ALASKA BUILDING
THERMAL PERFORMANCE STANDARDS
FOR NEW BUILDINGS
WITH MORE THAN 12,000 SF

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for

State of Alaska
Department of Transportation and Public Facilities
Building Research Section

and

University of Alaska at Fairbanks
Mechanical Engineering Department
College, Alaska

by

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SECTION - THERMAL STANDARDS

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1.0 PURPOSE

1.1 The purpose of the standard is to provide design requirements that will improve energy utilization in new buildings with gross areas of between 12,000 ft^2 and 150,000 ft^2. For buildings larger than 150,000 ft^2 energy conservation criteria should be based on individual life cycle cost analyses.

1.2 The requirements of this standard are directed: toward the design of building envelopes to ensure adequate thermal resistance and low air leakage; toward the design and selection of mechanical, electrical, service water heating, and illumination systems and equipment; and toward the prudent selection of fuel and energy sources. All of these will reduce annual energy consumption in the State of Alaska.

1.3 It is intended that the standard be a flexible document providing designers with a coherent set of thermal guidelines that accommodate the widely varying environmental and economic conditions present in the state today. Designers are encouraged to use innovative approaches and techniques to achieve efficient energy utilization.

Sections 10 and 11 of the standard provide for evaluation of alternative design solutions, which, while not conforming to the prescriptive envelope criteria. may provide equal performance under the standard.

1.4 The standard is in the format of a "Component Standard", that imposes minimum requirements for thermal characteristics of the various energy-consuming systems in the building. The standard addresses the applicability of mechanical system types for the wide variety of climate conditions that occur in Alaska. Additionally, the standard provides guidelines for level of complexity of HVAC systems for different economic areas of the state.

This standard uses the format and a number of the sections of ASHRAE Standard 90, which are applicable to Alaskan conditions.

There is a new version of ASHRAE Standard 90 in draft form. due to be finalized and published in 1988. Upgrades appearing in the draft 1988 ASHRAE Standard have been incorporated into this document where appropriate.

1.5 It is intended that this standard be used in the design of new buildings and that compliance with its requirements should be determinable in the preconstruction stage, by evaluation and analysis of the design.

Significant attention is devoted to the implementation of the design process, specifically with building controls, and HVAC systems. Requirements include documentation for maintenance staff. as well as air and water balancing, and systems testing requirements.

2.0 SCOPE

This standard sets forth requirements for the design of new buildings owned by the State of Alaska. The standard covers exterior envelopes, selection of the heating, ventilating and air-conditioning (HVAC) system, service water systems, energy distribution systems, illumination systems and other energy consuming equipment. This standard covers new state owned buildings with educational and office occupancies, and similar occupancies located in all parts of Alaska, between 12,000 and 150,000 gross square feet.

3.0 DEFINITIONS

Terminology used in this standard conforms to that used in the referenced ASHRAE Standard 90A (Reference 1). Section 3 DEFINITIONS from ASHRAE Standard 90A is included as Appendix A.

4.0 EXTERIOR ENVELOPE REQUIREMENTS

4.1 Scope:

This section establishes the minimum thermal requirements of the exterior envelope of new buildings. The equations, charts, and tables in this section are intended only for use in defining these criteria. In cases where a system analysis approach to building design is desired, the requirements of Appendix C apply.

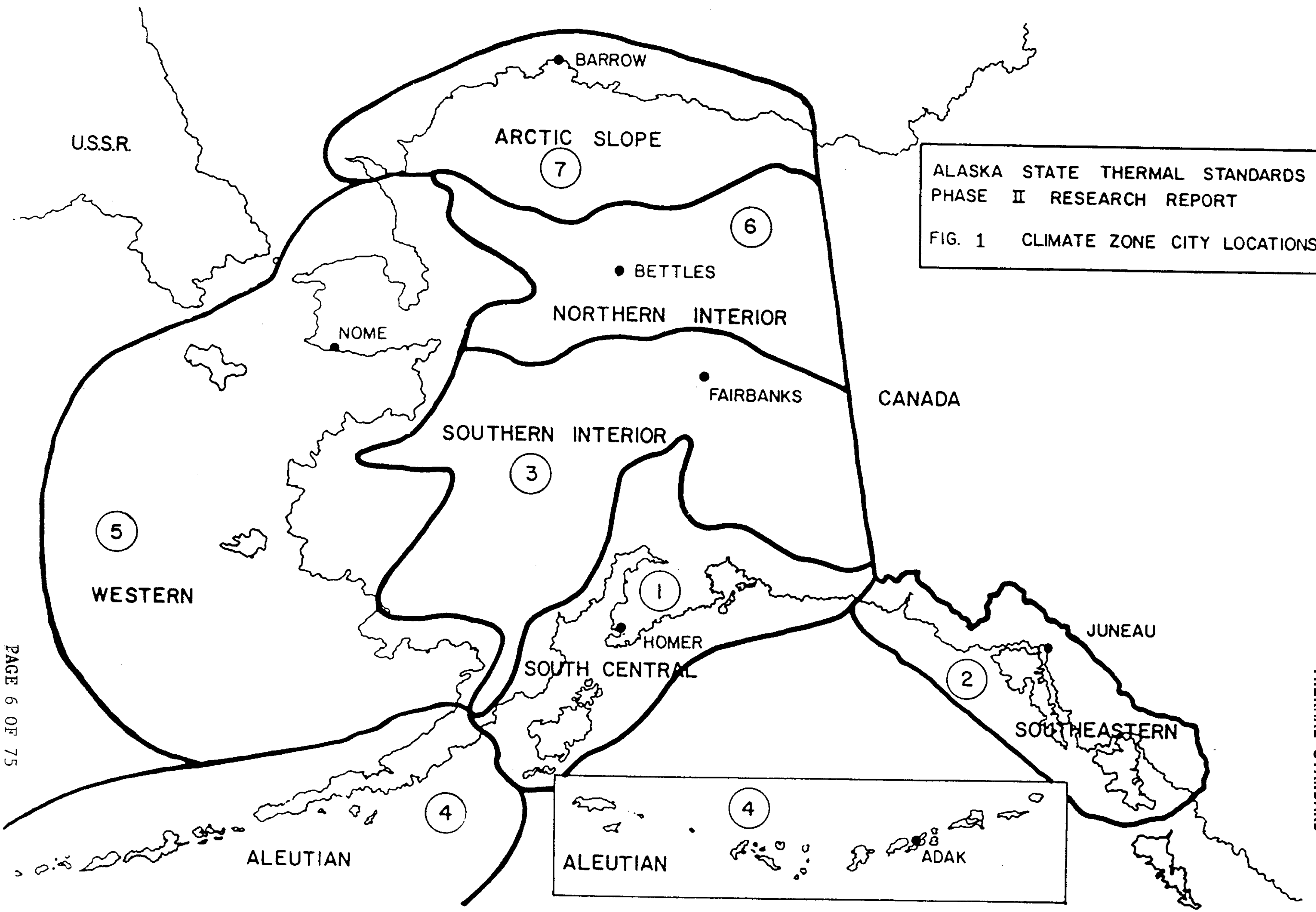
4.2 General:

4.2.1 The following subparagraphs provide minimum requirements for building envelope construction in the interest of energy conservation.

4.2.2 In addition to the criteria set forth in this section, the proposed design should consider energy conservation in determining the orientation of the building on its site; the geometric shape of the building; the building aspect ratio (ratio of length to width); the number of stories for a given floor area requirement; shading or reflections from adjacent structures, surrounding surfaces or vegetation; opportunities for natural ventilation; and wind direction and speed.

Discrete envelope requirements are set forth for seven climate zones of Alaska. These zones are presented on Figure 1.

4.2.2.1 To develop the exterior envelope requirements, the calculation procedures and information contained in Chapters 20-28 of the 1985 ASHRAE HANDBOOK, Fundamentals Volume (Reference 2), shall be used. Other available measured thermal performance data for envelope sections (either from laboratory or field data, or from engineering analysis) may be considered either in addition to, or in place of, the criteria set forth in this section providing equal and repeatable results can be proven.



ALASKA STATE THERMAL STANDARDS
PHASE II RESEARCH REPORT

FIG. 1 CLIMATE ZONE CITY LOCATIONS

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

4.2.3 A roof assembly shall be considered as all components of the roof/ceiling envelope through which heat flows, thus creating a building transmission heat loss or gain, where such assembly is exposed to outdoor air and encloses a heated and/or mechanically cooled space.

4.2.3.1 The gross area of a roof assembly consists of the total interior surface of such assembly, including skylights exposed to the heated and/or mechanically cooled space.

4.2.3.2 Where return air ceiling plenums are employed the roof/ceiling assembly shall, for thermal transmittance purposes. not include the ceiling proper nor the plenum space as part of the assembly, and for gross area purposes be based upon the interior face of the upper plenum surface.

4.2.4 All buildings that are heated and/or mechanically cooled shall be constructed to provide the required thermal performance of the various components.

4.2.4.1 The stated R-value of any one assembly. such as roof/ceiling, wall or floor, may be increased and the R-value for other components decreased provided that the overall heat gain and/or loss for the entire building envelope does not exceed the total resulting from conformance to the stated R-values.

4.2.4.2 The following dry bulb temperatures shall be used for calculations in this section:

	Indoor (Design Temperature)	Outdoor (Frequency Level Requirement)
Winter	70 degrees F	97.5 %
Summer	78 degrees F	2.5 %

4.2.5 A building designed to be heated and/or cooled shall meet the more stringent of the heating or cooling requirements of the exterior envelope as provided in this section when requirements differ.

4.2.6 The design of buildings for energy conservation may increase the water vapor pressure differentials between the interior and exterior environments. The use of vapor retarders is mandatory for all Alaskan buildings, and all envelope systems shall be engineered to minimize the leakage of air and the movement of moisture through this vapor retarder.

4.3 Envelope Criteria:

4.3.1 Heating:

4.3.1.1 **Walls:** Any building that is heated and/or mechanically cooled shall have combined thermal resistance values (R-values) for each envelope component greater than or equal to values shown in Table 1.

TABLE 1. COMPOSITE WALL R-VALUE REQUIREMENTS

Climate Region	Region Title	Required Minimum R-Value (hr-sq ft -deg F/BTU) Educational	Office
1	South Central	8.0	5.0
2	South Eastern	11.0	8.0
3	Southern Interior	11.0	8.0
4	Aleutian	7.0	5.0
5	Western	11.0	8.0
6	Northern Interior	11.0	8.0
7	Barrow	11.0	8.0
7	North Slope	11.0	8.0

Note: Composite wall R-values include windows and doors.

The following equation is to be used for determining component R-values for wall sections:

$$R = \frac{Ao}{(A/R)wall + (A/R)fenestration + (A/R)door} \quad (1)$$

where

R	=	the average thermal resistance of the gross wall area, hr-sq ft -deg F/BTU
Ao	=	the gross area of exterior walls, sq ft
Awall	=	opaque wall area, sq ft
Afenestration	=	window area (including sash), sq ft
Adoor	=	door area, square feet
Rwall	=	the thermal resistance of all elements of the opaque wall area, hr-sq ft -deg F/BTU
Rfenestration	=	the thermal resistance of the window area, hr-sq ft -deg F/BTU
Rdoor	=	the thermal resistance of the door area. hr-sq ft -deg F/BTU

Note : Where more than one type of wall. window and/or door is used, the A/R term for that exposure shall be expanded into its subelements-

$$R = \frac{Aroof1 + Aroof2 + Aroof3 + \ldots}{(A/R)roof1 + (A/R)roof2 + (A/R)roof3 + \ldots}$$

4.3.1.2 **Roof/Ceiling.** Any building that is heated shall have a thermal resistance value (R-value) for the gross area of the roof assembly greater than or equal to the value shown in Table 2. Values shall be selected for the climatic region of the proposed facility.

Equation 2 shall be used to determine acceptable combinations where the designer elects to use a concept different than listed in Table 2.

TABLE 2. COMPOSITE ROOF R-VALUE REQUIREMENTS

Climate Region	Region Title	Required Minimum R-Value (hr-sq ft -deg F/BTU)
1	South Central	23.0
2	South Eastern	35.0
3	Southern Interior	42.0
4	Aleutian	23.0
5	Western	42.0
6	Northern Interior	42.0
7	Barrow	23.0
7	North Slope	42.0

The following equation is to be used for determining average thermal resistance values for combinations of roofs and skylights.

$$R = \frac{Ao}{(A/R)roof + (A/R)skylight} \qquad (2)$$

where

R - the average thermal resistance of the gross roof/ceiling area, hr-sq ft -deg F/BTU

Ao = the gross area of a roof/ceiling assembly, sq ft

Aroof = opaque roof/ceiling assembly, sq ft

Askylight = skylight area (including frame), sq ft

Rroof = the thermal resistance of all elements of the opaque roof/ceiling area, hr-sq ft -deg F/BTU

Rskylight = the thermal resistance of all skylight, hr-sq ft -deg F/BTU

Note: Where more than one type of roof/ceiling and/or skylight is used, the A/R terms for that exposure shall be expanded into its subelements.

$$R = \frac{Aroof1 + Aroof2 + Aroof3 + \ldots}{(A/R)roof1 + (A/R)roof2 + (A/R)roof3 + \ldots}$$

4.3.1.3 Floors Over Unheated Spaces: The R-value shall be greater than or equal to the values shown in Table 3. For floors of heated spaces over unheated spaces, including pile-supported floors.

For heated crawlspace foundations, R-values for wall insulation installed on exterior of perimeter foundation walls shall be greater than or equal to the R-value in Table 3.

TABLE 3. COMPOSITE FLOOR R-VALUE REQUIREMENTS

Climate Region	Region Title	Required Minimum R-Value (hr-sq ft -Deg F/BTU) Elevated Floor	Heated Crawlspace
1	South Central	36.0	13.0
2	South Eastern	44.0	18.0
3	Southern Interior	44.0	18.0
4	Aleutian	36.0	13.0
5	Western	44.0	18.0
6	Northern Interior	44.0	18.0
7	Barrow	25.0	N/A*
7	North Slope	44.0	N/A*

* Not Applicable

4.3.2 Cooling Criteria: Building envelope systems shall be constructed to prevent overheating through appropriate mechanical/natural ventilation schemes, and careful orientation of window areas. The use of mechanical cooling is prohibited, except in the following cases:

where mechanical cooling is required to maintain interior summer time space temperatures

where use of such cooling can be shown to result in reduced energy consumption from that of a nonmechanically cooled design, in accordance with Appendix B of this Standard.

403.3 Air Leakage:

4.3.3.1 General Requirements: Compliance with the criteria for air leakage shall be determined by ANSI/ASTM E 283-84, Standard Method of Test for Rate of Air Leakage through Exterior Windows, Curtain Walls and Doors (Reference 3), at a pressure differential of 1.57 lb/sq ft, which is equivalent to the effect of a 25 mph wind.

4.3.3.2 Windows: Windows shall be designed to limit air leakage; the air infiltration rate shall not exceed 0.35 cu ft/min per foot of sash crack. See Section 4.3.3.1.

4.3.3.3 Swinging and Overhead Doors: Swinging doors shall be used exclusively for personnel access. Doors shall be designed to limit air leakage. Fitting shall be maintained tight, with full face weather stripping.

Overhead doors shall be tight fitting along the top and sides and shall have full face weather stripping along the bottom.

There is currently no standard for overhead access doors.

4.3.3.4 **Caulking and Sealants:** Exterior joints in the building envelope that are sources of air leakage (such as around window and door frames, between wall cavities and window or door frames, between wall and foundation, between wall and roof, between wall panels, at penetrations or utility services through walls, floors and roofs) shall be caulked, gasketed, weather stripped, or otherwise sealed. Seal joints using good construction practices that will not result in trapped moisture within envelope insulation.

Vapor Retarders: Install interior vapor retarders on the warm side of the wall section. Minimize penetrations in vapor retarder. Where penetrations must occur (such as around electrical boxes or duct penetrations), seal vapor barrier with caulking and/or tape. Minimum allowable permeance is 0.06 gr/hr ft^2 inch Hg.

Air Barriers: The use of air barriers on the cold side of the envelopes is encouraged. Carefully seal around all windows and door frames, to provide a smooth unbroken barrier to the flow of air through envelope components.

5.0 HEATING, VENTILATING AND AIR CONDITIONING SYSTEMS:

5.1 Scope:

This section covers determination of heating and cooling loads. design requirements, and control requirements for general comfort applications in new buildings where normally clothed people are engaged in sedentary or near-sedentary activities. Criteria are established for insulating systems and for duct construction.

5.2 General:

This section establishes HVAC system requirements for effective utilization 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 6. It is recommended that the HVAC system selection process include an annual energy use evaluation.

5.3 Calculation of Heating/Cooling Loads:

5.3.1 Procedures:

Heating and cooling design loads for the purpose of sizing systems shall be determined in accordance with one of the procedures described in the ASHRAE HANDBOOK 1985 Fundamentals Volume, Chapters 25 and 26 (Reference 2), or an equivalent computation procedure.

The procedures in Section 4 of this standard are used for determining the thermal design of the exterior envelope and are not considered equivalent for the purpose of sizing.

The design parameters in Section 5.3.2 shall apply for all computational methods.

5.3.2 Design Parameters:

The following design parameters shall be used for system design load calculations for general comfort applications.

5.3.2.1 Outdoor Design Conditions: Winter and summer outdoor design conditions shall be selected for listed locations in Table 4. Adjustments may be made to reflect local climates that differ from the temperatures listed in the Table 4, or local weather experience may be used for locations not listed.

5.3.2.2 Indoor Design Conditions: Although the recommended design points are established below, the system design should permit operating at minimum energy levels and at comfort conditions consistent with the criteria of ANSI/ASHRAE Standard 55-81 "Thermal Environmental Conditions for Human Occupancy" (Reference 4).

Winter:
The recommended heating design condition is 70 degrees F dry bulb. If humidification is provided, it shall be designed to provide and maintain a maximum relative humidity of 30%, measured at 70 deg F space temperature.

Summer:
Where comfort cooling is required or used, the recommended design condition is 78 degrees dry bulb. The actual design relative humidity within the comfort envelope as defined in ANSI/ASHRAE Standard 55-81 (Reference 4) shall be selected for minimum total energy use by the HVAC system when considering air quantities, system type, etc.

5.3.2.3 Ventilation Standards: The amount of ventilation air brought into the building shall conform to ASHRAE/ANSI Standard 62-81 "Natural and Mechanical Ventilation" (Reference 5). The minimum column for each type of occupancy shall be used.

TABLE 4. DESIGN WEATHER DATA

Station	Winter Design Dry Bulb Temperature	Heating Degree Days	Summer Design Dry Bulb Temperature	Location * N. Lat.	W. Long.	Pvlg. Wind (Dir.)	Mean Speed (Knots)
Adak	23	8,825	59	51-53	176-39	W	7
Anchorage IAP	-18	10,911	68	61-10	150-01	SE	3
Aniak	-39	13,412	71	61-35	159-32	E	3
Annette	17	7,053	70	55-02	131-34	NE	12
Anvil Mt.	-27	14,555	60	64-34	165-22	N	8
Attu	22	8,339	57	52-30	173E-10	NW	12
Barrow	-41	20,265	53	71-18	156-47	SW	8
Barter Island	-41	19,994	52	70-08	143-38	SW	7
Bear Creek	-35	13,861	73	65-15	151-55	W	10
Beaver Creek	-47	14,770	74	63-03	141-49	SW	2
Bethel Aprt	-28	13,203	69	60-47	161-48	NNE	10
Bettles	-45	15,925	75	66-55	151-31	NNW	4
Big Delta/Allen AAF	-43	13,698	76	64-00	145-44	S	4
Big Mountain	-13	12,144	61	59-23	155-13	N	10
Black Rapids	-30	12,553	73	63-29	145-50	S	4
Blair Lake AF Range	-46	14,068	77	64-23	147-41	S	2
Canyon Creek	-37	13,298	75	64-18	146-32	S	4
Cape Lisburne AFS	-31	17,063	56	68-53	166-07	SSE	7
Cape Newenham AFS	-11	11,481	58	58-39	162-04	N	11
Cape Romanzof AFS	-14	13,130	59	61-47	166-02	NE	18
Cape Sarichef	12	9,985	58	54-36	164-55	NNW	14

* NOTES: 1. Locations in units of degrees-minutes (Latitude N, Longitude W).
2. All design temperatures are 97.5% values.
3. Data source: Reference 6

TABLE 4. DESIGN WEATHER DATA

Station	Winter Design Dry Bulb Temperature	Heating Degree Days	Summer Design Dry Bulb Temperature	Location* N. Lat.	Location* W. Long.	Pvlg. Wind (Dir.)	Mean Speed (Knots)
Cathedral	-51	15,275	75	63-23	143-47	SW	2
Clam Gulch	-21	11,375	64	60-13	151-25	NNE	4
Clear AFS	-47	14,060	77	64-20	149-10	E	4
Cold Bay AFS	9	9,865	57	55-12	162-43	NNW	14
Cordova	-2	9,765	66	60-30	145-29	E	5
Diamond Ridge	2	10,394	61	59-41	151-37	NE	6
Donnelly	-30	12,683	72	63-47	145-51	S	4
Driftwood Bay AFS	11	10,637	59	53-58	166-53	N	15
Dutch Harbor	16	9,197	63	53-53	166-32	N	12
Eielson AFB	-48	14,498	77	64-40	147-06	S	2
Fairbanks IAP	-47	14,344	78	64-49	147-52	N	3
Fort Greely	-43	13,698	76	63-58	145-44	S	4
Fort Richardson/ Bryant AAF	-16	10,722	68	61-16	149-39	NE	4
Fort Wainwright	-47	14,344	78	64-50	147-37	N	3
Fort Yukon AFS	-57	16,084	77	66-34	145-15	SW	3
Galena	-46	15,087	75	64-44	156-56	NW	3
Gerstle River	-41	13,398	76	63-48	145-00	S	4
Gold King Creek	-35	13,364	74	62-12	149-55	E	10
Granite Mountain	-32	14,986	60	65-26	161-14	N	9
Gulkana	-40	13,938	75	62-09	145-27	NNW	3
Harding Lake	-41	13,398	76	64-24	146-57	S	4
Homer	-2	10,364	63	59-38	151-30	NE	6
Hoonah	0	9,552	68	58-07	135-25	N	7

NOTES:
1. *Locations in units of degrees-minutes (Latitude N, Longitude W).
2. All design temperatures are 97.5% values.
3. Data source: Reference 6

TABLE 4. DESIGN WEATHER DATA

Station	Winter Design Dry Bulb Temperature	Heating Degree Days	Summer Design Dry Bulb Temperature	Location* N. Lat.	Location* W. Long.	Pvlg. Wind (Dir.)	Mean Speed (Knots)
Iliamna	-19	12,144	68	59-45	154-55	NNW	8
Indian Mountain AFS	-40	15,169	72	66-00	153-42	NW	3
Juneau MAP	1	9,007	70	58-22	134-35	N	7
Kalakaket Creek	-32	13,942	72	64-26	156-50	NW	3
Kenai MAP	-23	11,615	64	60-34	151-15	NNE	4
King Salmon	-22	11,582	69	58-42	156-40	N	7
Knob Ridge	-49	15,080	75	63-38	144-03	SW	2
Kodiak	13	8,860	65	57-45	152-29	WNW	14
Kotzebue	-37	16,039	64	66-52	162-38	NE	6
Lonely	-41	20,265	53	70-55	153-15	SW	8
McCallum	-26	13,343	70	63-14	145-38	NNW	3
McGrath MAP	-47	14,487	74	62-58	155-37	NW	2
Middleton Island	21	8,188	60	59-27	146-18	NNE	15
Moses Point	-35	14,505	66	64-42	162-03	N	5
Murphy Dome AFS	-32	13,795	71	64-57	148-21	N	3
Naknek	-12	11,133	69	58-45	157-00	N	7
Naptowne	-26	12,054	72	60-32	150-35	NNE	4
Neklason Lake	-22	11,220	75	61-37	149-15	NE	4
Nenana	-50	14,539	77	64-33	149-05	E	4
Nikolski AFS	21	9,555	56	52-58	168-51	N	15
Nome MAP	-27	14,325	62	64-30	165-26	N	4
North River	-33	14,027	64	63-53	160-31	ESE	6
Northway Airport	-53	15,634	75	62-57	141-56	SW	2

NOTES:
1. *Locations in units of degrees-minutes (Latitude N, Longitude W).
2. All design temperatures are 97.5% values.
3. Data source: Reference 6

TABLE 4. DESIGN WEATHER DATA

Station	Winter Design Dry Bulb Temperature	Heating Degree Days	Summer Design Dry Bulb Temperature	Location* N. Lat.	W. Long.	Pvlg. Wind (Dir.)	Mean Speed (Knots)
Ocean Cap	5	9,533	63	59-32	139-51	E	6
Oliktok	-41	20,265	53	70-31	149-53	SW	8
Paxson Lake	-25	13,483	69	62-58	145-28	NNW	3
Pedro Dome	-33	13,600	72	65-02	147-30	N	10
Pillar Mountain	10	9,925	62	57-47	152-26	WNW	14
Point Barrow	-41	20,265	53	71-19	156-38	SW	8
Point Lay	-37	19,194	55	69-44	163-01	ESE	7
Port Heiden	-6	10,441	62	56-59	158-38	NNW	11
Port Moller	-1	10,290	57	55-59	160-30	NNE	12
Rabbit Creek	-13	10,814	65	61-05	149-44	NE	5
St. Paul Island	4	11,119	50	57-09	170-13	N	16
Sawmill	-18	13,531	69	61-48	148-19	NE	4
Seward Rec Annex	7	9,242	68	60-07	149-24	NE	6
Shemya AFB	24	9,573	52	52-43	174E-05	NW	16
Sitka	17	8,132	65	57-03	135-20	E	8
Smuggler Cove	17	7,053	70	55-05	131-35	NE	12
Soldotna	-23	11,615	64	60-32	151-05	NNE	4
Sparrevohn AFS	-26	12,982	67	61-06	155-35	N	9
Starisky Creek	-20	10,885	65	59-53	151-47	NNE	4
Tahneta Pass	-18	14,361	66	61-50	149-19	N	12
Talkeetna	-48**	11,708	91***	62-20	150-05		
Tanana	-48	15,116	76	65-10	152-06	W	4
Tatalina AFS	-28	13,453	71	62-54	155-58	E	4
Tin City AFS	-27	16,192	55	65-34	167-55	N	20
Tolsona	-27	12,763	72	62-06	146-10	N	8
Unalakleet	-34	14,027	65	63-53	160-48	ESE	6

NOTES: 1. *Locations in units of degrees-minutes (Latitude N, Longitude W).
2. All design temperatures are 97.5% values.
3. Data source: Reference 6

** Lowest of Record.
*** Highest of Record.

TABLE 4. DESIGN WEATHER DATA

Station	Winter Design Dry Bulb Temperature	Heating Degree Days	Summer Design Dry Bulb Temperature	Location* N. Lat.	Location* W. Long.	Pvlg. Wind (Dir.)	Mean Speed (Knots)
Valdez	-28**	10,545	85***	61-08	146-21		
Wainwright	-41	19,991	53	70-36	159-53	SW	8
Whittier	5	9,444	70	60-47	148-41	NE	4
Yakataga	10	9,222	63	60-04	142-25	E	6
Yakutat	5	9,533	63	59-31	139-40	E	6

NOTES: 1. *Locations in units of degrees-minutes (Latitude N, Longitude W).
2. All design temperatures are 97.5% values.
3. Data source: Reference 6

** Lowest of Record
*** Highest of Record

Occupancy levels used for computing outside air quantities shall be based on Alaska Department of Education guidelines. Office buildings shall use the Uniform Building Code section as a basis for occupancy, modified by the designer to reflect ultimate building occupancies. (Departures from UBC code requirements will require written authorization from the administrative authority.)

5.3.2.4 **Infiltration:** Infiltration quantities for heating and ventilating design loads shall be calculated using Table 5. These rates are to be used only for sizing central heat-generation equipment, and should be used in conjunction with safety factors as dictated by local practice. Pipe and duct sizing, and sizing the terminal heating unit shall be accomplished using ASHRAE Handbook 1985 Fundamentals Volume (Reference 2).

"Tight" construction results from taking extreme care with vapor and/or air retarder construction, minimum window areas, and doors on one side of the building.

"Medium" construction results from taking moderate care with vapor and/or air barrier construction, and medium amounts of window and door areas distributed on two or more walls of building.

Where the building is to be situated in areas of known extremes in high wind conditions, such as Alaska's coastal areas, air change rates should be adjusted upward, in accordance with local practice.

5.4 Allowable Systems Design Concepts:

The intent of the standard is to mandate levels of building construction to achieve energy conservation. For Alaska, a good energy-conserving design in an urban setting may be totally inappropriate in a remote rural location.

TABLE 5. NATURAL VENTILATION RATE (AC/HR)

Type of Construction	Design Temperature Difference											
	10	20	30	40	50	60	70	80	90	100	110	120
TIGHT	0.14	0.18	0.22	0.25	0.58	0.32	0.36	0.40	0.44	0.47	0.51	0.54
MEDIUM	0.42	0.50	0.57	0.64	0.72	0.80	0.87	0.94	1.02	1.10	1.17	1.25

Much of the building science used in urban settings achieves efficient energy consumption through the use of complex engineering systems that can require a technically trained maintenance staff throughout the life of the building. This type of design, while totally appropriate for the urban setting, can cause major operating problems throughout the life of the rural building, because of the different level of training that operators of rural buildings typically have.

This section presents requirements for the design philosophy of interior mechanical systems, Note that there are two different categories for buildings, **URBAN** and **RURAL** settings,

Additional criteria are levied in the **DESIGN CRITERIA SECTION** of this manual for building design.

5.4.1 System Applicability:

The designer must recognize the remoteness of a site and specify system concept accordingly, conforming to the following criteria.

RURAL SETTINGS:

HVAC systems shall be designed with equipment that is simple to operate, and that provides opportunities for conservation of energy through a combination of automatic and manual controls.

Provide building block systems, where more than one simple subsystem is employed, as opposed to a single central system that serves a number of different zones through complex and interrelated systems.

Opportunities for energy conservation should be provided in the form of clearly marked switches, and easily understood instructions.

Typically, in rural settings, operators of buildings have adequate time for daily operation of the building, preventive maintenance of the building, and monitoring of systems. Systems should, therefore. be designed to allow for daily or weekly monitoring by a maintenance person, with simple operating instructions and adequate manual gauges and readout devices that will allow for proper operation.

URBAN SETTINGS:

Design concepts should reflect the availability of trained controls installers and maintainers that are typically present in urban areas of Alaska. Designers may take advantage of newer, more sophisticated design concepts. The system should be designed for fully unattended operation.

5.4.2 Selection of System Concept:

The designer shall establish the system design concept for HVAC building systems, using the following criteria:

1. Establish the urban or rural character of the site.

   Determining available fuels on site for heat generation.

   Determining availability of heating and electrical energy from on-site total energy systems.

   Establish the occupancy of the building, the number of HVAC zones and the orientation of the building on the site.

   Determining the geographic location, to include wind speed and direction, ASHRAE design temperatures, high or low humidity conditions, and the expected amounts of dust and other outdoor pollutants.

2. The system concept shall be selected to use available fuel, convert this fuel to usable heat energy, transport this energy to all parts of the building, and maintain all spaces within temperature and ventilation criteria, as required by this standard.

3. The use of electric heat is prohibited, except where the following conditions occur:

   In areas where energy is available from renewable resources such as hydro.

In areas where total energy systems are in use. and electric heating is a means of maintaining minimum generator outputs for maintenance. or for load balancing to minimize the total consumption of energy in the building.

4. The HVAC system that is selected shall be capable of establishing the required number of occupancy and temperature control zones within the building.

5.4.3 Use of Heat Recovery:

Air-to-air heat recovery devices for use with outside air/exhaust air systems should be considered, where technically competent maintenance staff are available. Prior to inclusion of heat recovery in a design, an economic analysis of the concept should be accomplished. This analysis should include evaluation of total annual amounts of energy recovered (savings) and the total cost of installing and operating the system. System design concepts shall include a means of controlling frost build up and water/frost removal on exhaust air stream surfaces.

5.5 Controls Design Concepts:

Control systems for heating and ventilating systems shall reflect the rural or urban setting of the building, and shall provide for basic temperature and ventilation control for the building, as described herein. It is the intent of the standard that the availability of competent maintenance and repair personnel be considered when designing controls.

Where competent maintenance and repair personnel are available, more sophisticated controls may be used. For smaller facilities at remote locations, control sequences must be simplified.

5.5.1 Temperature Controls:

All **urban** buildings with sizes greater than 50,000 gross square feet in size shall be fitted with a direct digital control system. **Rural** buildings shall be fitted with electric or pneumatic controls. DDC controls may be employed if local maintenance staff are judged able to operate DDC systems, and power quality control equipment is installed to protect system electronics.

1. Each system shall be provided with at least one thermostat for the regulation of temperature.

2. **Zone Controls:**

   The supply of heating and/or cooling energy to each zone shall be controlled by an individual thermostat or temperature sensor located within each temperature control zone.

3. **Conventional Control System Thermostats:**

   Each thermostat shall be capable of being set by adjustment or selection of sensors as follows:

   a. Where used to control heating only: 55 to 75 degrees F.

   b. Where used to control cooling only: 70 to 85 degrees F.

   c. Where used to control both heating and cooling, each thermostat shall be capable of being set from 55 to 85 degrees F 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 up to 10 degrees F. Deadband is defined as the temperature range in which no heating or cooling energy is used.

5.5.2 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.

5.5.3 Zoning:

At least one thermostat or temperature sensor for regulation of space temperature shall be provided for:

1. Each separate system-

2. Each separate zone.

All building areas that have a separate exposure to exterior environmental loads or internal loads shall be considered as a separate zone.

5.5.4 Controls Setback and Shutoff:

Each system shall be equipped with a readily accessible means of shutting off or reducing the energy used during periods of nonuse or alternate uses of the building spaces or zones served by the system. The following meet this requirement:

1. Separately powered time clocks with spring power backup that will allow timer to continue to function during power failures.

2. Multichannel digital scheduling controllers, with battery backup for scheduling programs.

3. Setback schedules provided by software programming in direct digital control systems.

5.5.5 Ventilation Control Sequencing:

Ventilation air handlers employing outside air for cooling shall be provided with the following minimum control sequencing:

1. Outside and return air dampers shall modulate to maintain mixed air temperature.

2. Outside air damper shall have minimum positioner to provide minimum amount of outside air for ventilation.

3. Outside air dampers shall cycle to minimum position prior to control valve opening on air handling tempering coil.

556 Use of Economizer Cycle:

Each ventilation system shall be designed to automatically use up to 100% of the fan system capacity for cooling with outdoor air.

Exceptions: Cooling with outdoor air is not required under any one or more of the following conditions:

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

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

3. In areas requiring humidification or clean environments, where the use of outside air will increase humidification load beyond that saved by the reduction in mechanical cooling.

5.5.7 Scheduling Outside Air Ventilation:

Each mechanical ventilation system (supply and/or exhaust) shall be equipped with a control capability for the shutoff or volume reduction of outside air ventilation, when ventilation is not required. Automatic powered dampers that close when the system is not operating shall be provided for outdoor air intakes and exhausts. Dampers installed to shut off outside air intakes and exhausts for ventilation systems shall be designed with tight shutoff characteristics to minimize air leakage. All building reliefs shall be fitted with low leakage backdraft dampers and a two-position shutoff damper that is normally open and that closes when power to the fan is withdrawn.

Exception: Motorized dampers are not required on exhaust air outlets where exhaust air flow is less than 1200 CFM.

5.5.8 Requirement for Separate Systems:

1. Separate occupancy zones (that is, spaces that are expected to operate under substantially different operating schedules) either shall be served by separate systems or off-hour controls shall be provided in accordance with Section 5.5.4. For the purposes of this section, spaces shall be considered to operate under substantially different operating schedules if they are expected to operate non-simultaneously for 750 or more hours per year.

2. Spaces with special process temperature and/or humidity requirements shall be served by separate systems from those serving spaces requiring only comfort heating and cooling, or shall include supplementary provision so that the primary system may be specifically controlled for comfort purposes.

3. Separate systems shall be considered for areas of the building having substantially different heating or cooling load characteristics, such as perimeter zones in contrast to interior spaces.

5.5.9 Energy Management Requirements:

All buildings shall be designed with control systems that include adequate controls, and adequate monitoring equipment that will allow the building operator to continuously monitor the functioning of building systems.

The process of energy management hinges on installation of ergonomically adequate controls, and on the ability of the building operator to understand how the building operates. and to be able to intelligently operate the building controls to maintain space temperature conditions and energy efficiency.

5.5.9.1 URBAN SETTING:

For buildings greater than 50,000 SF in size, all control shall be via direct digital controls. For smaller buildings, the designer has the option of using other types of controls.

Buildings shall have the following minimum components:

Building Control: Clearly marked controls for each major piece of equipment. (May be H-O-A with indicators at motor control centers for DDC.)

Manual Monitoring:

Thermometers and flow indicators for hydronic and air systems.

Status and annunciation lights. (Optional for DDC systems where this is supplied at a CRT terminal.)

Visual display of all damper positions for all air handlers.

Indicator lights for the operation of manually controlled exhaust and make-up air fans.

Boiler draft and stack temperature gauges.

Automatic Monitoring

Non-DDC Systems: Provide centralized control panel with readout for all heating and ventilation systems.

DDC Systems: Provide software both for control, and monitoring and alarm annunciation. that has the capability for auto dial modems. Software shall include menu-driven software that will allow access to all building control parameters, and an annunciation display that allows central monitoring the status of building systems.

Metering: Capability of measuring the consumption of energy for the facility. Electrical consumption shall be measured for the total facility by a single service meter- Heating energy shall be measured as follows:

Fuel Oil: Record of filling.

Steam: Metering on steam service, vortex shedding, or inline turbine. (Condensate metering not allowed.)

Coal: Tons delivered.

Natural Gas: mmcf (Utilize totalizing meter. by serving utility)

Electricity: KWH, by serving utility.

Where the building is served by a district steam or hot water source, provide metering for overall delivery of heat energy.

5.5.9.2 RURAL SETTING:

All buildings shall the minimum controls:

Building Controls: Clearly marked controls for each major piece of equipment.

Manual Monitoring:

Thermometers. pressure gauges, and flow indicators for hydronic and air systems.

Status and display lights.

Visual display of outside air damper positions for all air handlers.

Indicator lights for the operation of manually controlled exhaust and make-up air fans.

Boiler draft and stack temperature gauges.

Automatic Monitoring:

Provide limited central monitoring panel with status lights for all critical systems.

Energy Metering:

Provide a means of recording monthly consumption of energy, both electrical and heat energy, as follows:

Electrical energy consumption, (standard service meter-)

Heating fuel consumption. (Provide fuel level gauge; to allow monitoring. Use locking cap to prevent pilfering. Consumption may be determined from fill records.)

Gas consumption. (Meter provided by gas utility.)

Visual display of all damper positions.

Run time for boilers.

During boiler setups, provide means for establishing the flow rate of fuel with nozzle supply pressure.

Generator Waste Heat Utilization Systems:

Where the facility is tied to a waste heat extraction system (such as a jacket water heat extraction system), the design shall allow easy disconnection of waste heat systems from the primary heating systems of the building.

Provide, as a minimum, the following metering capability for energy flow:

Heat flow rate and cumulative delivery of heat energy from waste heat source to building.

5.6 Transport Energy:

5.6.1 General:

Mechanical systems shall be designed to minimize the consumption of electrical energy in the energy conversion and transportation system within the building.

Water and glycol distribution systems shall be designed to accommodate all potential diversities that can be expected between loads in the building.

Larger systems shall be designed with a reverse return, to minimize the use of balance valves for controlling system pressure.

Primary secondary systems shall be used to allow for high temperature drops, and lower pressure losses. wherever possible.

5.6.2 Constant Volume Fan Systems:

For supply and return fan systems which provide a constant air volume whenever the fans are operating, the power required by the prime movers for the combined system at design conditions shall not exceed 1.0 W/CFM.

5.6.3 Variable Air Volume (VAV) Fan Systems:

For supply and return fan systems which are able to vary system air volume automatically as a function of load, the power required by the fan prime movers for the combined system at design conditions shall not exceed 1.4 W/CFM.

5.6.4 Volume Controls:

One of the following shall be installed to control and modulate VAV fans with motors 10 hp and larger. Consideration shall be given to one of the following for VAV systems with motors of less than 10 hp rating.

Vane-axial fans with automatic variable pitch blades.

Mechanical or electrical speed drives, such as AC variable frequency drives, DC variable voltage drives.

Other devices that provide part load performance equivalent or better than the above devices.

5.7 Piping Insulation:

All piping installed to serve buildings and within buildings shall be thermally insulated in accordance with Table 6. (For service water heating systems see Section 7.)

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

1. Piping installed within HVAC equipment-

TABLE 6. MINIMUM PIPE INSULATION THICKNESS (in Inches)

Piping System Types	Fluid Temperature Range, deg F	Pipe Sizes: Runouts* up to 2"	1" & Less	1-1/4" to 1-1/2"	2" to 2-1/2"	3" to 4"	5" & 6"	8" & up
HEATING SYSTEMS								
Hot Water and Steam								
High Pressure/Temp	351 - 450	1.5	2.5	2.5	2.5	3.0	3.5	3.5
Medium Pressure/Temp	251 - 350	1.5	2.0	2.5	2.5	2.5	3.5	3.5
Low Pressure/Temp	201 - 250	1.0	1.5	1.5	2.0	2.0	2.0	3.5
Low Temperature	141 - 200	1.0	1.0	1.0	1.5	1.5	1.5	1.5
Low Temperature	105 - 140	0.5	1.0	1.0	1.0	1.0	1.5	1.5
Steam Condensate (for Feed Water)	Any	1.0	1.0	1.0	1.0	1.5	2.0	2.0
COOLING SYSTEMS								
Chilled Water (Cooling)	40 - 60	0.5	0.5	0.75	0.75	1.0	1.0	1.0
Refrigerant or Brine	Below 40	1.0	1.0	1.5	1.5	1.5	1.5	1.5

* Runouts to individual terminal units not exceeding 12 feet in length.
** Applies to recirculatin gsections of service or domestic hot water sytsems and first 8 feet from storage tank for noncirculating systems.

2. Piping at fluid temperatures between 55 to 105 degrees F).

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

5.7.1 Other Insulation Thicknesses:

Insulation thicknesses in Table 6 are based on insulation having thermal resistivity in the range of 4.0 to 4.6 hrs-sq ft -deg F/BTU-inches on a flat surface at a mean temperature of 75 degrees F. Minimum insulation thickness shall be increased for materials having R-values less than 4.0 hrs-sq ft -deg F/BTU-inches, or may be reduced for materials having R-values greater than 4.6 hrs-sq ft -deg F/BTU-inches.

1. For materials with thermal resistivity greater than 4.6 hrs-sq ft -deg F/BTU-inches the minimum insulation thickness may be deduced as follows:

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

where: TT = Table 6 Insulation Thickness

2. For materials with thermal resistivity less than 4.0 hrs-sq ft -deg F/BTU-inches, the minimum insulation thickness shall be increased as follows:

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

where: TT = Table 6 Insulation Thickness

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

5.8 Insulation of Air Handling System:

All ducts, plenums and enclosures installed in or on buildings shall be thermally insulated as follows.

All duct systems, or portions thereof, shall be insulated to provide a thermal resistance, excluding film resistances, of

R = Delta T/15 hrs-sq ft -deg F/BTU

where Delta T is the design temperature differential between the air in the duct and the duct surface in degrees F.

Ranges of R-values are presented in Table 7.

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

1. Where Delta T is 15 degrees F or less.
2. Ducts in crawl spaces shall be insulated, except where duct heat loss is required to offset crawl space heat **loss.**
3. When the heat gain or loss of the ducts, without insulation, will not increase the energy requirements of the building.
4. Within HVAC equipment.
5. Exhaust air ducts. except within heated envelope downstream of shut-off/back draft dampers.

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

5.9 Duct Construction:

All ductwork shall be constructed and erected in accordance with the following Sheet Metal and Air Conditioning Contractors National Association. Inc. (SMACNA) Standards:

1. HVAC Duct Construction Standards. Metal and Flexible, 1985
2. HVAC Duct Leakage Test Manual, 1985.
3. Fibrous Glass Duct Construction Standards, 5th Edition, 1979.

5.9.1 Ductwork designed to operate at pressure differences greater than 3 inches W. G. shall be tested and be in conformance with the requirements of the **HVAC Duct Leakage Manual.**

TABLE II. REQUIRED R-FACTORS (hrs-sq ft -deg F/BTU)

Delta T Degrees F	R
27	1.8
54	3.6
81	5.4
108	7.2
136	9.1
162	11.0

5.9.2 Ductwork shall not be located outside of the heated thermal envelope, except for insulated and sealed outside and exhaust air ducts.

5.9.3 All ductwork shall be constructed in accordance with the recommendations of the SMACNA HVAC Duct Construction Standard.

5.10 System Testing and Balancing:

5.10.1 Testing:

The system shall be fully tested for correct operation in accordance with the design. This test shall include a full inspection of all installed equipment, and operation of this equipment under all expected operating conditions that may practically be duplicated at the time of inspection.

5.10.2 Balancing:

All control equipment shall be tested, and all pumps, fans and other motor driven equipment shall be operated.

The system design shall provide means for balancing the Building HVAC System. Detailed requirements shall be included in the design documents that will accomplish the following.

1. Provide for the measurement and record of operating parameters of all energy consuming mechanical equipment.

2. Provide verification that all equipment installed is operating in the manner predicted in the design.

5.10.3 Maintenance Documents:

A full and complete maintenance and operations manual shall be a part of the design requirements. This document shall require the construction contractor to assemble complete equipment literature for all energy-consuming components in the building, and a full set of control system equipment components. start-up and operating instructions, system wiring drawings as well as panel and field layouts. A spare parts list shall be a part of the document.

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

Terminology used in this standard conforms to that used in the referenced ASHRAE Standard 90A (Reference 1). Section 6 HEATING, VENTILATING AND AIR-CONDITIONING (HVAC) EQUIPMENT from ASHRAE Standard 90 is included as Appendix B.

7.0 SERVICE WATER HEATING

Terminology used in this standard conforms to that used in the referenced ASHRAE Standard 90A (Reference 1). Section 7 SERVICE WATER HEATING from ASHRAE Standard 90A is included as Appendix B.

8.0 ENERGY DISTRIBUTIONS SYSTEMS - OUTSIDE OF BUILDINGS

There is at present no standard for energy distribution systems outside of buildings. Systems shall be designed for maximum energy efficiency, using the following design concepts.

1. Temperatures for heating and cooling mediums shall be selected to minimize temperature differences between mediums and surrounding areas.

2. Piping insulation shall be adequate for temperatures of heating and cooling mediums.

3. Piping shall be sized to balance pressure drops (pumping energy) and piping surface areas (heat loss).

4. The use of steam as a medium for energy distribution is not allowed, except where necessary for process energy requirements, or where the use of steam will reduce energy loss and pumping costs for energy distributions.

9.0 LIGHTING SYSTEMS

9.1 Purpose:

The purpose of this lighting standard is to conserve energy by providing an upper limit of power consumed to provide the lighting needs for public facilities, in accordance with referenced criteria and calculation procedures.

9.2 Scope:

This standard is not designed to be used as the total lighting design procedure; its purpose is solely to outline a process for determining the limit of maximum power consumption for facility lighting.

9.3 General:

The provisions of this standard establish the maximum watts allowed per square foot of floor area for interior and exterior illumination of public facilities.

Exception:

In lieu of the watts per square foot procedures set forth in this standard, the designer may design the interior lighting requirements in accordance with ASHRAE Standard 90A, Section 9 (Reference 1). ASHRAE Standard 90A, Section 9, is herewith adopted as part of these standards by reference. If ASHRAE Standard 90A is used, the lighting power budget shall be used. In developing the lighting power budget, the designer is encouraged to minimize power consumption.

9.4 Design Procedure Using Watts Per Square Foot of Floor Areas:

To establish the maximum lighting load under the watts per square foot method, the following procedure shall be used.

9.4.1 Interiors:

1. Categorize of the building's occupancy areas with Table 8.

2. Multiply the assigned watts per square foot for the listed use by the gross floor area in square feet included in that category.

TABLE 8. MAXIMUM LIGHTING POWER DENSITIES

Type of Use Categories	Maximum Watts per Square Foot
Interior:	
Auditoriums and Theaters	1.1
Libraries	2.1
Office	2.5
Schools -	
a) Administration, Support Areas	1.9
b) Classroom Areas	2.1
c) Gymnasiums	1.5
High Bay Industrial Occupancies	
a) Repair Garages	1.5 (estimated)
b) Transportation Terminals	2.1 (estimated)
Exterior:	
Facade Lighting	5.0 (per linear foot)
Outdoor Parking and Landscape Lighting	0.1 (per square foot)

Note: All occupancies not listed shall be evaluated using procedures used in Reference 1.

3. In rooms with ceiling height in excess of 20 feet. the watts per square foot of room area may be increased by two percent per foot of height above 20 feet. to a maximum of twice the use limit in Table 8.

9.4.2 Exteriors:

1. Multiply the assigned watts given in Table 8 by the linear feet of the building perimeter to arrive at the lighting power budget for facade lighting.

2. For other exterior lighting, multiply the assigned watts given in Table 8 by the square footage of area to be illuminated.

9.4.3 Lighting Power Budget:

Add the total watts for each use area to arrive at the lighting power budget for the building. Lighting power budgets shall be calculated separately for the building interior and exterior. Total watt budget shall not exceed the allowable budget calculated from Table 8.

9.4.4 Exceptions:

1. Specialty lighting shall not be included in the building lighting power budget.

2. Lighting for8 but not limited to, theatrical, television, spectator sports and like performance areas are not included in the building lighting power budget, nor is the area to be included in the computation of gross floor area.

9.5 Documentation:

Lighting calculations and/or plans shall be submitted for review unless waived in writing. The data shall provide for each use category defined in Table 8. including: total area (square feet); identification of each lighting fixture; its total watts consumption; and the total lighting power budget load in watts/square feet for the area.

9.6 Lighting Switching:

Switching shall be provided for each lighting circuit, or portion of each circuit, so that:

1. Lighting may be operated selectively for custodial services.
2. Lighting in task-lit areas larger than 200 square feet can be reduced by at least one-half when the task is not being performed or is relocated.
3. Lighting may be turned off when an area is empty and not used.
4. Lighting may be reduced or turned off (manually or automatically) where daylighting is adequate and can be used effectively.

10.0 ENERGY REQUIREMENTS FOR BUILDING DESIGN ON SYSTEMS ANALYSIS

Terminology used in this standard conforms to that used in the referenced ASHRAE Standard 90-75 (Reference 7). Section 10 ENERGY REQUIREMENTS FOR BUILDING DESIGN ON SYSTEMS ANALYSIS from ASHRAE Standard 90-75 is included as Appendix C.

11.0 REQUIREMENTS FOR BUILDINGS UTILIZING SOLAR, GEOTHERMAL. WIND OR OTHER NONDEPLETING ENERGY SOURCES

Terminology used in this standard conforms to that used in the referenced ASHRAE Standard 90-75 (Reference 7). Section 11 REQUIREMENTS FOR BUILDINGS UTILIZING SOLAR, GEOTHERMAL, WIND OR OTHER NON-DEPLETING ENERGY SOURCES from ASHRAE Standard 90-75 is included as Appendix C.

12.0 REFERENCES

American National Standards Institute/American Society of Heating, Refrigerating & Air-conditioning Engineers/Illuminating Engineers Society, "ASHRAE Standard: Energy Conservation in New Building Design", Standards 90A-1980. 90B-1975, 90C-1977.

2. American Society of Heating, Refrigerating & Air-Conditioning Engineers, "ASHRAE Handbook and Product Directory, Fundamentals Volume", 1985.

3. American National Standards Institute/American Society of Testing & Materials, "Standard Method of Test for Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors", Standard E 283-84.

4. American Society of Heating, Refrigerating & Air-Conditioning Engineers, "Thermal Environmental Conditions for Human Occupancy", Standard 55-81.

5. American Society of Heating. Refrigerating and Air-Conditioning Engineers, "Natural and Mechanical Ventilation". Standard 62-81.

6. Department of the Air Force, the Army. and the Navy. "Engineering Weather Data". No. AFM 88-29, TM-5-875, NAVFAC P-89, 1 July 1978.

American National Standards Institute/American Society of Heating, Refrigerating & Air-conditioning Engineers/ Illuminating Engineers Society, "ASHRAE Standard: Energy Conservation in New Building Design", Standard 90-75, 1975.

APPENDIX A

ASHRAE Standard 90A

Section 3

3.0 DEFINITIONS

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

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

air conditioning, comfort. 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.[2]

air transport factor. 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.

automatic. 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 manual.)'

BBL. Barrel of oil, **159** litres **(42 U.S.** liquid gallons) Nominal Higher Heating Value **5.924** GJ/BBL **(5.615 × 10⁶** Btu/BBL) for crude oil, **6.145 (5.825 × 10⁶)** for **No. 2** distillate fuel oil and **6.633 (6.287 × 10⁶)** for residual oil. (Source: "Monthly Energy Review", DOE National Information Center. See heating *value* and Chapter **14** of Ref.2).

boiler capacity. The rate of heat output in **W** (Btu/h) 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 × **1.055 = kJ. (See *energy*.)**

building envelope. The elements of a building which enclose conditioned spaces through which thermal energy may **be** transferred **to** or from the exterior or to or from unconditioned spaces exempted by the provisions of **2.1.2.** ***(See*** Section **4.)**

building project. **A** building or group of buildings, including on-site energy conversion or electric-generating facilities which utilize a single submittal for a construction permit **or** are within the boundary of a contiguous area under one ownership, 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; $W/m^2 \cdot {}^\circ C$ $(Btu/ft^2 \cdot h \cdot F)$.

COP. *See coefficient of performance.*

coefficient of beam utilization (CBU). The ratio of the luminous flux (lumens) reaching a specified area directly from a floodlight or projector **to** the total beam luminous flux.[3]

coefficient of performance (COP)—cooling. See the following paragraphs for various definitions of COP as appropriate:

Electrically Operated HVAC System Equipment—Cooling	**6.3.3**
Applied HVAC System Components-Cooling	**6.4.1**
Heat Operated HVAC System Equipment—Cooling	Table **6.7**

coefficient of performance (COP), heat pump—heating. See 6.7.3 for definition.

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.

color rendition. General expression for the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source.

comfort envelope. The area on a psychrometric chart enclosing all those conditions described in ANSI/ASHRAE Standard 55-74[4], Fig. 1, as being comfortable.

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

conditioned space. Space within a building which is provided with heated and/or cooled air or surfaces and, where required, with humidification or dehumidification means so as to maintain a space condition falling within the comfort zone set forth in ANSI/ASHRAE Standard **55-74** "Thermal Environmental Conditions for Human Occupancy." (See **6.1.2** for application)

cooled space. Space within a building which is provided with a ***positive cooling supply.***

degree day, heating. A unit, based upon temperature difference and time, used in estimating fuel consumption and specifying nominal heating load of a building in winter. For any one day, when the mean temperature is less than 18.3°C **(65 F),** there are as many Degree Days as degrees Celsius (Fahrenheit) difference in temperature between the mean temperature for the day and 18.3°C **(65 F).**[2]

dwelling **unit.** A single housekeeping unit comprised of one or more rooms providing complete, independent living facilties for one or more persons including permanent provisions for living, sleeping, eating, cooking and sanitation.

EER. *See energy efficiency ratio.*

economizer cycle. **A** control sequence of an air supply system that modulates the quantity of outdoor air supplied for the purpose of space conditioning in order *to* reduce or eliminate the use of refrigeration energy for cooling.

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 SI units, measured in joules (J), where 1 joule = 1 watt-second; in customary units, measured in kilowatt hours (kWh) or British thermal units (Btu).

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.)***

energy resources. (See ***resource utilization factor, resources consumed.)***

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.

equivalent sphere illumination **(ESI).** The level of sphere illumination which would produce task visibility equivalent to that produced by a specific lighting environment.

exterior envelope. (See ***building envelope.***)

floodlighting. **A** lighting system designated **to** light an area using projector-type luminaires usually capable of being pointed in any direction.

fuel, fossil. Depletable carbonaceous substances which may be oxidized to produce heat or chemically combined to produce electricity (e.g., fuel cell). The heat may be utilized directly or used to produce electricity.

fuel, nuclear. Depletable radioactive substances which, through the process of controlled fission, produce heat. The heat may be utilized directly or used **to** produce electricity.

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

- Covered walkways, open roofed-over areas, porches and similar spaces.

- Pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

gross wall area. See **4.2.2** for definition.

HHV. Higher heat value ***(See hearing value).***

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 **6.1.2.2** and HVAC ***system equipment)***

HVAC system equipment. (See 6.I.**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.

HVAC system efficiency. (See ***efficiency,*** HVAC ***system.)***

heat. The form of energy that is transferred by virtue of a temperature difference.*

heated space, Space, within a building, which is provided with a ***positive heat supply.*** Finished living space within a basement, or registers or heating devices designed to supply heat to a basement space, shall automatically define that space as ***heated space.***

heating value. The amount of heat produced by the complete combustion of a unit quantity of fuel. The gross or Higher Heat Value (HHV) is that which is obtained when all of the products of combustion are cooled to the temperature existing prior to combustion and any water vapor formed during combustion is condensed (contributes the latent heat of vaporization). For fuels containing hydrogen, the net or Lower Heating Value (LHV) is obtained by deducting the latent heat of vaporization of the water vapor, formed by the combustion of the hydrogen in the fuel, from the Higher Heat Value (See *BBL*).

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

illumination. 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.

LHV. Lower heating value ***(See hearing*** value).

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 atmosphere 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.

MCF. Customary term for one thousand cubic feet **(28,320 *l*).**

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

manufactured building. Any building (except a mobile home) which is of closed construction and which is made **or** assembled in manufacturing facilities on or off the building site, or any building of open construction which is made away from the building site for installation or assembly and installation on the building site.

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

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

multi-family dwelling. **A** building containing three or more dwelling units.

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).***

OTTV. Overall thermal transfer value. The maximum thermal transfer permissible into the building through its walls or roof, due to solar heat gain and outdoor- indoor temperature difference, as determined by the equation appearing in Section **4.**

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

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. (For the complete technical definition, **see** Ref. ***5.)***

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. (For the complete technical definition, see Ref. **31.)**

positive cooling supply. Mechanical cooling deliberately supplied to a space, such as through a supply register. **Also,** mechanical cooling indirectly supplied to a space through uninsulated surfaces of space cooling components, such as evaporator coil cases and cooling disbribution systems, which continually maintains air temperatures within the space of 29.4°C **(85 F)** or lower during normal operation. To be considered 'exempt from inclusion in this definition, such surfaces shall comply with the insulation requirements of this Standard.

positive heat supply. Heat deliberately supplied to a space such as a supply register, radiator or heating element. **Also,** heat indirectly supplied **to** a space through uninsulated surfaces of service water heaters and space heating components such as furnaces, boilers, and heating and cooling distribution systems, which continually maintains air temperature within the space of 10°C **(50** F) or higher during normal operation. To be considered exempt from inclusion in this definition, such surfaces shall comply with the insulation requirements of this Standard.

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 SI Units it is measured in joules per second (J/s) or in watts (W); in customary units, it is measured in watts (W) or British thermal units per hour (Btu/h).

public facility restroom. **A** restroom used by the transient public on a 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 7.7.2.)

R. = Thermal resistance. The reciprocal of thermal conductance; **(m²·°C)/W** or (hr·ft²·F)/Btu.

RIF. (See ***resource impact factor.)***

RUF. (See ***resource utilization factor.*)**

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.)'***

recommend. Suggest as appropriate; not required.

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 which would otherwise be wasted **(i.e.** not contribute to a desired end use) from an energy utilization system.

reflectance. The ratio of the light reflected by a surface to the light falling upon it.

registered **engineer.** An appropriately qualified and licensed professional engineer. In addition, with respect **to** Sections **10** and **11,** this means a qualified professional engineer familiar with the climatology of the geographic area in question.

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.

residential building. Living units of one story, two stories, or other low-rise, multi-family dwellings, not exceeding three stories above grade. ***(See Type "A" Building, 4.3,*** and ***dwelling unit.)***

resource energy impact. The product of an energy resource (includes application of RUF) anticipated to be used in providing fuel or energy to a building site multiplied by a RIF for that particular form of energy resource. The total resource energy impact is the sum of all Resource Energy Impacts for a building project.

resource impact factor **(RIF).** Mutipliers applied to fuel and energy resources required by a building project to permit a quantitative evaluation of the effect on those resources resulting from the selection of on-site fuel and energy forms, giving consideration to availability, social, economic, environmental, and national interest issues.

resource utilization factor **(RUF).** Groups of multipliers, applied to the quantity of fuel or energy delivered to a building site, which provide quantitative estimates of the energy resources consumed in providing that fuel or energy. These multipliers account for the burden of processing, refining, transporting, converting and delivering fuel or energy from the point of extraction to the building site.

$$RUF = \frac{\text{resources consumed}}{\text{energy delivered}}$$

where:

resources consumed. The resource extracted from the earth, in standard gravimetric or volumetric units of measure—litres (*l*) of oil, kilolitres (k*l*) of natural gas, tonnes **(Mg)** of coal, grams **(g)** of uranium, etc.— required **to** provide the respective fuel and energy quantities supplied to the building site. Corresponding conventional units are barrels **(BBL)** oil, thousands of cubic feet (MCF) gas, short tons (S. Tons) coal, grams (Grams) uranium, etc. The burdens of extraction are not included.

energy delivered. The fuel and energy supplied to the building site—litres of oil, kilolitres of natural gas, tonnes of coal, gigajoules of electricity—expressed in gigajoules (Higher Heat Value for fossil fuels).(See ***heating value*).** For conventional units energy delivered is expressed in millions of Btu (Higher Heat Value).

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.6

room cavity ratio **(RCR).** A number related to room dimensions used in average illumination calculations.'

S. Ton. Short Ton. Customary term for two thousand pounds mass [0.907 Mg (tonne)].

sequence. A consecutive series of operations.

service systems. **All** energy-using systems in a building that are operated to provide services for the occupants or 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 (SC).

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

Note: To be compared under the same conditions. See Chapter 26. Ref. No. 2.

shall. Where shall is used with a special 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-deplefableenergysources).*

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 $W/m^2 \cdot °C$ $(Btu/ft^2 \cdot h \cdot F)$. 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 $W/m^2 \cdot °C (Btu/ft^2 \cdot h \cdot F)$. 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 which normally include an evaporator or cooling coil, a compressor and condenser combination, and may include a heating function as well. Where such equipment is provided in more than one assembly, the separate assemblies shall be designed to be used together.

unitary heat pump. One or more factory-made assemblies which 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.'

veiling reflections. Regular reflections superimposed upon diffuse reflections from an object that partially or totally obscure the details to be seen by reducing the contrast. This sometimes is called reflected glare.

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 which comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space. (See Reference **8** and Section **5** 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.)

Work plane. The plane at which work usually is done and at which the illumination is specified and measured. Unless otherwise indicated, this is assumed to be a horizontal plane **0.76 m** (30 in.) above the floor.

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.

APPENDIX B

ASHRAE Standard 90A

Sections 6 and 7

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

6.1 Scope. This section deals with equipment and component performance and manufacturers' documentation, in accordance with the criteria for effective utilization of on-site energy established in this Standard, for HVAC-system equipment and HVAC-system components used in new buildings. (see also **2.3)**

6.1.1 This section excludes refrigerating equipment not used to heat, ventilate or air-condition buildings for human comfort.

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

a. Central Air-Distribution Systems. In this type, either HVAC System Equipment **(6.1.2.1),** or an engineered and field-assembled combination of HVAC System Components **(6.1.2.2),** 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.

6.1.2.1 HVAC System Equipment. HVAC System Equipment (6.3, ***6.5,*** 6.6, 6.7. 6.8) 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 separated 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 **6.5.1.**

6.1.2.2 HVAC System Components. HVAC System Components (6.4, 6.6, 6.7) 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, electricallydriven type, or heat-operated type. In aircooled 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.

6.1.3 On-Site Energy. It is recognized that virtually all types of quipment used in HVAC systems will use energy which has been extracted, refined, transported, transformed, or otherwise modified to the state in which it is delivered to the site and then used to drive 'the quipment. The manufacturer cannot predict the relationship between a given form of energy which will be used to drive his products and the nature, source and amount of any or all forms of source energy involved. Therefore, in this Section 6 all energy performance requirements will be based on energy as delivered at the site.

6.1.4 Minimum COP/Efficiency Levels. In succeeding portions of this Section 6, minimum COP and/or efficiency levels are established for HVAC System Equipment (6.1.2.1) and HVAC System Components (6.1.2.2). It is intended that no lower values than those established in this Section shall be acceptable. It is further intended that where equipment of higher COP/Efficiency capability is known to be available on the open market, it shall be the system designer's option to specify such higher efficiencies as he deems to be suitable.

6.2 Responsibility of HVAC System Equipment and System Component Suppliers. Suppliers of HVAC system equipment and system 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.

6.2.1 Where equipment efficiency levels are specified in this section, data furnished by the equipment supplier 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.

6.3 Efficiency Requirements for HVAC System Equipment, Electrically Operated, Cooling Mode. HVAC System Equipment as listed in 6.3.1 and qualified in 6.3.2, whose energy input in the cooling mode is entirely electric, shall, at the Standard Rating Conditions specified in Table 6.1 and additional Standard Rating Conditions specified in applicable standards for particular HVAC system equipment, have an Energy Efficiency Ratio (EER) as defined in Section 3, or a Coefficient of Performance (COP)— Cooling as defined in 6.3.3, not less than values shown in Table 6.2.'

6.3.1 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.

Exception. These requirements do not apply to equipment serving areas such as supermarkets, having

7 a k 6.2. Notes 3, 4 and 5 indicate exceptions whkh shall be observed where DOE regulations apply.

open, refrigerated food display cases, or computers or other equipment contributing a large amount of heat to the area served.

6.3.2 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 6.2).

6.3.3 Coefficient of Performance (COP) — Cooling. This is the ratio of the rate of net heat removal to the rate of total on-site energy input to the air conditioner, expressed in consistent units and under designated rating conditions (See Tables 6.1, 6.3.1 and 6.3.2).

The rate of net heat removal shall be defined as the change in the total heat content of the air entering and leaving the equipment (without reheat).

Total on-site energy input shall be determined by combining the energy inputs to all elements supplied with the package of the equipment, including but not limited to, compressor(s), compressor sump heater(s), pump(s), supply-air fan(s), return-air fan(s), condenser-air fan(s), cooling-tower fan(s) and circulating water pump(s), and the HVAC system equipment control circuit.

6.3.3.1 In the case where any of the above elements is 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 system performance and annual energy consumption.

6.4 Efficiency Requirements for Applied HVAC Syslem Components, Electrically Operated, Cooling Mode. HVAC System Components, as listed in Tables 6.4 and 6.5, whose energy input is entirely electric, shall, at the Standard Rating Conditions specified in Table 6.3.1 for water-chillers and hydronic system water-source heat pumps, and Table 6.3.2 for condensing units, and at additional Standard Rating Conditions specified in applicable standards for particular system components, have an Energy Efficiency Ratio (EER) as defined in Sec. 3, or a Coefficient of Performance (COP) — Cooling, as defined in 6.4.1 and qualified in 6.4.2, not less than the values shown in Tables 6.4 and 6.5.

6.4.1 Coefficient of Performance (COP) — Cooling. This is the ratio of the rate of net heat removal to the rate of total on-site energy input, expressed in consistent units and under designated rating conditions. (See Tables 6.3.1, 6.3.2, 6.4 and 6.5).

The rate of net heat removal from the component is defined as the difference in total heat contents of the water or refrigerant entering and leaving the components.

Total on-site energy input to the component shall be determined by combining the energy inputs to all elements and accessories as included in the component, including but not 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.

6.4.2 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 6.2).

6.5 COP Requirements for HVAC System Equipment — Heat Operated, Cooling Mode

6.5.1 Efficiency Limitation, Equipment., Heat-operated cooling equipment shall have a COP — Cooling not less than the values shown in Table 6.7 when tested at Standard Rating Conditions shown in Table 6.6. These requirements apply to, but are not limited to, absorption equipment, engine-driven equipment, and turbine-driven equipment.

6.5.2 Electrical Auxiliary Inputs. Table 6.7 defines the COP for equipment in a footnote, which excludes electrical auxiliary inputs from the calculation of COP. However, this input shall be included by the system designer in the calculation of the annual energy consumption of the building, or of the total HVAC system COP.

6.6 HVAC System Combustion Heating Equipment

6.6.1 Residential/Commercial Furnaces and Boilers. These include oil- and gas-fired residential furnaces and boilers as defined in the Federal Register Vol. 43, No. 91-May 10, 1978, 430.2 Definitions, page 20154[29] (see Section 3); to vented home heating equipment, as defined therein; and to commercial furnaces and boilers with inputs under 117 kW (400,000 Btu/h).

6.6.1.1 Minimum Required Steady State Efficiencies. All gas- and oil-fired residential furnaces and boilers, and all vented home-heating equipment, shall, when tested in accordance with the applicable DOE furnace test procedures, have not less than the minimum steady state combustion efficiency specified in Table 6.8.

6.6.2 Commercial/Industrial Furnaces and Boilers. For the purposes of this standard, all gas- or oil-fired furnaces and boilers not included in the definitions specified in 6.6.1 shall be referred to as commercial/industrial furnaces and boilers.

6.6.2.1 Minimum Required Steady Slate Efficiency. All gas-and oil-fired commercial/industrial furnaces and boilers shall, when tested in accordance with applicable standards have not less than the minimum steady state combustion efficiency specified in Table 6.8.

6.6.2.2 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 **6.2).**

6.6.3 Adequate Combustion Air. a. Residential/Commercial Installations. a. Residential and Commercial Installations. For residential and commercial installations with inputs under **117 kW (400,000** Btu/h), it is the system designer's responsibility either to establish that the total minimum calculated infiltration rate will provide sufficient combustion air for fuel-fired equipment, or to provide positive means for introducing adequate outdoor air for that purpose.[32,33]

b. Commercial/Industrial. For commercial/industrial installations with inputs 117 kW (400,00 Btu/h) and over, a machine room, or boiler or furnace room, or installation outdoors, shall be provided as required to insure adequate direct outdoor air supply and to comply with governing local codes or ordinances.

6.7 COP Hequirements 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 6.9 and other Standard Rating Conditions specified in applicable standards for particular types of heat pumps (see 6.7. 1), have a Coefficient of Performance (COP)—Heating, as defined in 6.7.3, not less than the values shown in Table 6.10.

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

6.7.1 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.

6.7.2 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 **6.2).**

6.7.3 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 ***6.9*** and **6.10).**

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), retutn-air fan(s), outdoor-air fan(s), cooling-tower fan(s), and the HVAC system equipment control circuit.

6.7.3.1 In the case where any of the above elements including supplementary heaters 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.

6.7.3.2 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.

6.7.4 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, which 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 the compression heating shall be higher than the cut-off temperature for the supplementary heat. Supplementary heat may be derived from any source including, but not limited **to,** electric resistance heating, combustion heating, or solar or stored-energy heating.

6.8 Electric Resistance 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.

6.9 **Maintenance.** Equipment and components which 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 maintenance 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 **6.1**
HVAC Syslem Equipment, Electrically Driven[1]
Standard Rating Temperatures[2] Cooling

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

1. Data in this Table **6.1** apply to the following types of equipment:
   Central Air Conditioners-Air-, Evaporatively- and Water-cooled. ARI Std. **210-78**
   Commercial/Industrial Unitary Air-conditioning Equipment. ARI Std. **360-75**
   Central Unitary Heat Pumps—Air Source, ARI Std. **240-77** (Cooling Mode)
   Central Unitary Heat Pumps—Water Source, ARI Std. **320-76** (Cooling Mode)
   Commercial and Industrial Unitary Heat Pumps-Air and Water Source, ARI Std. **340-76** (Cooling Mode)
   Packaged Terminal Air-Conditioners, ARI Std. **310-76**
   Packaged Terminal Heat Pumps, ARI Std. **380-78** (Cooling Mode)
   Room Air-Conditioners, ANSI **Z234.1-1972**
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 **6.2**
HVAC System Equipment, Electrically Driven[1]
Minimum COP **(EER)—(Cooling)**[2,3,4,5]

Effective Date	Under 19 kW (65,000 Btu/h) Air-Cooled	Under 19 kW (65,000 Btu/h) Evap. or Water Coaled	19 kW (65,000 Btu/h) and Over Air-Coaled	19 kW (65,000 Btu/h) and Over Evap. or Water Cooled
Beginning January **1, 1980**	**1.99 (6.8)**	—	**2.20 (7.5)**	—
Beginning January **1, 1984**	**2.28 (7.8)**	**2.58 (8.8)**	**2.40 (8.2)**[6]	**2.69 (9.2)**

1. **Applies to** quipment as listed for Table ***6.1.* All** performances at sea level.
2. EER is Energy Efficiency Ratio. defined in **Sec. 3;** COP is defined in **6.3.3.**
3. The Department of Energy has established required test procedures for single-phased, aircooled residential central airconditioners under 19 kW **(65,000** Btu/h) in capacity, which have been incorporated into ARI Standard **210-79.** EER (COP) values in Table **6.2** are based on Test **A** of the **DOE** Test Procedures.
4. Any minimum efficiency standard(s) promulgated by the Fedral Government may supersede minimum values, for the products **to** which they apply, established in this Table. **See 2.3.**
5. For Room Air-Conditioners, **DOE** will base its weighted average annual efficiency **on EER** determined in accordance with **ANSI Z 234.1-1972.**
6. Applies when return-air fans are not included under the manufacturer's model **No.** When return-air fans are included, the rquired minimum values are **2.34 (8.0).**

Table 6.3.1
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.		°C (F)	6.7 (44)	6.7 (44)	—
Entering Chilled Water Temp.		°C (F)	12.2 (54)	12.2 (54)	—
Leaving Condenser Water Temp.		°C (F)	35.0 (95)	—	35.0 (95)
Entering Condenser Water Temp.		°C (F)	29.4 (85)	—	29.4 (85)
Air Temperature Entering Indoor Portion of Unit		°C (F)			26.7°C (80 F) DB 19.4°C (67 F) WB
Fouling Factor, Water[3]	Non-Ferrous Tubes		0.00009 (0.0005)[4]	0.00009 (0.0005)[4]	—
	Steel Tubes		0.00018 (0.0010)[4]	0.00018 (0.0010)[4]	—
Fouling Factor. Refrigerant			0.00000[4]	0.00000	—
Condenser Ambient	Air-or	°C (F)	35.0 (95) DB	—	—
	Evap.-Cooled	°C (F)	23.9 (75) WB	—	—
Compressor Saturated Discharge Temperature	Water-or Evap.-Cooled	°C (F)	—	40.6 (105)	—
	Air-Cooled	°C (F)	—	48.9 (120)	—
Refrigerant Liquid Temperature	Water-or Evap.-Cooled	°C (F)	—	35.0 (95)	—
	Air-Cooled	°C (F)	—	43.3 (110)	—
Air Temperature Surrounding Unit		°C (F)	—	—	26.7 (80)

1. Data in this Table 6.3.1 apply to the following types of HVAC System Components:
   Centrifugal or Rotary Water-Chilling Packages ARI Standard 550-77
   Reciprocating Water-Chilling Packages ANSI/ARI Standard 590-76
   Water-Source Heat Pumps ARI Standard 320-76 (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 Standard 450-74 for Water-cooled Refrigerant Condensers, Remote Type
   ARI Standard 480-74 for Refrigerant-Cooled Liquid Coolers, Remote Type
   ARI Standards 550-77 and 590-76 also contain procedures for adjusting ratings for other than the Standard Rating fouling factor.
4. Fouling Factor Units: $m^2 \cdot K/W$ ($ft^2 \cdot h \cdot F/Btu$)

Table 6.3.2
Applied HVAC Syslem Components — Electrically Driven[1]
Standard Rating Conditions—Cooling[2]

Group	Temperatures (Evaporator)[2] Saturation	Return Gas	Condenser[3] Air-Cooled[4] Air Entering (Dry Bulb)	Water-Cooled Water In	Water-Cooled Water Out	Evaporatively-Cooled Air Entering (Wet Bulb)
No.	°C (F)	°C (F)	°C (F)	°C (F)	°C (F)	°C (F)
1	7.2 (45)	18.3 (65)	35 (95)	—	—	—
2	4.4 (40)	18.3 (65)	—	29.4 (89	35 (95)	23.9 (75)

1. Data in this Table apply to HVAC Condensing Units. See ARI Standard 520-78 for Positive Displacement Refrigerant Compressors, Compressor Units and Condensing Units. Data are from Table 3 of ARI 520-78, Groups I and 2.
2. Not put of Condensing Unit; conditions to be maintained by separately furnished condenser.
3. Refrigerant liquid subcooling, in °C (F), shall be stated by the manufacturer as obtained under the conditions below as measured at the liquid line leaving the Condensing Unit.
4. With 35°C (95 F) dry bulb ambient air temperature surrounding unit.

Table 6.4
Applied HVAC System Components, Electrically Driven[1]
Minimum COP (EER)—Cooling[2]

		Water Chilling Packages				Hydronk Heat Pumps	
	Types	Condenser Included		Condenserless		Water Source	
Condenser Cooling Means		Air	**Water**	Air	**Water**	Under 19 kW (65,000 Btu/h)	19 kW (65,000 Btu/h) and Over
Beginning January 1, 1980	C	2.28 (7.8)[4]	3.98 (13.6)[4]	—	—	—	—
	R	2.20 (7.5)	3.40 (11.6)	2.78 (9.5)	3.40 (11.6)	—	—
Beginning January 1, 1984	C	2.34 (8.0)[4]	4.04 (13.8)[4]	—	—	2.64 (9.0)	2.75 (9.4)
	R	2.46 (8.4)	3.51 (12.0)	2.90 (9.9)	3.51 (12.0)	—	—

1. Applies to equipment as listed in Table 6.3.1. 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 Standard 550-77)
   R = Reciprocating Type (ARI Standard 590-76).
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 *5.9.*

Table 6.5
Applied HVAC System Components, Electrically Driven
Condensing Units 19 kW (65,000 Btu/h) and Over[1]
Minimum COP (EER)—Cooling[2]

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

1. Per ARI Standard 520-78 for Positive Displacement Refrigerant Compressors, Compressor Units and Condensing Units.
2. Based on Standard Rating Capacity at Conditions in Table 6.3.2 and at sea level.

Table 6.6
HVAC System Cooling Equipment, Heat-Operated
Standard Rating Conditions — Cooling

		Heat Source	
Standard Rating Conditions		Direct Fired (Cas, Oil)	Indirect Fired (Steam, Hot Water)
Air Conditionen[1]	Units	Temperatures	Temperatures
Entering Conditioned Air	°C (F)	26.7 (80) DB; 19.4 (67) WB	—
Entering Condenser Air	°C (F)	35.0 (95) DB; 23.9 (75) WB	—
Water Chillers[2]			
Leaving Chilled Water	°C (F)	7.2 (45)	6.7 (44)
Fouling Factor	m² · WW (ft² · h · F/Btu)		.00009 (.0005)
Entering Chilled Water	°C (F)	Per Mfgr. Spec.	12.2 (54)
Entering Condenser Water	°C (F)	23.9 (75)	29.4 (85)
Fouling Factor	m² · K/W (ft² · h · F/Btu)		.00018 (.0005)
Leaving Condenser Water	°C (F)	33.0 (95)	—
Condenser Water Flow Rate	litre/W · min (gpm/ton)	—	Pa Mfgr. Spec.

[1] Per ANSI Standard Z21.40.1-1973 and Addenda for Gas-Fired Absorption Summer Air-conditioning Appliances
[2] Per ARI Standard 560-75 for Absorption Water-Chilling Packages

Table 6.7
HVAC System Cooling Equipment, Heat-Operated[1]
Minimum COP[2]

Heat S u m	
Direct Fired (Gas, Oil)	Indirect Fired (Steam, Hut Water)
0.48	0.68

[1] As listed in Table 6.6. At sea level.

[2] Minimum COP = $\frac{\text{Net Cooling Output}}{\text{Total Heat Input (Electrical Auxiliary Inputs Exciudcd)}}$

Table 6.8
HVAC System Heating Equipment—Gas- and Oil-Fired

Types of Equipment	Minimum Steady-State Combustion Efficiencies — Residential/Commercial Boilers and Furnaces — Residential[1]: Furnaces with Inputs less than 65.9 kW (225,000 Btu/h); Boilers with Inputs less than 87.8 kW (300,000 Btu/h); In accordance with DOE Test Procedures	Residential/Commercial[1,2]: Residential Furnaces with Inputs 65.9 kW (22S.000 Btu/h) up to I I7 kW (400,000 Btu/h); Residential Boilers with Inputs 87.8 kW (300,000 Btu/h) up to I17 kW (400,000 Btu/h); Commercial Boilers and Furnaces with Inputs up to 117 kW (400,000 Btu)	Commercial/Industrial Boilers and Furnaces[2,3,4]: Commercial/Industrial Boilers and Furnaces with Inputs 117 kW (400,000 Btu/h) or more
	Steady-State Combustion Efficiencies. Percent		
Forced-Air Furnaces and Low-Pressure Steam or Hot-Water Boilers	74	74	75
Gravity Central Furnaces and other Vented Home Heating Equipment	69	—	—

[1] Residential/Commercial Equipment Including Residential Equipment Covered Under DOE Requirements

ARI 280-74 Central Forced Air Electric Heating Equipment
ANSI 221.1 1.1-1977 (with Addenda 1979)—Gas-Fired Room Heaters, Vol. 1—Vented Room Heaters
ANSI 221.13-1977 (with Addenda 1979)—Gas-Fired Low-Pressure Steam and Hot Water Heating Boilers
ANSI 221.44-1977 (with Addenda 1979)—Gas-Fired Gravity and Fan-Type Direct-Vent Wall Furnaces
ANSI Z21.47-1978—Gas-Fired Gravity and Forced-Air Central Furnaces
ANSI Z21.48-1979—Gas-Fired Gravity and Fan-Type Floor Furnaces
ANSI Z21.49-1979—Gas-Fired Gravity and Fan-Type Vented Wall **Furnaces**
ANSI **Z91.1-1972—Performance** Requirements for Oil-Powered Central Furnaces
ANSI/UL 727—Safety Standard for Oil-Fired Central Furnaces **(October** 1975)
ANSI/UL 729-1975—Safety Standard for Oil-Fired **Floor** Furnaces
ANSI/UL 730-1978—Safety Standard for Oil-Fired Wall Furnaces
UL896-1974—Safety Standard for Oil Fired Room Heaters
HI (January 1977)—Testing and Rating Cast-iron and Steel Heating Boilers

[2] Commercial/Industrial Equipment

ABMA Packaged Firetube Boiler Ratings—1978
ABMA Packaged Commercial-Industrial Boiler Rating Criteria—1978
ASME PTC 4.1—ASME Power Test Code for Steam Generating Units—1976
ANSI **Z21.34-1971—(with** Addenda 1973, 1974)—Gas-Fired Duct Furnaces
ANSI **Z21.52-1971—(with** Addenda 1973) Gas-Fired Single-Firebox Boilers
ANSI Z21.59-1974—Gas-Fired High-Pressure Steam and Hot Water Boilers (Inputs not over **400,000** Btu/h)
ANSI **Z83.3-1971—(with** Addenda 1972,1976)—Gas Utilization Equipment in Large Boilers
UL795-1975—Safety Standard for Gas-Fired Heating Equipment, Commercial-Industrial

In addition, **ANSI** Z21.13, ANSI Z21.47, **ANSI** 291.1, ARI 280 and HI standards listed above are also applicable to commercial/industrial installations.

[3] See 6.6. I
[4] See 6.6.2

Tabk 6.9
HVAC System Heating Equipment (Heat Pumps), Electrically Operated[1]
Standard Rating Conditions'

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

[1]Data apply to following:
Air-Source Unitary H a t Pump Equipment-ARI Standard 240-77
Central Water-Source Heat Pumps-ARI Standard 320-76
Commercial and Industrial H a t Pump Equipment-ARI Standard 340-76
Packaged Terminal H a t Pumps-ARI Standard 380-78
[2]Additional Standard Rating Requirements are specified in the applicable standard
[3]See ARI Standards 320-76, 340-76

Table 6.10
HVAC System Heating Equipment and System Components, Electrically Driven (Heat Pumps)[1,2]
Minimum COP[3]

	Air-Source		Water-Source
Heal Source Entering Temperature °C (F)	8.3 DB/6.1 WB (47 DB/43 WB)	−8.3 DB/−9.4 WB (17 DB/15 WB)	15.6 (70)
Beginning January I, 1980	2.5	1.5	2.5
Beginning January 1, 1984	2.1	1.8	3.0

'Equipment as listed in Table 6.9. 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 6.7.3. 1).
[4]Any minimum efficiency standard(s) promulgated by the Federal Government may supersede such minimum values established in this Table. See 2.3.

7.0 SERVICE WATER HEATING

7.1 Scope

7.1.1 The purpose of this section is to provide criteria for design and equipment selection that will produce energy savings when applied to service water heating.

7.1.2 It is not the intention of this section to develop either a procedure or method for designing a hot water distribution system, other than to offer criteria which, when applied, will reduce unnecessary uses of energy. For a more complete systems design guide, the reader should consult the 1976 ASHRAE HANDBOOK and Product Directory, Systems Volume, Chapter 37, Service Water Heating.[25]

Note: The Department of Energy is developing minimum efficiency standards or several classes of residential appliances in accordance with Public Law 95-619. If and when such standards become effective, they may preempt the recommended minima in this standard.

7.2 General. Hot water for domestic, sanitary and swimming pool purposes shall be generated and delivered in a manner conducive to saving energy.

7.3 Water Heaters, Storage Tanks, Boilers and Piping

7.3.1 Performance Efficiency

7.3.1.1 Electric Water Heaters

7.3.1.1.1 All automatic, electric, storage water heaters having a storage capacity of 450 liters (120 gallons) or less, and an input rating of 12 kW or less, shall have a standby loss not exceeding 43 W/m² (4 W/ft²) of tank surface area, or 43 W, whichever is greater, when tested in accordance with section 430.22e of the D.O.E. water heater test procedure published in the October 4, 1977 Federal Register, amended as to final rule in the September 7, 1979 Federal Register, and calculated at a 44.4°C (80 F) temperature difference.

7.3.1.1.2 All automatic, electric, storage water heaters having either a storage capacity greater than 450 litres (120 gallons) or an input rate greater than 12 kW shall have all water backed storage tank surfaces insulated to an R value of at least $1.76 m^2 \cdot °C/W$ ($10 ft^2 \cdot h \cdot F/Btu$) or a standby loss not exceeding 43 W/m^2 (4 W/ft^2) of tank surface area when tested in accordance with Section 4.3.1 of ANSI C 72.1-72 Household Automatic Electric Storage-Type Water Heaters.

7.3.1.2 Gas and Oil Fired Water Heaters

7.3.1.2.1 All gas and oil fired storage water heaters having an input rate of 22 kW (75,000 Btu/h) or less shall have a recovery efficiency (E,) not less than 75 percent and a stand-by loss not exceeding

$$S = 2.3 + 250/V$$

where S is expressed in percent per hour of the stored thermal energy and where V = volume in litres (S = 2.3 + 67/V, where V = rated volume in gallons) when tested in accordance with section 430.22e of the D.O.E. water heater test procedure published in the October 4, 1977 Federal Register, amended as to final rule in the September 7, 1979 Federal Register.

7.3.1.2.2 All other gas fired water heaters shall have a thermal efficiency (E,) of not less than 75 percent when tested in accordance with section 2.8 of ANSI 221.10.3 - 1975.

7.3.1.2.3 All other oil fired water heaters shall have a combustion efficiency (E,) of not less than 80 percent. Where combustion efficiency is 100 - flue loss, when measured at smoke = 0 (trace is permitted).

7.3.1.2.4 All gas and oil fired water heaters having an input rate over 22kW (75,000 Btu/h) but less than 0.3kW/litre (4,000 Btu/h per gallon) of self stored water shall also have a standby loss not exceeding

$$S = 2.8 + 25.9\ Q/V \quad (S = 2.8 + 0.002\ Q/V)$$

After January 1, 1982 the standby loss shall not exceed

$$S = 2.8 + 250/V \quad (S = 2.8 + 67/V)$$

Where V is the volume in litres and Q is the input in kW (where V = rated volume in gallons and Q = rated input in Btu/h).

7.3.1.2.5 All natural gas and oil fired water heaters having an input rate of more than 0.3 kW/litre (4,000 Btu/h per gallon) of stored water and having a pilot input rate greater than *0.5* percent of the maximum heater input rate (but not exceeding .22 W (750 Btu/h) shall be equipped with an ignition system which is not a continuously burning pilot light.

7.3.2 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.

7.3.2.1 *Exception:* For systems where the use of a single heating unit will lead to energy savings then such a unit should be utilized.

7.3.2.2 *Exception:* Excepted from the provisions of 7.3.2 are systems with service/space heating boilers having a standby loss of W (Btu/h) less than

$$\frac{3.7 \times 10^6\ pmd + 117}{n} \qquad \frac{(13.3\ pmd + 400)}{n}$$

where pmd is the probable maximum demand in m^3/s (gallons/h) determined by the fixture count method as per Chapter 37 of the 1976 ASHRAE HANDBOOK and Product Directory, Systems Volume[25] and n is the fraction of the year when the outdoor daily mean temperature is greater than 18.3°C (*64.9* F).

The standby loss is to be determined for a test period of 24 hour duration while maintaining a boiler water temperature of 32°C (90 F) above an ambient of 16°C (60 F) to 32°C (90 F) and a 1.5 m (5 ft) stack on appliance.

7.3.3 Insulation

7.3.3.1 Heat loss from unfired hot water storage tanks shall be limited to a maximum of 43 W/m^2 (13.6 $Btu/h \cdot ft^2$) of external tank surface area. The design ambient temperature shall be no higher than 18°C (65 F).

7.3.3.2 For recirculation systems, piping heat loss shall be limited to a maximum of 16.8 W per linear metre (17.5 Btu/h per linear ft) of pipe in accordance with Table 7.1 which is based on design external temperature no lower than 18°C (65 F). Other design temperatures must be calculated.

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.

7.4 Temperature Controls. 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 1976 HANDBOOK and Product Directory, Systems Volume, Chapter 37.[25])

7.5 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 the main burner(s) of all other types of service water heating systems.

7.6 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 hot water system is not in operation.

7.7 *Conservation of* Hot Water

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

7.7.2 Lavatories in restrooms of public facilities shall:

a. Be equipped with outlet devices which limit the flow of hot water to a maximum of **0.032** litres/s *(0.5*

APPENDIX C

ASHRAE Standard 90-75

Sections 10 and 11

Table 7.1
Minimum Pipe Insulation

Service Water Heating Temperatures		Insulation Thickness for Pipe Sizes*							
		Non-circulating runouts up to 1"		Circulating Mains & Runouts					
				Up to 1 1/4"		1 1/2"-2"		Over 2"	
°C	F	mm	In.	mm	In.	mm	In.	mm	In.
76.5-82	170-180	12.7	0.5	25.4	1.0	38.1	1.5	50.8	2.0
60-71	140-160	12.7	0.5	12.7	0.5	25.4	1.0	38.1	1.5
38-54	100-130	12.7	0.5	12.7	0.5	12.7	0.5	25.4	1.0

*Nominal Iron pipe size and insulation thickness.
Conductivity K ~ .27

gpm) or, be equipped with self-closing valves that limit delivery to a maximum of 0.94 litres (0.25 gallons) of hot water for recirculating systems and to a maximum of 1.9 litres (0.50 gallons) for non-recirculating systems.

b. Be equipped with devices which limit the outlet temperature to a maximum of 43°C (110 F).

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

7.8 Swimming Pools

7.8.1 Pool Heaters

7.8.1.1 All pool heaters shall 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 to allow restarting without relighting the pilot light.

7.8.1.2 After January 1, 1982, all gas and oil fired pool heaters shall have a thermal efficiency of 75 percent when tested in accordance with ANSI Z21.56-1975.

7.8.1.3 Active solar heating systems should be used to supply a portion of the pool heating requirements when conditions permit their cost effective installation.

7.8.2 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.)

7.8.3 Time Clocks. Time clocks shall be installed so that the pump can be set to run in the off-peak electric demand period and can be set for the minimum time necessary to maintain the water in a clear and sanitary condition in keeping with applicable health standards.

7.9 Utilization of Waste Heat or Solar Energy

7.9.1 Consideration should be given to the use of condenser heat, waste energy, or solar energy to supplement hot water requirements when the first year's fuel cost savings resulting from the installation of such devices exceeds 20 percent of the initial additional cost.

7.9.2 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.

ASHRAE/IES 90B-1975 (Sections 10 and 11 of ASHRAE/IES Standard 90-75)

The following Sections 10 and 11 (90B-1975) are identical to Sections 10 and 11 of Standard 90-75. They are included here for completeness and for the convenience of the user.

90B-1975 (designated for review 90.2-75R) is currently under revision and when and if the revision is approved it will supersede the Sections 10 and 11 in this document.

10.0 ENERGY REQUIREMENTS FOR BUILDING DESIGN ON SYSTEMS ANALYSIS

10.1 Scope

This section is included to provide an opportunity to deviate from the specific design criteria of Sections 4 through 9 by demonstrating that such deviations will result in annual energy consumption equal to or less than that resulting from compliance with these criteria.

10.1.1 Annual energy analyses are not required for buildings and alternative designs using various combinations of source energy which comply with Sections 4 through 9. Analysis criteria set forth in this section may be used to establish the annual energy requirements of each proposed design and in so doing will indicate the relative energy effectiveness of each design, thereby providing a basis on which the building owner and/or designer may select one system over another.

10.1.2 If any proposed design deviates from the specified design criteria of Sections 4 through 9, that design's annual energy consumption shall be compared to a similar building/system/energy source combination which does conform to Sections 4 through 9 (defined as a "standard design") to qualify it as an acceptable design. For instance, if electric heating and/or electric cooling are proposed for an alternate design which deviates from the criteria of Sections 4 through 9, then electric heating and/or electric cooling shall also be used in the comparative standard design to justify the deviation from the design criteria of Sections 4 through 9.

10.2 Equivalent Annual Energy Consumption

The standard design, conforming to the criteria of Sections 4 through 9, and the proposed alternative design shall be analyzed using the same procedures. The comparison shall be on a common basis. That is, it shall use equal floor area and equal environmental requirements. The comparison shall be expressed as Btu input per gross building square foot per year (MJ/m^2 per year).

10.2.1 Basis for Comparison. All forms of energy usage by both designs (standard and proposed alternate) covered under the provisions of Sections 4 through 9, shall be included in the comparison. Common climatic data, building occupancy, and building usage operational schedules shall be used in comparison. Where similar generic types of equipment and energy sources are applicable to the standard and proposed alternative design, such equipment and specific part load performance of such equipment along with related accessories shall be used in the comparison. In this type of comparison, identical energy forms shall serve the same purpose in both the standard and proposed alternative designs. (Electric cooling shall be compared to electric cooling, gas heating shall be compared to gas heating, etc.)

If the proposed alternative design results in an increase in consumption of one energy source and a decrease in another energy source (even though similar sources are used for similar purposes) the differences in each energy source shall be converted to equivalent energy units for purposes of comparing the total energy used.

10.3 Analysis Procedure

The analysis of the annual energy usage of the standard and the proposed alternative building and system designs shall meet the following criteria:

10.3.1 The building heating/cooling load calculation procedure used for annual energy consumption analysis shall be of sufficient detail to permit the evaluation of effect of building data (such as orientation, size, shape, transfer characteristics of mass, air, moisture, and heat) and hourly climatic data.

10.3.2 The calculation procedure used to simulate the operation of the building and its service systems through a full year operating period shall be of sufficient detail to permit the evaluation of the effect of system design, climatic factors, operational characteristics, and mechanical equipment on annual energy usage. Manufacturer's data or comparable field test data shall be used when available in the simulation of all system and equipment. The calculation procedure shall be based upon 8760 hr of operation of the building and its service systems and shall utilize techniques recommended in the appropriate ASHRAE publications or produce results consistent with such recommended procedures.

10.3.2.1 The calculation procedure shall explicitly cover the following items:

a. Climatic data: coincident hourly data for temperatures' solar radiation, wind and humidity of typical days in 'the year representing seasonal variation
b. Building data: orientation, size, shape, mass, air, moisture and heat transfer characteristics
c. Operational characteristics: temperature, humidity, ventilation, illumination, control mode for occupied and non-occupied hours
d. Mechanical equipment: design capacity, part load profile
e. Internal heat generation, lighting, equipment, number of people during occupied and non-occupied periods

10.4 Documentation

Proposed alternative designs, submitted as requests for exception to the standard design criteria, shall be accompanied by an energy analysis comparison report prepared by a registered engineer. The report *shall* provide sufficient technical detail on the two building and system designs and on the data used in and resulting from the comparative analysis to verify that both the analysis and the designs meet the criteria of 10.1 through 10.3.2.

10.4.1 The documentation *shall* demonstrate that the analysis used is consistent with the techniques and procedures specified by the following ASHRAE documents:

a. 1972 ASHRAE HANDBOOK OF FUNDAMENTALS[1]
b. 1973 ASHRAE HANDBOOK & Product Directory, Systems Volume[2]
c. *Energy Calculations* I: "Procedures for Determining Heating and Cooling Loads for Computerizing Energy Calculations – Algorithms for Building Heat Transfer Subroutines," 1975[3]
d. *Energy Calculations* II: "Procedures for Simulating the Performance of Components and Systems for Energy Calculations," 1975[4]

EXCEPTION. Proposed alternative designs for single-family, detached residential buildings and for light commercial structures having the indoor temperature controlled from a single point *may* be exempted from the full-year energy analysis as described in 10.3. A registered professional engineer shall, however, provide a comparison of energy consumption between the alternative design and the standard design. Simplified energy analysis, such as bin or Degree-Day methods, details of which can be found in Chapter 11[5] and 43[6] of the 1973 ASHRAE HANDBOOK & Product Directory, Systems Volume, may be used for this comparison.

References Used in Section 10

[1] ASHRAE HANDBOOK OF FUNDAMENTALS, ASHRAE, New York, NY, 1972.

[2] ASHRAE HANDBOOK & Product Directory, Systems Volume, ASHRAE, New York, NY, 1973.

[3] *Energy Calculations I:* "Procedure for Determining Heating and Cooling Loads for Computerizing Energy Calculations – Algorithms for Building Heat Transfer Subroutines," ASHRAE. New York, NY, 1975.

[4] *Energy Calculations II:* "Procedures for Simulating the Performance of Components and Systems for Energy Calculations:' 3rd ed., ASHRAE. New York, NY, 1975.

[5] ASHRAE HANDBOOK & Product Directory, Systems Volume, Chapter 11, ASHRAE, New York. NY, 1973.

[6] ASHRAE HANDBOOK & Product Directory. Systems Volume, Chapter 43, ASHRAE, New York, NY, 1973.

11.0 REQUIREMENTS FOR BUILDINGS UTILIZING SOLAR, GEOTHERMAL, WIND OR OTHER NON-DEPLETING ENERGY SOURCES

11.1 General

When a proposed alternative building and service system design, submitted and evaluated in accordance with Section 10 of this Standard, utilizes solar, geothermal, wind or other nondepletable 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 specific collection, storage and distribution system, The solar energy passing through windows *shall* also be considered as qualifying if such windows are provided with (1) operable insulating shutters or other devices which, when drawn or closed, *shall* cause the window area to reduce maximum outward heat flows to those in accordance with Fig. 1 and 3 of Section 4, and (2) the window areas are shaded or otherwise protected from the direct rays of the sun during periods when cooling is required.

11.1.1 This provision shall also apply to nocturnal cooling processes in lieu of energy-consuming refrigeration processes.

11.1.2 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, submitted as requests for exception to the standard design criteria, *shall* be accompanied by an energy analysis prepared by a registered engineer, as defined in Section 3. 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 as to verify that both the analyses and the designs meet the criteria of 10.2 and 10.3 and this section. The energy derived from nondepletable sources and the reduction in conventional energy requirements derived from nocturnal cooling, *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 or nocturnal cooling means, must be submitted.

EXCEPTIONS. Proposed alternative designs for residential and light commercial structures of less than 20,000 ft^2 (1860 m^2) that derive a significant portion of their total annual energy usage from nondepletable sources or from nocturnal cooling, shall be exempt from the requirement of a full-year energy system analysis, providing that a registered engineer concurs in writing that the average annual input of such nondepletable sources, or the extent of such nocturnal cooling can reasonably be expected to meet the demands imposed by the proposed alternative design. Other commercial, institutional and industrial structures that derive over 50 percent of their annual thermal requirements (heating, cooling, service water heating) or over 30 percent of their annual total energy requirements from nondepletable sources *shall* be exempted from the necessity of comparing the proposed design to a standard design which follows the provisions of Sections 4 through 9. Documentation, provided by a registered engineer, verifying the percentage of annual energy use derived from such nondepletable sources *shall* be required as provided in 11.2.