						(21)

Orientation	(6) Conduction	(13) Solar Gain	(20) Lighting Gain	(22)=(6)+(13)+(20) Totals	(23) Mass Factor M_{TH} (Fig. 5.5)	(24) = (22)(23) Compliance Value H		Compliance Criterion (Fig. 5.3)
1								
2								
3								
4								
5								
6								
Total						(25)	≤	

Page ____ of ____

WORKSHEET 2
ANNUAL WALL COOLING COMPLIANCE

Building:______________________________ City:______________________________
Cooling Degree Hours (80F Base):______________ Latitude:____________ Date:____________

Conduction	Orientation	(1) Surface Area (ft^2)	(3) Fraction of Total Fc	(4) U_o	(5) C_1 (Fig. 5.8)	(6) = (3)(4)(5) Conduction
1						
2						
3						
4						
5						
6						
Total		(2)	1.00			(7)

Solar	Orientation	(8) Window Area (ft^2)	(9) = (8) ÷ (2) Fraction of Total Fs	(10) Shading Coef. Sc	(11) S_{EC} (Fig. 5.8)	(12) C_2 (Fig. 5.8)	(13) = (9)(10)(11)(12) Solar Gain
1							
2							
3							
4							
5							
6							
Total							(14)

Light	Orientation	(1) Surface Area (ft^2)	(3) Fraction of Total F_c	(15) Power Limit w/ft^2 R_p	(16) Fraction Contr R_c	(17) Daylight Factor K_c (Fig 5.8)	(18) = 1-[(17)·(16)] Daylight Modifier $(1-R_c.K_c)$	(19) C_3 (Fig. 5.8)	(20) = (3)(15)(18)(19) Lighting Gain
1									
2									
3									
4									
5									
6									
Total		(2)	1.00						(21)

Orientation	(6) Conduction	(13) Solar Gain	(20) Lighting Gain	(22)=(6)+(13)+(20) Totals	(23) Mass Factor M_{TC} (Fig. 5.9)	(24) = (22)(23) Compliance Value C_a		Compliance Criterion (Fig. 5.7)
1								
2								
3								
4								
5								
6								
Total						(25)	≤	

WORKSHEET 3
PEAK WALL COOLING COMPLIANCE

Building: ______________________ City: ______________________

Cooling Degree Days (65F Base): ______________ Design Temp: ________ Date: __________

Conduction	Orientation	(1) Surface Area (ft^2)	(3) Fraction of Total Fc	(4) U_o	(5) P_1 (Fig. 5.11)	(6) = (2)(3)(4) Conduction
1						
2						
3						
4						
5						
6						
Total		(2)	1.00			(7)

Solar	Orientation	(8) Window Area (ft^2)	(9) = (8) ÷ (2) Fraction of Total Fs	(10) Shading Coef. Sc	(11) S_{EP} (Fig. 5.11)	(12) P_2 (Fig. 5.11)	(13) = (9)(10)(11)(12) Solar Gain
1							
2							
3							
4							
5							
6							
Total							(14)

Light	Ori en ta tion	(1) Surface Area (ft^2)	(3) Fraction of Total F_c	(15) Power Limit w/ft^2 L_p	(16) Fraction Contr R_c	(17) Daylight Factor K_p (Fig 5.11)	(18) = 1-[(17)·(16)] Daylight Modifier $(1-R_c \cdot K_p)$ (Fig 5.11)	(19) P_3 (Fig. 5.11)	(20) = (3)(15)(18)(19) Lighting Gain
1									
2									
3									
4									
5									
6									
Total		(2)	1.00						(21)

Orien-tation	(6) Conduction	(13) Solar Gain	(20) Lighting Gain	(22) = (6)+(13)+(20) Totals	(23) Mass Factor M_{TP} (Fig. 5.12)	(24) = (22) (23) Compliance Value C_p		Compliance Criterion (Fig. 5.10
1								
2								
3								
4								
5								
6								
Total						(25)	≤	

In reviewing the worksheets, it should be noted that the format, headings, and numerical descriptions for data entry are identical. The only items that change on the worksheets are certain conduction, solar, lighting and mass coefficients which are determined from figures in Section 5 based upon the worksheet being used. To facilitate the use of the worksheets, these guidelines will follow the numerical designations circled on the worksheets.

The data from the building being evaluated is to be entered by component or orientation and the specific component or orientation noted in that column. Throughout the completion of the worksheets, where actual orientation is different than the cardinal values (N, E, S & W), the applicable figure for that data entry shall be interpolated. While each worksheet contains rows for six components, as many components as necessary may be included by using additional copies of each worksheet.

Conduction

(1) The wall surface areas should be entered in column (1) on each worksheet and include the total exterior wall surface area exposed to outdoor air (including glazed surfaces) of each designated component.

(2) The total exterior exposed wall area for the building is determined by summing the surface areas in column (1) for all components and entering the total in (2) on each worksheet.

(3) The area of each component as a fraction of the total exterior wall area (F_C) is determined by dividing the value of the surface area in column (3) for each component by the total wall area in (2) and entering the result on each worksheet. As a check the fraction of total exterior wall area in column (3) should add up to 1.00.

(4) The overall thermal transmittance (U_o) in Btu/ft^2·H·F is calculated for the exposed exterior wall surface area for each component and entered in column (4) on each worksheet by component.

The U_o is determined by the following equation:

$$U_o = \frac{U_1A_1 + U_2A_2 + \ldots.\text{etc.}}{A_o}$$

Where:

U_o = the average thermal transmittance of the wall area for the component

A_o = the gross area of the wall for the component

$U_{1,2}$ = the thermal transmittance of wall assembly 1, 2, etc.

$A_{1,2}$ = the area associated with wall assembly 1, 2, etc.

All wall assembly components shall be included in determining the U_o for each wall component.

(5) The transmission coefficients in column (5) are determined as follows for each listed component:

Annual Wall Heating - H_1 from Figure 5.4 in Section 5 of the Standard based on the orientation of the component and the annual heating degree hours (55F base) for the building location.

Annual Wall Cooling - C_1 from Figure 5.8 in Section 5 of the Standard based on the orientation of the component and the annual cooling degree hours (80F base) for the building location.

Peak Wall Cooling - P_1 from Figure 5.11 in Section 5 of the Standard based on the orientation of the component and the summer design temperature for the building location.

(6) The conduction total for each component in each worksheet is derived by multiplying the data in columns (3), (4) and (5) for each component and entering the result in the corresponding line in column (6).

(7) The conduction total for the building is derived by adding the data in column (6) on each worksheet and entering the result in item (7).

Solar

The components listed in the orientation column for conduction in each worksheet should be entered in the orientation column for solar. This will help ensure all evaluations are performed on the same wall components.

(8) The window area in column (8) should be entered for each component in the same manner in all three worksheets. The window area includes areas of both glazed surface and framing members associated with the glazing.

(9) The fraction of total exterior wall area (F_S) in column (9) is determined for each component by dividing the data entries in column (8) by the total exposed wall surface area in item (2). This will be identical in all three worksheets.

(10) The shading coefficient (S_C) is that applicable for the glazing used in the component being evaluated and is entered by component in column (10). Where a wall component has no glazing, the shading coefficient should be zero. The S_C values by component should be identical in all three worksheets.

(11) The external shading coefficients in column (11) are determined as follows for each listed component.

> Annual Wall Heating - S_{EH} from Figure 5.4 in Section 5 of the Standard based on the orientation of the component and the ratio of horizontal shading projection in feet to the window height in feet.

Annual Wall Cooling - S_{EC} from Figure 5.8 in Section 5 of the Standard based on the orientation of the component and the ratio of horizontal shading projection in feet to the window height in feet.

Peak Wall Cooling - S_{EP} from Figure 5.11 in Section 5 of the Standard based on the orientation of the component and the ratio of horizontal shading projection in feet to the window height in feet.

(12) The solar coefficients in column (12) are determined as follows for each component by orientation:

Annual Wall Heating - H_2 from Figure 5.4 in Section 5 of the Standard based on the orientation of the component and the annual heating degree hours (55F base) for the building location.

Annual Wall Cooling - C_2 from Figure 5.8 in Section 5 of the Standard based on the orientation of the component and the degrees north latitude for the building location.

Peak Wall Cooling - P_2 from Figure 5.11 in Section 5 of the Standard based on the orientation of the component and the summer design temperature for the building location.

(13) The solar total for each compnent in each worksheet is derived by multiplying the data in column (9), (10), (11) and (12) for each component and entering the result in the corresponding line in column (13).

(14) The solar total for the building is derived by adding the data in column (13) on each worksheet and entering the result in item (14).

Lighting

The components listed in the orientation column for conduction and solar in each worksheet should be entered in the orientation column for lighting. This will help ensure all evaluations are performed on the same wall components. Note also that the data from columns (1) and (3) and item (2) in conduction also apply to lighting and should be entered in the lighting portion of each worksheet at this time.

(15) The lighting power limit (L_P in column (15) is the average lighting power for the building interior determined from Section 4.4.1 of the Standard. If the lighting power limits for the activity areas within 15.0 feet of the exterior wall surface of the component are substantially different than the average lighting power limit for the appropriate activity areas may be used as determined from Section 4.3 of the Standard. The values for column (15) should be identical on each worksheet.

(16) The fraction of lamps automatically controlled (R_C) for daylighting relative to all lamps within a 15.0 feet band adjacent to the exterior wall surface is entered in column (16) on each worksheet for each component. If no lamps are so controlled, than R_C is to be set equal to zero.

(17) The daylighting factors in column (17) are determined as follows for each listed component.

Annual Wall Heating - K_H from Figure 5.4 in Section 5 of the Standard per Section 5.3.1.2.3 based on the product of glass shading coefficient (S_C) in column (10), the external shading coefficient (S_{EH}) in column (11) and the percentage of the wall component being considered for Worksheet 1.

Annual Wall Cooling - K_C from Figure 5.8 in Section 5 of the Standard per Sections 5.3.2.1.5 and 5.3.2.1.6 based on the product of glass shading coefficient (S_C) in column (10), the external shading coefficient (S_{EC}) in column (11) and the percentage of the wall component being considered for Worksheet 2.

Peak Wall Cooling - K_P from Figure 5.11 in Section 5 per Sections 5.3.2.1.5 and 5.3.2.1.6 based on the product of glass shading coefficient (S_C) in column (10), the external shading coefficient (S_{EP}) in column (11) and the percentage of the wall component being considered for Worksheet 3.

(18) The daylighting modifier in column (18) is determined for each component on each worksheet as follows:

1.- Column (16) Value X Column (17) Value

Note that if no lamps are automatically controlled in association with the component, then the column (16) value would be zero and the column (18) value for that component would be one.

(19) The lighting coefficients in column (19) are determined as follows for each component by orientation:

Annual Wall Heating - H_3 from Figure 5.4 in Section 5 of the Standard based on the orientation of the component and the annual heating degree hours (55F base) for the building location.

Annual Wall Cooling - C_3 from Figure 5.8 in Section 5 of the Standard based on degrees north latitude for the building location.

Peak Wall Cooling - P_3 from Figure 5.11 in Section 5 of the Standard based on the summer design temperature for the building location.

(20) The lighting total for each component in each worksheet is derived by multiplying the data in columns (3), (15), (18) and (19) for each component and entering the result in the corresponding line in column (20).

(21) The lighting total for the building is derived by adding the data in column (20) on each worksheet and entering the result in item (21).

Building Totals

The determination of the compliance value in item (25) is based in part on the data in columns (6), (13) and (20) on each worksheet. The data for each of these columns on each worksheet should, therefore, be entered in columns (6), (13) and (20) at the bottom of each worksheet.

(22) The total conduction, solar and lighting in column (22) is derived by adding the values for each component from columns (6), (13) and (20) and entering the result in column (22).

(23) The mass factors in column (23) are determined as follows for each component by orientation:

Annual Wall Heating - M_{TH} from Figure 5.5 in Section 5 of the Standard per Section 5.3.1.2.4 based on the orientation of the component and the annual heating degree days (65F base) for the building location.

Annual Wall Cooling - M_{TC} from Figure 5.9 in Section 5 of the Standard per Section 5.3.2.1.7 based on the orientation of the component and the annual cooling degree days (65F base) for the building location.

Peak Wall Cooling - M_{TP} from Figure 5.12 in Section 5 of the Standard per Section 5.3.2.1.7 based on the orientation of the component and the average daily temperature for the design day for the building location less the indoor design temperature.

(24) The component compliance value is derived by multiplying the column (22) and (23) values for each component in each worksheet and entering the result in the appropriate component line of column (24).

(25) The compliance values are determined by adding up column (24) on each worksheet and entering the result in item (25).

For building compliance the item (25) value in each worksheet must be no greater than the compliance criterion determined in accordance with Section 5 of the Standard.

6.0 HEATING, VENTILATING AND AIR-CONDITIONING (HVAC) SYSTEMS

6.1 Scope

This section covers determination of building heating and cooling system design, insulation, duct construction, and control requirements for general comfort applications where normally clothed people are engaged in sedentary or near-sedentary activities.

Exceptions: Portions of the building with special applications, such as but not limited to hospitals, laboratories, thermally sensitive equipment, computer rooms and supermarkets, are exempt from the requirements of this section. Where these special applications are described in the 1982 ASHRAE Handbook, Applications Volume, the criteria described therein should be used.

6.2 General

This section establishes HVAC system requirements for efficient use of energy. System criteria developed from the requirements of this section may influence the type of controls furnished with the equipment selected in accordance with Section 7. The HVAC system(s) selection process shall include an annual energy use evaluation.

6.3 Calculation of Heating and Cooling Loads

6.3.1 Calculation Procedures. Heating and cooling system design loads for the purpose of sizing systems shall be determined in accordance with one of the procedures described in the 1981 ASHRAE Handbook, Fundamentals, Chapters 25 and 26, the 1978 ASHRAE Load Calculation Manual, or an equivalent computation procedure.

6.3.2 System Sizing. HVAC systems shall be sized to meet the calculated space loads, consistent with available equipment capacity, unless it can be shown oversizing will not increase annual energy use. Where heating setback or pickup is to be utilized in the building operation, additional capacity not to exceed 25 percent of the heating system design capacity may be specified.

The procedures in Section 5 of this Standard are used for specifying the thermal design of the exterior envelope. They are not appropriate for the purpose of HVAC system selection and sizing in that other loads (such as ventilation and process loads) have not been included.

6.3.3 Design Parameters. The following design parameters shall be used for system design load calculations for general comfort applications:

6.3.3.1 Outdoor Design Conditions. Winter and summer outdoor design conditions shall be selected for listed locations in Chapter 24 of the 1981 ASHRAE Handbook, Fundamentals, from the columns of 97-1/2 percent values for winter and 2-1/2 percent values for summer. Local weather experience may be used for locations not listed in Chapter 24.

6.3.3.2 Indoor Design Conditions. Although the recommended design points are established below, the system design shall permit operating at minimum energy levels and at comfort conditions consistent with the criteria of ANSI/ASHRAE Standard 55-1981 "Thermal Environmental Conditions for Human Occupancy."

Winter

The maximum heating design space temperature shall be 70 F (21.1°C) dry bulb. If humidification is provided, the system shall be designed to provide a maximum relative humidity of 30 percent in the conditioned space.

Summer

The minimum cooling design space temperature shall be 78 F (25.5°C) dry bulb. The actual design relative humidity within the comfort envelope, as defined in ANSI/ASHRAE Standard 55-1981, shall be selected for minimum total HVAC system energy use.

Where heating systems are not installed, the design minimum space temperature shall be 78 F (25.5°C) dry bulb and where cooling systems are not installed the maximum design space temperature shall be 70 F (21.1°C) dry bulb.

6.3.3.3 Ventilation. For system design and equipment sizing, ventilation air rates shall conform to ASHRAE Standard 62-1981, "Natural and Mechanical Ventilation."

<u>Exceptions</u>: If outdoor air quantities other than those shown in ASHRAE Standard 62-1981 are used or required because of special occupancy or process requirements, source control of air contamination, or conflicting codes, the required outdoor air quantities shall be used as the basis for calculating the heating and/or cooling design loads. In such cases the use of heat recovery shall be evaluated.

6.3.3.4 Infiltration. Infiltration for heating and cooling design loads shall be calculated by the procedures in the 1981 ASHRAE Handbook, Fundamentals. When buildings are operating under a positive pressure, only ventilation air shall be considered in calculating heating and cooling loads.

6.4 System Selection

6.4.1 Variable Air Volume Systems. The use of variable air volume system(s) or their hybrids shall be evaluated when their use will meet system(s) objectives. When considering a single duct shutoff variable air volume system, it is recommended that the heating system be entirely separate and that controls be sequenced to minimize simultaneous heating and cooling in the conditioned space.

Where single or double duct variable air volume systems that employ reheat or mixing for space temperature control are utilized, the cooled air volume shall be designed to be modulated to the minimum air flow (typically 30% of design) consistent with ventilation and air movement requirements before heating energy is utilized to raise the supply air temperature to the conditioned space. The use of recovered energy for reheat or mixing shall be considered.

6.4.2 Simultaneous Heating and Cooling Systems. The use of both heating and cooling simultaneously in order to achieve comfort conditions within a space is inefficient energy utilization. HVAC systems shall be designed to eliminate or minimize simultaneous heating and cooling.

6.4.2.1 Simultaneous heating and cooling by reheating or recooling supply air or by concurrent operation of independent heating and cooling systems serving a common zone shall be restricted as delineated below.

Separate systems, with reduced air flow in the heating mode, shall be considered to serve areas of buildings with substantially different heating/cooling load characteristics (for example, the perimeter space as compared to the interior space).

not more than 3,000 cubic ft/min (1.42 m^3/s) or 10 percent of the total supply air of the system, whichever is less, shall be exempt from the supply air temperature reset requirements of 6.4.2.7 through 6.4.2.9.

6.4.2.7 Concurrent operation of independent heating and cooling systems serving common spaces and requiring the use of new energy for heating or cooling shall use one or both of the following control strategies:

a. Provide sequential temperature control of both heating and cooling in each zone.

b. Limit the heating energy input through automatic reset control of the heating medium temperature (or energy input rate) to only that necessary to offset heat loss due to transmission and infiltration and, where applicable, to heat the ventilation air supply to the space.

6.4.2.8 Reheat System. Systems employing reheat and serving multiple zones, other than those employing variable air volume for temperature control, shall be provided with control that will automatically reset the system cold air supply to the highest temperature level that will satisfy the zone requiring the coolest air.

6.4.2.9 Recooling Systems. Systems in which heated air is recooled, directly or indirectly, to

6.4.2.2 If energy is used for reheating to control temperatures or humidity, recovered energy should be used. In this case, recovered energy is defined as the net energy used for the purpose of heating or cooling.

6.4.2.3 New energy may be used, when necessary, to prevent relative humidity from rising above 60 percent for comfort control or to prevent condensation on terminal units or outlets.

6.4.2.4 New energy may be used for control of temperature if minimized as delineated in 6.4.2.5 through 6.4.2.9.

6.4.2.5 Mixing Systems (Dual Duct and Multi-Zone Systems). These systems, other than those employing variable air volume for temperature control, shall be provided with control that will automatically reset (a) the cold deck air supply to the highest temperature that will satisfy the zone requiring the coolest air and (b) the hot deck air supply to the lowest temperature that will satisfy the zone requiring the warmest air.

6.4.2.6 For systems with multiple zones, one or more zones may be chosen to represent a number of zones with similar heating/cooling characteristics. A multiple zone system that employs reheating or recooling for control of maintain space temperature shall be provided with control that will automatically reset the temperature to which the supply air is heated to the lowest level that will satisfy the zone requiring the warmest air.

6.4.3 Fan Coil Systems. Perimeter heating-only systems employing fan coils shall be controlled by temperature reset to minimize overheating. Zoning, and control by exposure of perimeter fan coil systems shall be evaluated.

6.4.3.1 The use of heat recovery shall be evaluated whenever fan coil perimeter heating systems are utilized with interior zone cooling systems.

6.4.4 Radiation Systems

6.4.4.1 Zoning. Where perimeter radiation heating systems are utilized, zoning and temperature reset control by exposure shall be evaluated.

6.4.4.2 Control. Where perimeter radiation heating systems are utilized, control from the conditioned space temperature shall be evaluated. The radiation system control shall be separate from the cooling system control and sequenced to minimize simultaneous heating and cooling.

6.5 System Controls

6.5.1 Temperature Control. Each system shall be provided with at least one thermostat for the regulation of temperature. Each thermostat shall be capable of being set by adjustment or selection of sensors for at least the following ranges:

a. Where used to control confort heating only: 55 to 75 F (12.8 to 23.9°C).

b. Where used to control comfort cooling only: 70 to 85 F (21.1 to 29.4°C).

c. Where used to control both comfort heating and cooling, it shall be capable of being set from at least 55 to 85 F (12.8 to 29.4°C) and shall be capable of operating the system heating and cooling in sequence. The thermostat and/or control system shall have an adjustable deadband of at least 10 F (5.6°C) except as allowed in 6.4.2.7b. Deadband is defined as the temperature range in which no heating or cooling energy is used.

6.5.1.1 Zoning for Temperature Control. At least one thermostat for regulation of space temperature shall be provided for:

a. Each separate system.

b. Each separate zone as defined in Section 3. A readily accessible manual or automatic means shall be provided to restrict or shut off the heating and/or cooling input to each zone or floor of a building when all zones or floors are not occupied.

6.5.1.2 Control Setback and Shutoff. Night setback or shutoff capability shall be evaluated and provided on all buildings where its use will reduce building energy consumption.

Each system shall be equipped with an accessible means of shutting off or reducing the energy used during periods of non-use or alternate uses of the building spaces or zones served by the system. The following are examples that meet this requirement:

a. Manually adjustable automatic timing devices

b. Manual devices for use by operating personnel

c. Automatic control systems

6.5.2 Humidity Control. If a system is equipped with a means for adding moisture to maintain specific selected relative humidities in spaces or zones, a humidistat shall be provided. This device shall be capable of being set to prevent new energy from being used to produce space relative humidity above 30 percent. Where a humidistat is used in a system for controlled moisture removal to maintain specific selected relative humidities in spaces or zones, it shall be capable of being set to prevent new energy from being used to produce a space relative humidity below 60 percent.

6.6 Cooling with Outdoor Air

6.6.1 Economizer Cycle. Each fan system shall be designed to automatically use up to and including 100 percent of the fan system capacity for cooling with outdoor air. Activation of the economizer cycle shall be controlled by sensing outdoor air enthalpy and return air enthalpy jointly or outdoor air dry-bulb temperature alone to accomplish the above. Alternatively, outdoor air dry-bulb temperature and return air wet-bulb temperature may be sensed.

<u>Exceptions</u>: Cooling with outdoor air is not required under any of the following conditions:

a. The fan system capacity is less than 3,000 cubic ft/min (1.42 m^3/s) or total cooling capacity is less than 80,400 Btu/h (23.6 kW).

b. The quality of the outdoor air, as defined in ASHRAE Standard 62-1981, is so poor as to require extensive treatment.

c. The need for humidification and/or dehumidification requires the use of more energy than is conserved by outdoor air cooling on an annual basis.

d. The use of outdoor air cooling may affect the operation of other systems (such as return or exhaust air fans, supermarket refrigeration, or heating in single fan dual duct or multi-zone systems) so as to increase the overall energy consumption of the building.

e. When energy recovered from an internal/external zone heat recovery system exceeds the energy conserved by outdoor air cooling on an annual basis.

f. The Annual Fahrenheit Heating Degree Days are less than 1,200 (670 Celsius Degree Days).

g. An Outdoor Summer Wet Bulb Design Condition (2-1/2 percent occurrence ASHRAE Handbook, Fundamentals Chapter 24 of more than 72 F (22.2°C) and Annual Fahrenheit Heating Degree Days less than 2000 (1110 Celsius Degree Days).

h. When space cooling is accomplished by a circulating liquid that transfers space heat directly or indirectly to a heat rejection device such as a cooling tower without the use of a refrigeration system.

i. When the use of 100 percent outside air will cause coil frosting, controls may be added to reduce the quantity of outside air. However, the intent of this exception is to use 100 percent air in lieu of mechanical cooling when less energy usage will result. This exception applies only to direct expansion systems when the compressor(s) is running.

j. When the total design sensible cooling load is less than 5.1 Btu/h·ft^2 (16.2 w/m^2) of conditioned floor area.

6.6.2 Natural Ventilation. Consideration should be given to providing for natural ventilation to supplement or replace economizer cycle operation.

6.7 Energy Recovery

An evaluation shall be made of the possible use of energy recovery systems that conserve energy (the amount expended must be less than the amount recovered). Typical applications that should be analyzed include but are not limited to the use of exhaust air to intake air heat exchangers for pre-heating outdoor ventilation air, the use of desuperheaters for heating domestic hot water, the use of boiler economizers for preheating make-up air or water and the use of double-bundle condensers for building comfort or domestic hot water heating applications. In the evaluation, sources of recoverable energy, such as coincident heating-cooling aplications (with or without storage), and system operating hours shall be considered.

6.7.1 In water chilling applications heat recovery chillers (double-bundle condenser) shall be evaluated. The evaluation shall consider the use of multiple machines. This will permit sizing one or more heat recovery machines for base loading to closely match system heating requirements with minimum increase in system cost. Additional water chilling machines may then be cooling only machines at higher efficiency for peak cooling load operation.

6.8 Mechanical Ventilation

Each mechanical ventilation system (supply and/or exhaust) shall be equipped with a readily accessible switch or other means for volume reduction and/or shut off. Automatic or gravity dampers that positively close when the system is not operating shall be provided for outdoor air intakes and exhausts.

Dampers shall be designed with tight shut-off characteristics to minimize air leakage.

Exceptions:

a. Manual dampers for outdoor air intakes may be used when the fan system capacity is less than 3000 cubic ft/min (1.42 m^3).

b. Dampers are not required when ventilation airflow is less than 100 cubic ft/min (0.047 m^3/s).

6.9 Transport Energy

6.9.1 All-Air Systems. The air transport factor (ATF) for each all-air constant volume system with fan motors rated one horsepower or more shall not be less than the values shown below. Condition A is for constant volume systems where life/safety codes require a fully ducted return and the system is not excepted by 6.1. Condition B is for all other constant volume systems. The minimum air transport factor for variable air volume systems shall not be less than 75 percent of the values shown below:

	Largest Fan Motor in System, HP		
	1 - 10	Over 10 - 25	Over 25
Condition A	8.5	7.0	5.5
Condition B	10.0	8.5	7.0

The factor shall be based on design system air flow. Energy for transfer of air through heat recovery devices shall not be included in determining the factor; however, such energy shall be included in the evaluation of the effectiveness of the heat recovery system.

$$\text{Air Transport Factor} = \frac{\text{Space Sensible Heat Removel}^{*}}{(\text{Supply + Return Fan(s) Power Input})^{*}}$$

*Both expressed in either Btu/h or watts.

Where:

Space Sensible Heat Removal = the design sensible cooling load used to calculate design system air flow of all spaces to which the system provides cooling.

Fan Power Input = the rate of energy delivered to the fan prime mover at design system air flow.

Exception: HVAC system equipment that includes supply and/or return or exhaust air fans in the EER (COP) listed in Section 7.

6.9.2 Other Systems. Air and water, all water and unitary systems employing chilled, hot, dual temperature or condenser water transport systems to space terminals shall not require greater transport energy (including central and terminal fan power and pump power) than an equivalent all-air system providing the same space sensible heat removal and having an air transport factor not less than that shown in 6.9.1, Condition B.

6.9.3 In buildings with multiple systems or in systems where multiple buildings are served from a central plant, consideration shall be given to reducing transport energy by utilizing high temperature drops for chilled water, primary/secondary pumping loops, variable volume pumping, variable speed pumping and design of pipe systems that are inherently well balanced.

6.9.4 In buildings with all air heating/cooling constant air volume systems, design consideration shall be given to permit reducing system air quantities during the heating mode when life/safety codes and ventilation requirements allow.

6.10 Piping Insulation

All piping installed to serve buildings and within buildings shall be thermally insulated in accordance with Table 6.1. (For service water heating systems see Section 8.)

Exceptions: Piping insulation is not required in any of the following cases:

a. Piping installed within HVAC equipment

b. Piping at fluid temperatures between 55 to 100 F (12.8 and 37.8°C)

c. When the heat loss and/or heat gain of the piping, without insulation, does not increase the energy requirements of the building.

6.10.1 Other Insulation Thicknesses. Insulation thicknesses in Table 6.1 are based on insulation having thermal resistivity in the range of 4.0 to 4.6 $ft^2 \cdot h \cdot F/Btu \cdot in$ (0.028 to 0.032 $m^2 \cdot °C/W \cdot mm$) on a flat surface at a mean temperature of 75°F (23.9°C). Minimum insulation thickness shall be increased for materials having R values less than 4.0 $ft^2 \cdot h \cdot F/Btu \cdot in$ (0.028 $m^2 \cdot °C/W \cdot mm$) or may be reduced for materials having R values greater than 4.6 $ft^2 \cdot h \cdot F/Btu \cdot in$ (0.032 $m^2 \cdot °C/W \cdot mm$).

a. For materials with thermal resistivity greater than 4.6 $ft^2 \cdot h \cdot F/Btu \cdot in$ (0.032 $m^2 \cdot °C/W \cdot mm$) the minimum thickness may be reduced as follows:

In Conventional Units:

$$\frac{4.6 \times \text{Table 6.1 Thickness}}{\text{Actual R}} = \text{New Minimum Thickness}$$

In SI Units:

$$\frac{0.032 \times \text{Table 6.1 Thickness}}{\text{Actual R}} = \text{New Minimum Thickness}$$

b. For materials with thermal resistivity less than 4.0 $ft^2 \cdot h \cdot F/Btu \cdot in$ (0.028 $m^2 \cdot °C/W \cdot mm$), the minimum insulation thickness shall be increased as follows:

In Conventional Units:

$$\frac{4.0 \times \text{Table 6.1 Thickness}}{\text{Actual R}} = \text{New Minimum Thickness}$$

In SI Units:

$$\frac{0.028 \times \text{Table 6.1 Thickness}}{\text{Actual R}} = \text{New Minimum Thickness}$$

6.10.2 The required minimum thicknesses do not consider condensation. Additional insulation with vapor barriers may be required to prevent condensation under some conditions.

TABLE 6.1
MINIMUM PIPE INSULATION

Piping System Types	Fluid Temperature Range		INSULATION THICKNESS FOR PIPE SIZES*					
			Runouts 2"**	1" and Less	1-1/4-2"	2-1/2-4"	5 & 6"	8" and Larger
	F	°C	in.	in.	in.	in.	in.	in.
Heating Systems Steam & Hot Water								
High Pressure/Temp	351-450	177.2-232.2	2.0	3.0	4.0	4.0	4.0	4.5
Medium Pressure/Temp	251-350	121.7-176.7	2.0	2.5	3.0	4.0	4.0	4.0
Low Pressure/Temp	151-250	66.1-121.1	1.5	2.0	2.5	3.0	3.5	3.5
Low Temperature	100-150	37.8-65.6	1.0	1.0	1.5	2.0	2.0	2.5
Steam Condensate (for Feed Water)	Any	Any	1.5	1.0	1.5	2.0	2.0	2.5
Cooling Systems								
Chilled Water,	40-55	4.4-12.8	0.5	0.5	0.75	1.0	1.0	1.0
Refrigerant, or Brine	Below 40	Below 4.4	1.0	1.0	1.5	1.5	1.5	1.5

*See 6.10.1 and 6.10.2 (Pipe sizes are nominal dimensions.) For piping exposed to ambient temperatures of 65 F or less, increase thickness by 0.5 in.

**Runouts to Individual Terminal Units (not exceeding 12 ft. in length).

6.11 Air Handling Duct System Insulation

All ducts, plenums and enclosures installed to serve buildings and within buildings shall be thermally insulated as follows:

$$R = \frac{\Delta t}{15}\ ft^2 \cdot h \cdot F/Btu \qquad \left(\frac{\Delta t}{47.3}\ m^2 \cdot {}^\circ C/W\right)$$

Where:

Δt = the design temperature differential between the air in the duct and the duct surface in F (°C)

R = thermal resistance of the insulating material excluding film resistances.

For buildings with uninsulated roofs over attics containing ducts the air temperatures shown in Table 6.2 shall be used.

TABLE 6.2
ATTIC TEMPERATURES

Summer Conditions		
Roof Pitch	F	°C
5 in 12 and up	130	54.4
3 in 12 to 5 in 12	140	60.0
Less than 3 in 12	150	65.6
Winter Conditions		
Roof Pitch	F	°C
All	10° Above Outdoor Design	5.6° Above Outdoor Design

Exceptions: Duct insulation is not required in any of the following cases:

a. Where Δt is 25 F (-3.9°C) or less

b. When the heat gain or loss of the ducts, without insulation, will not increase the energy requirements of the building

c. Within HVAC equipment

d. Exhaust air ducts

6.11.2 The required thermal resistances do not consider condensation. Additional insulation with vapor barriers may be required to prevent condensation under some conditions.

6.12 Duct Construction

All duct work shall be constructed and erected in accordance with the following SMACNA standards:

a. Heating and Air Conditioning Systems Installation Standards, 3rd Edition, February 1977

b. Low Pressure Duct Construction Standards, 5th Edition, 1976

c. High Pressure Duct Construction Standards, 3rd Edition, 1975

d. Fibrous Glass Duct Construction Standards, 5th Edition, 1979

6.12.1 High-pressure and medium-pressure ducts shall be leak tested and shall not exceed the maximum rate specified in the applicable SMACNA Standard. .

6.12.1 When low pressure supply air ducts are located outside of the conditioned space (except return air plenums), all transverse joints shall be sealed using mastic tape or mastic plus tape. For fibrous glass ductwork, pressure sensitive tape is acceptable.

6.13 Balancing

The system design shall provide for balancing the air and water systems. This shall include, but not be limited to dampers, temperature and pressure test connections and balancing valves. Air system balance shall be accomplished in a manner to minimize balancing losses and then fan speed shall be adjusted to meet design conditions. Water system balance shall be accomplished in a manner to minimize balancing losses and then consideration shall be given to trimming the pump impeller to reach design conditions.

7.0 HEATING, VENTILATING AND AIR-CONDITIONING (HVAC) EQUIPMENT

7.1 Scope

This section covers HVAC system equipment and system component performance requirements for general comfort applications. Excluded is refrigerating equipment not used to heat, ventilate or air-condition buildings for human comfort.

7.1.2 HVAC Systems. For the purposes of this section, "HVAC Systems" (defined in Section 3) are considered to be of three basic types:

a. Central Air-Distribution Systems. In this type, either HVAC System Equipment (7.1.2.1), or an engineered and field-assembled combination of HVAC System Components (7.1.2.2), that receive recirculated room air (plus outside air as required) from a central duct system, perform the required heating, ventilating or air-conditioning functions, and deliver the conditioned air to the central duct system, for final delivery to the conditioned space(s) of the building.

b. Central Circulating Water Systems. In this type, a centrifugal, or reciprocating, compression refrigeration or absorption refrigeration type water-chilling package provides chilled water to a central piping system; either a fossil-fuel-fired or electric boiler, or central heat exchanger, provides heated water to the central piping system; and the piping system supplies heated or cooled water, as required, to water-air heat exchangers (terminal units) serving the conditioned space(s) of the building. The water chilling package, including its heat-rejecting element; the boiler; the central heat exchanger; and the terminal units are considered to be HVAC System Components.

c. Multiple Unit Systems. In this type, a number of units of HVAC Equipment, each receiving a supply of electric and/or fossil fuel energy, or in some cases steam or hot water from a central source, each performs the functions of heating and/or cooling air for distribution to a conditioned space or zone of the building.

7.1.2.1 HVAC System Equipment. HVAC System Equipment (7.3, 7.5, 7.6, 7.7, 7.8) provides, in one (single-package) or more (split system) factory-assembled packages, means for air-circulation, air-cleaning, air-cooling with controlled temperature, and dehumidification; and optionally either alone or in combination with a heating plant, the functions of heating and humidifying. The cooling function may be either electrically- or heat-operated, and the refrigerant condenser may be air-, water-, or evaporatively-cooled. Where the equipment is provided in more than one package, the separate packages shall be designed by the manufacturer to be used together. The equipment may provide the heating function as a heat pump, or by the use of electric or fossil-fuel-fired elements.

In the case of heat-operated unitary air-conditioners, established practice is for the efficiency or COP published by the manufacturer to be based only on the on-site heat-energy supplied to the unit. In this case, the system designer must add the electrical energy furnished to the unit, and to any auxiliaries or accessories, in establishing HVAC system efficiency. See also 7.5.1.

7.1.2.2 HVAC System Components. HVAC System Components (7.4, 7.6, 7.7) provide, in one or more factory-assembled packages, means for chilling and/or heating water, with controlled temperature, for delivery to terminal units serving the conditioned spaces of the building.

One type of HVAC system component is the water chilling package. The chiller may be of the centrifugal, rotary or reciprocating, electrically-driven type, or heat-operated type. In air-cooled packages, the fan-motor(s) energy is included by the manufacturer in determining the EER (COP) of the package. In water-cooled or evaporatively-cooled types, if a cooling tower or evaporative condenser is included in the package, the circulating pump motor(s) are also taken into account by the manufacturer in determining the EER (COP).

In the heat-operated types, pumps included in the package for circulating fluids in the refrigeration cycle, are not included in determining the EER (COP) of the component. Chilled water pumps circulating chilled water through the piping systems external to the package, and cooling tower pumps and fans circulating water or air through the condenser and cooling tower also are not included in the EER (COP) published by the manufacturer for the component, but their on-site energy input, as well as that for internal refrigerant circulating pumps, must be taken into account by the system designer in computing the system EER (COP) and annual energy consumption of the HVAC system.

A second type of HVAC System Component is the reciprocating condensing unit. This unit receives its suction refrigerant vapor from a packaged or field-assembled combination of cooling coil and fan (central station air handling unit), and delivers liquid refrigerant to the air handling unit. The EER (COP) of the condensing unit is based on the energy input to the condensing unit, and the change in enthalpy of the refrigerant entering and leaving the condensing unit. The energy consumed by the heat rejecting device (cooling tower or heat exchanger) is not included in the condensing unit manufacturer's published EER (COP), unless the device (i.e., air-cooled condenser) is integrally incorporated into the package by the manufacturer.

A third type of HVAC System Component, for use in a central circulating water system is the a water-source (hydronic) heat pump. Individual units are usually installed for each space or zone, in combination with a water circulating system with central boiler or heat exchangers, and central cooling tower or evaporative cooler, to produce chilled or heated air for direct delivery to each zone or space to be conditioned. In this case also, for cooling operation the EER (COP) of the system component does not include the energy for circulating water through the system or driving the cooling tower fan; for heating, the COP does not include water circulation on-site energy or on-site fossil-fuel energy for operating the boiler; these energy requirements shall be taken into account by the HVAC system designer.

7.2 Responsibility of HVAC System Equipment and System Component Suppliers

Suppliers of HVAC equipment and components shall furnish, upon request by prospective purchasers, system designers, or contractors, the input(s) and output(s) of all such HVAC products.

These shall be based on equipment or components in new condition, and shall cover full load, partial load, and standby conditions, as required, to enable determination of their compliance with this Standard. This includes performance data under modes of operation and at ambient conditions necessary to make the analysis outlined in Section 10 of this Standard.

7.2.1 Where equipment efficiency levels are specified in this section, data furnished by the equipment supplies or certified under a nationally recognized certification program or rating procedure may be used to satisfy these requirements. This paragraph shall not be interpreted as removing the requirement for detailed part-load performance data, as agreed between the purchaser or designer and supplier, if requested.

7.3 Efficiency Requirements for HVAC System Equipment, Electrically Operated, Cooling Mode

HVAC System Equipment as listed in 7.3.1 and qualified in 7.3.2, whose energy input in the cooling mode is entirely electric, shall, at the Standard Rating Conditions specified in Table 7.1 and additional Standard Rating Conditions specified in applicable standards for particular HVAC system equipment, have an Energy Efficiency Ratio (EER), Seasonal Energy Efficiency Ratio (SEER), as defined in Section 3, or a Coefficient of Performance (COP)--Cooling as defined in 7.3.3, not less than values shown in Table 7.2.

7.3.1 These requirements apply to, but are not limited to, unitary (central) cooling equipment (air-cooled, water-cooled and evaporatively-cooled); the cooling mode of unitary (central) and packaged terminal heat pumps (air source and water source); packaged terminal air-conditioners; and room air-conditioners.

Exceptions: These requirements do not apply to equipment whose primary purpose is to cool special processes such as but not limited to computers.

7.3.2 Where components from more than one supplier are used to function as the unitary equipment, it shall be the function of the system designer to determine compliance with these requirements, using data provided by the component supplier (See Section 7.2).

7.3.2.1 Cooling Equipment Auxiliary Controls. The use of either hot gas by-pass or evaporator pressure regulator control shall be limited to those cases where evaporator coil frosting or excessive compressor cycling at part load conditions will occur without their use. Hot gas by-pass and evaporator pressure regulator control will result in increased system energy consumption when employed. In many cases the same result, within acceptable control tolerances, can be obtained through limited and controlled cycling of the refrigerant prime mover without increased energy consumption.

limited to compressor(s), internal circulating pump(s), condenser-air fan(s), evaporative-condenser cooling water pump(s), purge devices, and the HVAC system component control circuit.

7.4.2 Where the motor-compressor, evaporator, or condenser is supplied by different manufacturers, it shall be the function of the system designer to determine compliance with these requirements, using data provided by the suppliers of the elements (see Section 7.2).

7.5 COP Requirements for HVAC System Equipment--Heat Operated, Cooling Mode

7.5.1 Efficiency Limitation, Equipment. Heat-operated cooling equipment shall have a COP--Cooling not less than the values shown in Table 7.7 when tested at Standard Rating Conditions shown in Table 7.6. These requirements apply to, but are not limited to, absorption equipment, engine-driven equipment, and turbine-driven equipment.

7.6 HVAC System Combustion Heating Equipment

7.6.1 All HVAC system combustion heating equipment shall have not less than the minimum steady state combustion efficiency specified in Table 7.8.

7.6.2 Combustion Efficiency. Combustion efficiency of commercial/industrial furnaces and boilers is defined as 100 percent minus stack losses in percent of heat input. Stack losses are:

a. Loss due to sensible heat in dry flue gas

b. Loss due to incomplete combustion

c. Loss due to sensible and latent heat in moisture formed by combustion of hydrogen in the fuel

and shall be determined as provided by applicable standards (See Section 7.2).

7.6.3 Standby Loss Limitation. Space heating boilers used for the generation of service hot water during non-space heating seasons shall meet the standby loss limitations in 8.2.

7.7 COP Requirements for HVAC System Heating Equipment--Heat Pumps, Heating Mode

Heat pumps whose energy input is entirely electric, shall at the Standard Rating Conditions specified in Table 7.9 and other Standard Rating Conditions specified in applicable standards for particular types of heat pumps (see 7.7.1) have a Coefficient of Performance (COP)--Heating, as defined in 7.7.3, not less than the values shown in Table 7.10.

Note: Heat pumps used only for the heating function of a complete HVAC System shall be considered as HVAC System Components.

7.7.1 These requirements apply to, but are not limited to unitary (central) heat pumps (air source and water source) in the heating mode, to water source (hydronic) heat pumps as used in Multiple Unit Hydronic HVAC Systems and to heat pumps in the packaged terminal air-conditioner and room air-conditioner forms, in the heating mode.

7.7.2 Where elements, such as indoor or outdoor coils, from more than one supplier are used as parts of the unitary heat pump, it shall be the function of the system designer to determine compliance with these requirements, using data provided by the component suppliers (see Section 7.2).

7.7.3 Coefficient of Performance (COP)--Heating. This is the ratio of the rate of net heat output by the heat pump to the rate of total on-site energy input to the heat pump, expressed in consistent units and under designated rating conditions. (See Tables 7.9 and 7.10).

The rate of net heat output shall be defined as the change in the total heat content of the air entering and leaving the equipment (not including supplementary heat).

Total on-site energy input to the heat pump shall be determined by combining the energy inputs to all elements, except supplementary heaters, of the heat pump, including, but not limited to, compressor(s), compressor sump heaters, pump(s), supply-air fan(s), return-air fan(s), outdoor-air fan(s), cooling-tower fan(s), and the HVAC system equipment control circuit.

7.7.3.1 In the case where any of the above elements including supplementary heaters and condenser rejected heat, are incorporated in the HVAC System, but not furnished as part of the package (covered by the manufacturer's Model No.) it is the system designer's responsibility to take the corresponding on-site energy inputs into account in determining the total HVAC System performance and annual on-site energy consumption.

7.7.3.2 Most hydronic heat-pump systems utilize condenser-rejected heat from air conditioners serving building central core areas needing cooling during the heating season, or other available waste heat, to raise the temperature of the water from its value leaving the heat-pumps serving the perimeter of the building, to its required value entering the heat pumps. Where the quantity of such reclaimed heat is not sufficient, it must be supplemented by additional new on-site energy and, during cooling operation, on-site energy supplied to the evaporative cooling device. It is the system designer's responsibility to take these energies into account in determining total HVAC system performance and annual on-site energy consumption.

7.7.4 Supplementary Heater. The heat pump shall be installed with a control to prevent electric supplementary heater operation when the heating load can be met by the heat pump alone.

Electric supplementary heater operation is permitted during transient periods, such as start-ups, following room thermostat set-point advance, and during defrost.

A two-stage room thermostat, that controls the supplementary heat on its second stage, shall be accepted as meeting this requirement. The cut-on temperature for the compression heating shall be higher than the cut-on temperature for the supplementary heat, and the cut-off temperature for compression heating shall be higher than the cut-off temperature for the supplementary heat. Supplementary heat may be derived from any source.

7.8 Electric Resistant Comfort Heating Equipment

The manufacturer of electric resistance comfort heating equipment shall make available to prospective purchasers, designers, or contractors, upon request, full-load energy input, over the range of voltages at which the equipment is intended to operate. Where electrically-operated fans, blowers or pumps are integrally incorporated, or separately furnished, their electrical input shall be included by the system designer as part of the energy input to the equipment.

7.9 Maintenance

Equipment and components that require preventive maintenance to maintain efficient operation shall be furnished with complete necessary maintenance information. Required routine maintenance actions shall be clearly stated and incorporated on a readily accessible label, which may be limited to identifying, by title and/or publication number, the operation and maintenance manual for that particular model and type of product.

At least one copy of this information shall be furnished by the manufacturer for the original owner upon request.

In installations that are made up of more than one item of equipment or components, efficient operation of any one device may be dependent on proper maintenace of one or more other components of the system. Under such conditions, it is the function of the system designer to provide, or cause to be provided, for the original owner, upon request, the necessary maintenance information for the installation.

TABLE 7.1
HVAC SYSTEM EQUIPMENT, ELECTRICALLY DRIVEN[1]
STANDARD RATING TEMPERATURES[2] COOLING

Item		Air-Cooled		Water-Cooled (Water-Source)	
		Dry-Bulb (DB)	Wet-Bulb (WB)	Inlet	Outlet
Room Air Entering Equipment	F (°C)	80 (26.7)	67 (19.4)	--	--
Condenser Ambient (Air Cooled)	F (°C)	95 (35.0)	75 (23.9)	--	--
Refrigerant-Water Heat Exchanger[3]	F (°C)	--	--	85 (29.4)	95 (35.0)

[1] Data in Table 7.1 apply to the following types of equipment:
Central Air Conditioners-Air-, Evaporatively- and Water-Cooled, ARI Std. 210-81
Commercial/Industrial Unitary Air-Conditioning Equipment, ARI Std. 360-81
Central Unitary Heat Pumps--Air Source, ARI Std. 240-81 (Cooling Mode)
Central Unitary Heat Pumps--Water Source, ARI Std. 320-81 (Cooling Mode)
Commercial and Industrial Unitary Heat Pumps-Air and Water Source, ARI Std. 340-82 (Cooling Mode)
Packaged Terminal Air-Conditioners, ARI Std. 310-82
Packaged Terminal Heat Pumps, ARI Std. 380-82 (Cooling Mode)
Room Air-Conditioners, ANSI/AHAM RAC 1-1982

[2] Standard Ratings are also based on other Standard Rating Conditions, such as, but not limited to, electrical conditions; cooling coil air quantity; condenser air quantity; requirements for separated (split) assemblies; and minimum external static conditioned-air flow resistances, as provided in the applicable standards.

[3] Refrigerant-Water Heat Exchanger serves as Condenser in Cooling Mode, and as Evaporator in Heating Mode, of Water Source Heat Pumps.

TABLE 7.2
HVAC SYSTEM EQUIPMENT, ELECTRICALLY DRIVEN[1]
MINIMUM COP (EER-SEER) COOLING

Effective Date	Standard Rating Capacities: Under 65,000 Btu/h (19kW) — Air Cooled — Single Phase (SEER)	Under 65,000 Btu/h (19kW) — Air Cooled — Single Phase COP (EER)	Under 65,000 Btu/h (19kW) — Air Cooled — Three Phase COP (EER)	Under 65,000 Btu/h (19kW) — Evap. or Water Cooled Three Phase COP (EER)	65,000 Btu/h (19kW) and Over — Air Cooled Three Phase COP (EER)	65,000 Btu/h (19kW) and Over — Evap. or Water Cooled Three Phase COP (EER)
Beginning January 1, 1980	—	1.99 (6.8)	1.99 (6.8)	—	2.20 (7.5)	—
Beginning January 1, 1984	—	2.28 (7.8)	2.28 (7.8)	2.58 (8.8)	2.40 (8.2)[2]	2.69 (9.2)
Beginning January 1, 1988	8.5	—	2.34 (8.0)	2.64 (9.0)	2.49 (8.5)[3]	2.78 (9.5)

[1]Applies to equipment as listed in Table 7.1. All performances at sea level.

[2]Applies when return-air fans are not included under the manufacturer's model number. When return-air fans are included, the required minimum values are 2.34 (8.0).

[3]Applies to cooling only units when return air fans are not included under the manufacturer's model number. When return air fans are included, the required minimum value is 8.2 for cooling only units. When heating and cooling units are required lower minimum EER's by .2.

TABLE 7.3.1
APPLIED HVAC SYSTEM COMPONENTS--ELECTRICALLY DRIVEN[1]
STANDARD RATING CONDITIONS--COOLING[2]

Conditions		Centrifugal or Self-Contained Reciprocating Water-Chilling Package	Condenserless Reciprocating Water-Chilling Package	Hydronic System Water-Source Heat Pump
Leaving Chilled Water Temp Entering Chilled Water Temp	F (°C) F (°C)	44 (6.7) 54 (12.2)	44 (6.7) 54 (12.2)	--- ---
Leaving Condenser Water Temp Entering Condenser Water Temp	F (°C) F (°C)	95 (35.0) 85 (29.4)	--- ---	95 (35.0) 85 (29.4)
Air Temperature Entering Indoor Portion of Unit	F (°C)	----	---	80 (26.7) DB 67 (19.4) WB
Fouling Factor, Water[3] — Non-Ferrous Tubes Steel Tubes		0.0005 (0.00009)[4] 0.0010 (0.00018)[4]	0.0005 (0.00009)[4] 0.0010 (0.00018)[4]	--- ---
Fouling Factor, Refrigerant		0.00000[4]	0.00000	---
Condenser Ambient — Air or Evap.-Cooled	F (°C) F (°C)	95 (35.0) DB 75 (23.9) WB	--- ---	--- ---
Compressor Saturated Discharge Temperature — Water or Evap.-Cooled Air-Cooled	F (°C) F (°C)	--- ---	105 (40.6) 120 (48.9)	--- ---
Refrigerant Liquid Temperature — Water or Evap.-Cooled Air-Cooled	F (°C) F (°C)	--- ---	95 (35.0) 110 (43.3)	--- ---
Air Temperature Surrounding Unit	F (°C)	---	---	80 (26.7)

[1] Data in this Table 7.3.1 apply to the following types of HVAC System Components:
Centrifugal or Rotary Water-Chilling Packages ARI Std. 550-83
Reciprocating Water-Chilling Packages ANSI/ARI Std. 590-81
Water-Source Heat Pumps ARI Std. 320-81 (For Hydronic Systems)

[2] Standard Ratings are also based on other Standard Rating Conditions, such as, but not limited to, electrical conditions; indoor or condenser air quantities; minimum external flow resistances, etc., as provided in the applicable standards.

[3] For information on fouling factors, see the following standards:
ARI Std. 450-79 for Water-Cooled Refrigerant Condensers, Remote Type
ARI Std. 480-80 for Refrigerant-Cooled Liquid Coolers, Remote Type
ARI Std. 550-83 and 590-81 also contain procedures for adjusting ratings for other than the Standard Rating fouling factor.

[4] Fouling Factor Units: ft^2·h·F/Btu (m^2·K/W)

TABLE 7.3.2
APPLIED HVAC SYSTEM COMPONENTS--ELECTRICALLY DRIVEN[1]
STANDARD RATING CONDITIONS--COOLING[2]

	Temperatures					
	(Evaporator)[2]		Condenser[3]			
			Air-Cooled[4]	Water-Cooled		Evaporatively-Cooled
			Air Entering	Water		Air Entering
Group	Saturation	Return Gas	(Dry Bulb)	In	Out	(Wet Bulb)
No.	F (°C)	F (°C)	F (°C)	F (°C)	F (°C)	F (°C)
1	45 (7.2)	65 (18.3)	95 (35.0)	—	—	—
2	40 (4.4)	65 (18.3)	—	85 (29.4)	95 (35.0)	75 (23.9)

1 Data in this Table apply to HVAC Condensing Units. See ARI Std. 520-78 for Positive Displacement Refrigerant Compressors, Compressor Units and Condensing Units. Data are from Table 3 of ARI 520-78, Groups 1 and 2.

2 Not part of Condensing Unit; conditions to be maintained by separately furnished condenser.

3 Refrigerant liquid subcooling, in F (°C), shall be stated by the manufacturer as obtained under the conditions below as measured at the liquid line leaving the Condensing Unit.

4 With 95 F (35°C) dry bulb ambient air temperature surrounding unit.

TABLE 7.4
APPLIED HVAC SYSTEM COMPONENTS—ELECTRICALLY DRIVEN[1]
MINIMUM COP (EER) COOLING[2]

<table>
<tr><th colspan="2"></th><th colspan="5">Water Chilling Packages</th><th colspan="2">Hydronic Heat Pumps</th></tr>
<tr><th colspan="2">Condenser</th><th colspan="3">Condenser Included</th><th colspan="2">Condenserless</th><th colspan="2">Water Source</th></tr>
<tr><th colspan="2">Cooling Means</th><th>Air</th><th colspan="2">Water</th><th>Air</th><th>Water</th><th>Under 65,000 Btu/h (19kW)</th><th>65,000 Btu/h (19kW) And Over</th></tr>
<tr><th>Size (Tons)</th><th>Types</th><th>All</th><th>Under 250</th><th>250 and Over</th><th>All</th><th>All</th><th></th><th></th></tr>
<tr><td>Beginning January 1, 1980</td><td>C</td><td>2.28 (7.8)[4]</td><td colspan="2">3.98 (13.6)[4]</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td></td><td>R</td><td>2.20 (7.5)</td><td colspan="2">3.40 (11.6)</td><td>2.78 (9.5)</td><td>3.40 (11.6)</td><td>—</td><td>—</td></tr>
<tr><td>Beginning January 1, 1984</td><td>C</td><td>2.34 (8.0)[4]</td><td colspan="2">4.04 (13.8)[4]</td><td>—</td><td>—</td><td></td><td>—</td></tr>
<tr><td></td><td>R</td><td>2.46 (8.4)</td><td colspan="2">3.51 (12.0)</td><td>2.90 (9.9)</td><td>3.51 (12.0)</td><td>2.64 (9.0)</td><td>2.75 (9.4)</td></tr>
<tr><td>Beginning January 1, 1988</td><td>C</td><td>2.40 (8.2)[4]</td><td>4.04 (13.8)[4]</td><td>4.25 (14.5)[4]</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td></td><td>R</td><td>2.55 (8.7)</td><td colspan="2">3.64 (12.4)</td><td>2.99 (10.2)</td><td>3.64 (12.4)</td><td>2.70 (9.2)</td><td>2.87 (9.8)</td></tr>
</table>

1 Applies to equipment as listed in Table 7.3.1. All performances at sea level.

2 Performance of Water-Chilling packages does not include energy to drive chilled-water and condenser-water pumps, or cooling-tower fans; for Hydronic Heat Pumps it does not include the energy to drive circulating water pump(s) and cooling-tower fan(s), but does include the conditioned supply-air fan-motor energy when included as part of the model number of the heat pump. The system designer shall determine the amount of the non-included energies and take them into account in determining the HVAC System COP (EER) and annual energy consumption.

3 C = Centrifugal or Rotary Type (ARI Std. 550-83)
R = Reciprocating Type (ARI Std. 590-81)

4 Where double-bundle heat recovery is employed on centrifugal or screw compressor units, a lower EER is acceptable, provided that the gain by heat exchange exceeds the loss by lower EER; See 6.7.

TABLE 7.5
APPLIED HVAC SYSTEM COMPONENTS, ELECTRICALLY DRIVEN
CONDENSING UNITS 65,000 BTU/H (19kW) AND OVER[1]
MINIMUM EER (COP)--COOLING[2]

Condensing Means	Positive Displacement		
	Air	Evaporative	Water
Beginning January 1, 1980	8.5 (2.50)	11.9 (3.48)	11.9 (3.48)
Beginning January 1, 1984	9.5 (2.78)	12.5 (3.66)	12.5 (3.66)
Beginning January 1, 1988	10.0 (2.93)	12.9 (3.78)	12.9 (3.78)

1 Per ARI Std. 520-78 for Positive Displacement Refrigerant Compressors, Compressor Units and Condensing Units.

2 Based on Standard Rating Capacity at Conditions in Table 7.3.2 and at sea level.

TABLE 7.6
HVAC SYSTEM COOLING EQUIPMENT, HEAT-OPERATED
STANDARD RATING CONDITIONS--COOLING

Standard Rating Conditions		Heat Source: Direct Fired (Gas, Oil)	Heat Source: Indirect Fired (Steam, Hot Water)
Air Conditioners[1]	Units	Temperatures	Temperatures
Entering Conditioned Air	F (°C)	80 (26.7) DB; 67 (19.4) WB	—
Entering Condenser air	F (°C)	95 (35.0) DB; 75 (23.9) WB	—
Water Chillers[2]			
Leaving Chilled Water	F (°C)	45 (7.2)	44 (6.7)
Fouling Factor	ft²·h·.F/Btu (m²·K/W)		.0005 (.00009)
Entering Chilled Water	F (°C)	Per Mfgr. Spec.	54 (12.2)
Entering Condenser Water	F (°C)	75 (23.9)	85 (29.4)
Fouling Factor	ft²·h·F/Btu (m²·K/W)		.0005 (.00018)
Leaving Condenser Water	F (°C)	95 (35.0)	—
Condenser Water Flow Rate	gpm/ton (litre/W·min)	—	Per Mfgr. Spec.

1 Per ANSI Std. Z21.40-1-1981 for Gas-Fired Absorption Summer Air-Conditioning Appliances

2 Per ARI Std. 560-82 for Absorption Water-Chilling Packages

TABLE 7.7
HVAC SYSTEM COOLING EQUIPMENT, HEAT-OPERATED[1]
MINIMUM COP[2,3]

Heat Source	
Direct Fired (Gas, Oil)	Indirect Fired (Steam, Hot Water)
0.48	0.68

1 As listed in Table 7.6. At sea level.

2 Minimum COP = $\dfrac{\text{Net Cooling Output}}{\text{Total Heat Input (Electrical Auxiliary Inputs Excluded)}}$

3 Electrical auxiliary inputs to be included in determining total HVAC System COP.

TABLE 7.8
HVAC COMMERCIAL HEATING EQUIPMENT[1]
MINIMUM STEADY STATE EFFICIENCIES (PERCENT)

Capacity/Input	Oil or Gas Powered Steam or Hot Water Boilers		Gas Atmospheric Steam or Hot Water Boilers		Solid Fuel Steam and Hot Water Boilers		Gas Forced Air Furnaces (Unit Htrs.)		Gas-Oil Powered Furnaces	
	1984	1988	1984	1988	1984	1988	1984	1988	1984	1988
Less than 5 Mil. Btu/h	85	88	80	83	72	75	75	78	80	82
5 to 100 Mil. Btu/h	85	88	80	83	75	78	75	78	80	82
Over 100 Mil. Btu/h	85	88	80	83	77	80	75	78	80	82

[1]Data in this table apply to fossil fuel fired heating equipment shown in Chapter 45 of the 1983 ASHRAE Handbook, Equipment.

TABLE 7.9
HVAC SYSTEM HEATING EQUIPMENT (HEAT PUMPS), ELECTRICALLY OPERATED[1]
STANDARD RATING CONDITIONS[2]

Conditions	Type	Air Source		Water Source
Air Entering Equipment	F (°C)	70 DB/max 60 WB (21.1 DB)/max (15.6 WB)	70 DB/max 60 WB (21.1 DB)/max (15.6 WB)	70 DB/max 60 WB (21.1 DB)/max (15.6 WB)
Outdoor Unit Ambient	F (°C)	47 DB/43 WB (8.3 DB/6.1 WB)	17 DB/15 WB (-8.3 DB/-9.4 WB)	— —
Entering Water Temperature	F (°C)	— —	— —	70 (21.1)
Water Flow Rate	—	—	—	As used in cooling mode[3]

1 Data apply to following:
Air-Source Unitary Heat Pump Equipment-ARI Std. 240-81
Central Water-Source Heat Pumps--ARI Std. 320-81
Commercial and Industrial Heat Pump Equipment--ARI Std. 340-82
Packaged Terminal Heat Pumps--ARI Std. 380-82

2 Additional Standard Rating Requirements are specified in the applicable standard.

3 See ARI Stds. 320-81, 340-82.

TABLE 7.10

HVAC SYSTEM HEATING EQUIPMENT AND SYSTEM COMPONENTS, ELECTRICALLY DRIVEN (HEAT PUMPS)[1,2]

MINIMUM COP[3]

Heat Source Entering Temperature F (°C)	Air Source 47 DB/43 WB) (8.3 DB/6.1 WB)	Air Source 17 DB/15WB (-8.3 DB/-9.4 WB)	Water Source 70 (21.1)	
Discharge Arrangement			Free Discharge	Ducted Discharge
Beginning January 1, 1980	2.5	1.5	2.5	
Beginning January 1, 1984	2.7	1.8	3.0	
Beginning January 1, 1988	2.8	2.0	3.0	3.2

1 Equipment as listed in Table 7.9. All performances at sea level and exclude supplementary heat.

2 "Equipment" here refers to central heat pumps, both air-source and water-source; "Components" refers to water-source heat pumps in hydronic systems.

3 For both central and hydronic system water-source heat pumps, the COP values in the table do not include the power consumed by the water pump. In order to determine total system performance, it is the system designer's responsibility to take this power consumption into account. In addition, new (fossil fuel or electric) energy supplied to a boiler or other water heating device to restore the water-source temperature entering the heat pump shall be taken into account by the system designer. (See 7.7.3.1)

8.0 SERVICE WATER HEATING

8.1 Scope

8.1.1 The purpose of this section is to provide criteria for design of service water heating systems and equipment selection for efficient use of energy.

8.1.2 Service water heating system design loads for the purpose of sizing and selecting systems shall be determined in accordance with the procedures described in the 1980 ASHRAE Handbook, Systems, Chapter 37, or an equivalent computation procedure.

8.2 Water Heaters and Hot Water Storage Tanks

All water heaters and hot water storage tanks shall meet the criteria of Table 8.1.

TABLE 8.1

Type of Water Heater	Capacity	Efficiency	Standby Loss
Automatic Electric Storage	Less than or equal to 120 gal (450 Liters) and 12 kW input	Recovery (E_r) greater than or equal to 98%[1]	Less than or equal to 25W plus 1W/gal (.264W/Liter)[1] or less than or equal to 43W
Automatic Electric Storage	Greater than 120 gal (450 Liters) or 12 kW input	Recovery (E_r) greater than or equal to 98%[2]	Less than or equal to 25W plus 1W/gal (.264W/Liter)[2] or/Insulated to R greater than or equal to 14 $ft^2 \cdot h \cdot °F/Btu$ ($2.5 m^2 \cdot °C/W$)
Gas and Oil	Less than or equal to 75,000 Btu/h (22kW)	Recovery (E_r) greater than or equal to 76%[1]	Less than or equal to 2.3+67/Vol in gal[1] (2.3+250/Vol in Liters)
Gas Atmospheric Burner (Natural Draft)	Greater than 75,000 Btu/h (22kW) and less than or equal to 4,000 Btu/h/gal (.3kW/Liter) input	Thermal (E_t) greater than or equal to 75%[3]	Less than or equal to 2.3+67/Vol in gal (2.8+250/Vol in Liters)
	Greater than 75,000 Btu/h (22kW) and 4,000 Btu/h/gal (.3 kW/Liter) input	Thermal (E_t) greater than or equal to 75%[3]	See Footnote [5]
Oil or Gas Powered	Greater than 75,000 Btu/h (22kW) and less than or equal to 4,000 Btu/h/gal (.3 kW/Liter) input	Combustion (E_c) greater than or equal to 80%[4]	Less than or equal to 2.3+67/Vol in gal (2.8+250/Vol in Liters)
	Greater than 75,000 Btu/h (22kW) and 4,000 Btu/h/gal (.3kW/Liter) input	Combustion (E_c) greater than or equal to 80%[4]	See Footnote [5]
Unfired	All	—	Less than or equal to 13.6 $Btu/h \cdot ft^2$ ($43W/m^2$) of external surface with design ambient less than or equal to 65 F (18.3°C)

[1] When tested in accordance with test procedures found in 10 CFR Part 430, Energy Conservation Program for Consumer Products, Subpart B, Appendix E.

[2] When tested in accordance with UL 174-1977, Household Electric Storage Tank Water Heaters.

[3] When tested in accordance with ANSI Z21.10.3-1981 (with Addenda 1982).

[4] Combustion efficiency = 100 - stack losses. Stack losses are: a) loss due to sensible heat in dry flue gas; b) loss due to incomplete conduction; c) loss due to sensible and latent heat in moisture formed by combustion of hydrogen in the fuel. For oil the measurement shall be measured at smoke = 0 (trace is permitted).

[5] Must have ignition from source other than a continuously burning pilot if pilot input greater than 5% of the water heater input.

8.3 Combination Service Water Heating/Space Heating Boilers

Service water heating equipment shall not be dependent on year round operation of space heating boilers, that is, boilers that have as another function winter space heating, and vice-versa.

8.3.1 Where operation of the space heating boiler is required solely for service hot water purposes in the summer, a separate smaller service water heater, properly sized, shall be installed as close to the point of use as practicable so that the larger boiler can be shut down during these periods of very light loads.

Exceptions:

a. Where the size of a separate service hot water boiler, as calculated per Chapter 37, ASHRAE Handbook, 1980 Systems, would be more than 30 percent of the input to the boiler used for providing service water in the summer.

b. Where the manufacturer certifies that the part load performance of the space heating boiler at that load meets the criteria of Table 8.1.

8.3.2 Boilers used for combination service and space heating must meet minimum efficiencies of Table 7.8.

8.4 Piping

8.4.1 Recirculation Systems. Piping heat loss shall be limited to a maximum of 10.0 Btu/h per linear foot in accordance with the following equation:

$$Q = \frac{(t_i - t_o)/[\ln r_o/r_i]}{2\ k}$$

where: t_i = 180°F

t_o = outdoor design temperature or ambient temperature if located in a conditioned space

r_i = 1/2 of outside pipe diameter in inches

r_o = r_i + insulation thickness in inches

k = thermal conductivity of insulation $Btu/h \cdot ft^2 \cdot F/in$

Exceptions: Piping insulation is not required when the heat loss of the piping, without insulation, does not increase the annual energy requirements of the building.

8.4.2 Nonrecirculation Systems. The first 8 feet (2.44 m) of piping from the storage system shall be insulated in accordance with 8.4.1.

8.5 Controls

8.5.1 Temperature. Service water heating systems shall be equipped with automatic temperature controls capable of adjustment from the lowest to the highest acceptable temperature settings for the intended use. (See Table 1 from ASHRAE 1980 Handbook and Product Directory, Systems Volume, Chapter 37).

8.5.2 Shut Down. A separate switch shall be provided to permit turning off the energy supplied to electric service water heating systems. A separate valve shall be provided to permit turning off the energy supplied to all other types of service water heating systems.

8.5.3 Pump Operation. Circulating hot water systems shall be arranged so that the circulating pump(s) can be conveniently turned off (automatically or manually) when the water heating equipment is not in operation.

8.6 Conservation of Hot Water

8.6.1 Showers used for other than safety reasons, shall limit the maximum hot water discharge to 3 gpm (0.19 litres/s) rated at pressure differences of 20 to 80 psi (138 to 551 kPa).

8.6.2 Lavatories in restrooms of public facilities shall:

a. Be equipped with outlet devices that limit the flow of hot water to a maximum of 0.5 gpm (0.032 litres/s) or, be equipped with self-closing valves that limit delivery to a maximum of 0.25 gallons (0.94 litres) of hot water for recirculating systems and to a maximum of 0.50 gallons (1.9 litres) for non-recirculating systems.

b. Be equipped with devices that limit the outlet temperature to a maximum of 110 F (43.3°C).

Exception: Separate lavatories for physically handicapped persons shall not be equipped with self-closing valves.

8.6.3 Service hot water systems whose primary use is for applications requiring temperatures of 120 F (48.9°C) and less (see Table 2, page 37.8, Chapter 37, ASHRAE Handbook, 1980 Systems) shall be capable of being operated at 120F (48.9°C). Where higher temperatures are required, separate remote heaters or booster heaters shall be installed at the point of use.

8.6.4 Point of use water heaters shall be considered where their use will reduce energy consumption.

8.7 Swimming Pools

8.7.1 Pool Heaters. All pool heaters shall meet the criteria of Table 8.1 and be equipped with an ON-OFF switch mounted for easy access to allow shutting off the operation of the heater without adjusting the thermostat setting and, when applicable, to allow restarting without relighting the pilot light.

8.7.2 Pool Covers. Heated swimming pools shall be equipped with a pool cover.

Exceptions: Outdoor pools deriving over 20 percent of the energy for heating from non-depletable sources (computed over an operating season.)

8.7.3 Time Clocks. Time clocks shall be installed on all swimming pool pumps.

8.8 Utilization of Waste Heat or Solar Energy

8.8.1 An evaluation shall be made as to the potential for the use of condenser heat, waste energy, or solar energy to supplement hot water requirements.

8.8.2 High temperature condensate, when returned to condensation pump tanks or other vented tanks, will have a certain portion flashed into steam, thus wasting energy. To conserve this energy, a heat exchanger shall be considered for use in the condensate return line to heat or preheat the service water, cool the condensate, and prevent flashing.

8.8.3 Storage should be used to optimize heat recovery when the flow of heat to be recovered is out of phase with the demand for heated water.

9.0 AUXILIARY SYSTEMS AND EQUIPMENT

9.1 Scope

This section provides design criteria for energy using auxiliary systems and equipment not specifically addressed elsewhere in the Standard.

9.2 Transportation Systems

In buildings that include horizontal and/or vertical transport systems, automatic elevator and/or conveyor system usage reduction control arrangements shall be evaluated.

9.3 Freeze Protection System

9.3.1 Consideration shall be given to the use of waste heat, heat recovery, or heat trace systems to conserve energy.

9.3.2 Boilers or water heaters utilized for freeze protection in fire protection storage vessels shall meet the requirements of Table 7.8 and/or Table 8.1 as applicable.

9.4 Energy Management

Consideration shall be given to the use of energy management systems to conserve energy.

10.0 ENERGY CONSERVATION IN NEW BUILDING DESIGN BY SYSTEMS ANALYSIS

10.1 Scope

This section provides an alternative to the application of the specific criteria of Sections 4 through 9 of this standard. It provides a procedure for determining compliance through an energy analysis which demonstrates that the expected annual energy use does not exceed a reference annual energy use which is based on the criteria of Sections 4 through 9. The energy analysis described in this section is not required for buildings which comply with all the requirements of Sections 4 through 9 or if the building, its systems, and equipment are modified to comply with the requirements of Sections 4 through 9.

10.2 General

This section shall be used to determine compliance with the standard in the following cases:

a. If one or more of the components or systems of a proposed building design do not comply with the criteria of Sections 4 through 9 while one or more of the other components or systems exceed the stated requirements.

b. If it is predetermined that an annual energy analysis will be used in lieu of the application of the specific criteria of Sections 4 through 9.

10.3 Analysis Procedure Criteria

The analysis procedures used to determine the expected and reference annual energy use of the proposed building and its service systems shall meet the following criteria:

10.3.1 For buildings with gross floor area less than 10,000 sq. ft. (900 m^2) with a system designed such that simultaneous heating and cooling of the same space is not possible, a simplified energy analysis, including bin or degree-day method, may be used.

10.3.2 For all other buildings the calculation procedures used in determining the expected and reference annual energy use shall be of sufficient detail to permit evaluation of the effects of:

a. Climatic data: sufficient coincident hourly data for temperatures, solar radiation, wind, and humidity to represent seasonal variations over a full year of operation.

b. Building data: orientation, size, shape and mass of the building, and the air, moisture, and heat transfer characteristics of the materials used in the building.

c. System design an operational data: full and part load performance characteristics of the systems used to control temperature, humidity, ventilation, and illumination (including variations between occupied and non-occupied hours).

d. Mechanical equipment data: both design capacity and part-load performance characteristics of equipment. Manufacturer's data or comparable field test data should be used, when available, in the simulation of all systems' components and equipment.

e. Internal heat generation data: heat gain from lighting, equipment, and people during occupied and non-occupied periods.

10.3.2.1 The calculation procedures shall utilize techniques consistent with those recommended in the appropriate ASHRAE publications[1-3], or produce results consistent with those obtained through the use of such techniques.

10.4 Determination of Compliance

Compliance with this section shall be established as specified in Sections 10.4.1 through 10.4.3. At such time as consensus design energy budgets and performance procedures have been developed, this section will be revised to include them as an alternative means of compliance.

10.4.1 Under the provisions of this procedure the reference annual energy use shall be determined by applying the individual criteria of Sections 4 through 9 of this standard as specified below:

Beginning with the design of the building to be built and systems, primary equipment and energy type to be utilized, compare the building components, systems and equipment characteristics with the criteria set forth in Sections 4 through 9. If the building components, systems or equipment do not meet these criteria, adjust them sufficiently to achieve minimum compliance. For the purpose of determining the reference annual energy use, building components, systems, or equipment which exceed the performance specified by these criteria may also be adjusted downward to achieve minimum compliance. The total floor area and primary equipment energy type shall not be changed from that of the proposed (unadjusted) design.

When sufficient adjustments have been made to achieve minimum compliance with Sections 4 through 9, utilize an analysis procedure which meets the requirements of Section 10.3 to determine the annual energy use for each energy type used by the adjusted building, systems, and equipment. This is the reference annual energy use of each energy type.

10.4.2 Calculate the annual energy use of the proposed (unadjusted) building, system, and equipment as designed utilizing the same climatic data, operating and use schedules, equal environmental requirements, and the same analysis procedures. This is the expected annual energy used of each energy type.

10.4.3 Compare the expected annual use of each energy type as determined in Section 10.4.2 with the reference annual energy use from Section 10.4.1. All forms of energy usage covered under the provisions of Sections 4 through 9 shall be included in the comparison. For purposes of determining compliance, the use of each energy type shall be expressed in Btu/year (kJ/year).

10.4.3.1 If the expected annual energy use is equal to or less than the reference annual energy use for each energy type, then the proposed building, system, and equipment as designed shall be determined to be in compliance with the requirements of this standard.

10.4.3.2 If the expected annual energy use exceeds the reference annual energy use of each energy type, the proposed building design does not comply.

10.4.3.3 If the expected annual energy use of one type is greater than, while another is less than its reference annual energy use, compliance shall be determined as follows:

(a) Multiply the expected annual use Btu/year (kJ/year) of each energy type by the cost $/Btu ($/kJ) of supplying that energy type and determine the sum for all energy types used.

(b) Do the same for the reference annual use.

(c) If the total energy cost ($/year) of all energy types for the expected annual use does not exceed that for

Beginning with the design of the building to be built and systems, primary equipment and energy type to be utilized, compare the building components, systems and equipment characteristics with the criteria set forth in Sections 4 through 9. If the building components, systems or equipment do not meet these criteria, adjust them sufficiently to achieve minimum compliance. For the purpose of determining the reference annual energy use, building components, systems, or equipment which exceed the performance specified by these criteria may also be adjusted downward to achieve minimum compliance. The total floor area and primary equipment energy type shall not be changed from that of the proposed (unadjusted) design.

When sufficient adjustments have been made to achieve minimum compliance with Sections 4 through 9, utilize an analysis procedure which meets the requirements of Section 10.3 to determine the annual energy use for each energy type used by the adjusted building, systems, and equipment. This is the reference annual energy use of each energy type.

10.4.2 Calculate the annual energy use of the proposed (unadjusted) building, system, and equipment as designed utilizing the same climatic data, operating and use schedules, equal environmental requirements, and the same analysis procedures. This is the expected annual energy used of each energy type.

10.4.3 Compare the expected annual use of each energy type as determined in Section 10.4.2 with the reference annual energy use from Section 10.4.1. All forms of energy usage covered under the provisions of Sections 4 through 9 shall be included in the comparison. For purposes of determining compliance, the use of each energy type shall be expressed in Btu/year (kJ/year).

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10.4.3.3 If the expected annual energy use of one type is greater than, while another is less than its reference annual energy use, compliance shall be determined as follows:

(a) Multiply the expected annual use Btu/year (kJ/year) of each energy type by the cost $/Btu ($/kJ) of supplying that energy type and determine the sum for all energy types used.

(b) Do the same for the reference annual use.

(c) If the total energy cost ($/year) of all energy types for the expected annual use does not exceed that for the reference annual use, the proposed building components, systems, and equipment shall be considered as having complied with the standard. The cost \$/Btu (\$/kJ) of supplying each energy type used in these calculations shall be determined from applicable current utility rate schedules.

10.5 Documentation

An energy analysis shall be conducted to demonstrate compliance. It shall provide sufficient technical detail on the proposed building and its service systems and on data used as input to the analysis to verify that the analysis procedures meet the criteria of Section 10.3. It shall also provide results from the analysis in sufficient detail to demonstrate that the expected annual energy use is equal to or less than the reference annual energy use as determined by the procedures of Section 10.4.

10.5.1 The calculations, evaluations, and analyses required by this section shall be performed by persons having qualifications specified by the responsible building regulatory agency.

References

1. ASHRAE HANDBOOK, 1981 FUNDAMENTALS.

2. Energy Calculations I: "Procedures for Determining Heating and Cooling Loads for Computerizing Energy Calculations--Algorithms for Building Heat Transfer Subroutines", ASHRAE 1975.

3. Energy Calculations II: "Procedures for Simulating the Performance of Components and Systems for Energy Calculations", ASHRAE 1975.

11.0 REQUIREMENTS FOR BUILDINGS UTILIZING NON-DEPLETING ENERGY SOURCES

11.1 General

When a proposed alternative building and service system design, conducted and evaluated in accordance with Section 10 of this standard, utilizes solar, geothermal, wind or other non-depletable energy sources (see Section 3 - Definitions) for all or part of its energy sources, such non-depletable energy supplied to the building shall be excluded from the total energy chargeable to the proposed alternative design. To qualify for this exclusion, solar energy must be derived from a specified collection, storage and distribution system.

11.1.1 All other criteria covered in Section 10 shall apply to the proposed alternative designs utilizing non-depletable sources of energy.

11.2 Documentation

Proposed alternative designs shall be accompanied by an energy analysis prepared by an individual meeting the criteria of 10.5.1. The report shall provide sufficient technical detail on the alternative building and system designs and on the data employed in and resulting from the comparative analyses to verify that the analyses meet the criteria of 10.3 and the design meets the criteria of 10.4 and this section. The energy derived from non-depletable sources shall be separately identified from the overall building energy use. Supporting documentation, on the basis of the performance estimates for the aforementioned non-depletable energy sources must be submitted.

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