PART 16

Energy Conservation and Design Conditions

16.01 *The 1989 CABO Model Energy Code*

A. *The 1989 CABO Model Energy Code* is common to all three major U.S. codes (*1990 BOCA, 1988 SBCCI, 1988 UBC*) and is based on *ASHRAE Standard 90A 1980, Energy Conservation in New Building Design.*

B. *1990 BOCA, 1988 SBCCI,* and the *1988 UBC* codes also reference *ASHRAE Standard 90A-1980.*

C. Model Energy Code Design Conditions:

1. Outdoor Latest Version of *ASHRAE Handbook of Fundamentals:*
   a. Heating 97½% Values, Minimum
   b. Cooling 2½% Values, Maximum
2. Indoor:
   a. Heating 70°F.; 30% RH Max.
   b. Cooling 78°F.; 30 to 60% RH

D. The Model Energy Code Economizer Requirements:

1. Systems 5,000 CFM and larger or 134,000 Btuh total cooling capacity and larger shall be designed to use up to and including 100 percent of the fan system capacity for cooling with outdoor air automatically whenever the use of outdoor air will result in lower usage of energy.
2. Exceptions (partial list):
   a. Systems where the quality of outdoor is poor and will require extensive treatment.
   b. Systems where humidification or dehumidification requires more energy than is saved by outdoor air cooling.
   c. Systems where outdoor air cooling will increase the overall energy consumed by other systems.
   d. Systems where cooling is accomplished by equipment other than refrigeration equipment (i.e., cooling towers—waterside economizer).

E. Ventilation:

1. Systems shall be provided with a readily accessible means for ventilation shutoff (close OA dampers) when ventilation is not required (i.e., unoccupied periods).

F. Simultaneous Heating and Cooling:

1. Systems that employ simultaneous heating and cooling in order to achieve comfort conditions shall be limited to those situations where more efficient methods of providing HVAC cannot be effectively utilized. Simultaneous heating and cooling by reheating or recooling supply air or by concurrent operations of independent HVAC systems shall be restricted as follows:
   a. Reheat systems shall be provided with controls to automatically reset the system's cold deck supply air temperature to the highest temperature that will satisfy the zone requiring the coolest air.
   b. Dual duct and multizone systems shall be provided with controls to automatically reset the cold deck and the hot deck supply air temperatures to the highest and lowest temperatures, respectively, that will satisfy the zones requiring the coolest and warmest air.

G. Controls:

1. Temperature Controls:
   a. Heating Only 55°F.–75°F.

   b. Cooling Only 70°F.–85°F.
   c. Heating and Cooling 55°F.–85°F.
2. Humidity Controls:
   a. Winter/Heating 30% Maximum.
   b. Summer/Cooling 60% Minimum.
   c. Note above items are values when using energy to humidify/dehumidify, respectively.
3. Setback and Shutoff. Each HVAC system shall be equipped with a readily accessible means of reducing energy used for HVAC during periods of non-use or alternate uses of the building spaces or zones served by the system.
   a. Winter. Night Setback.
   b. Summer. Night Setup.
   c. Occupied Periods. Time Clocks, Automatic Control Systems.
   d. Unoccupied Periods. Manually Adjustable Automatic Timing Devices.

16.02 *ASHRAE Standard 90A-1980, Energy Conservation in New Building Design*

A. Purpose:

1. To provide design requirements which will improve utilization of energy in new buildings and to provide a means of determining the anticipated impact of that energy utilization on the depletion of energy resources.
2. To provide energy efficient design of building envelopes, energy efficient design and selection of mechanical, electrical, service water heating, and illumination systems and equipment, and to provide prudent selection of fuel and energy sources.
3. To encourage the use of innovative approaches and techniques to achieve effective utilization of energy.
4. To provide energy efficient design standards for new buildings which can be utilized during the preconstruction stage.

B. Scope:

1. Design of new buildings for human occupancy.
2. Building Envelope.
3. Selection of Systems and Equipment:
   a. HVAC.
   b. Service Water Heating.
   c. Energy Distribution.
   d. Illuminating Systems.
4. Exceptions:
   a. Buildings whose peak energy usage is less than 3.5 Btu/Hr. Sq.Ft. of gross floor area
   b. Buildings which are neither heated nor cooled
5. This standard does not include operation and maintenance criteria.

C. HVAC Systems Design:

1. Heating and Cooling Load Calculation Procedures—*ASHRAE Handbook & Product Directory 1977 Fundamentals* or equivalent computational procedure.
2. Indoor Design Conditions: *ANSI\ASHRAE Standard 55-1974 Thermal Environmental Conditions for Human Occupancy:*
   a. Heating (Winter)
      1) *ASHRAE Standard 90A-1980:* 72°F. Dry Bulb Recommended; 30% RH Maximum.
      2) Most Commonly Used Design Condition: 72°F. DB.

b. Cooling (Summer):
   1) *ASHRAE Standard 90A-1980:* 78°F. Dry Bulb Recommended.
   2) Most Commonly Used Design Condition: 75°F./50% R.H.

3. Outdoor Design Conditions: *ASHRAE Handbook & Product Directory 1977 Fundamentals* or from local climate data:
   a. Heating (Winter): 97.5% Values, Minimum.
   b. Cooling (Summer): 2.5% Values, Maximum.
4. Ventilation:
   a. Meet *ASHRAE/ANSI Standard 62-1973, Natural and Mechanical Ventilation*.
   b. Air required for exhaust makeup, for source control of contaminants, or codes.

D. Controls:

1. System Control. At least 1 temperature control device:
   a. Heating Only: 55°F. to 75°F.
   b. Cooling Only: 70°F. to 85°F.
   c. Heating and Cooling: 55°F. to 85°F. with adjustable deadband of 10°F. or more.
2. Humidity Control:
   a. Humidistat is required for winter humidification, 30% maximum winter humidity level for comfort purposes.
   b. If a humidistat is used for summer dehumidification, 60% minimum summer humidity level is required for comfort purposes.
3. Zone Control:
   a. Residential Occupancies: Individual thermostatic controls for each system or dwelling unit.
   b. All Other Occupancies:
      1) Each System.
      2) Each Floor.
      3) Each Separate Zone. A zone is a space or group of spaces with similar heating and/or cooling requirements.
4. Off-Hours Controls:
   a. Provide each system with a readily accessible, manual, or automatic means of shutting off or reducing the energy used during unoccupied periods.

E. Simultaneous Heating and Cooling Systems:

1. The use of simultaneous heating and cooling systems will be limited to circumstances where more energy efficient systems cannot meet building design requirements.
2. Reheat, Dual Duct, Multi-Zone, and Recooling Systems will employ automatic temperature reset controls for both hot and cold airstreams.

F. Economizer controls are required:

1. Air Side Economizers: Dry-Bulb Temperature or Enthalpy.
2. Exceptions:
   a. Fans with a capacity of less than 5000 CFM or total cooling capacity of less than 134,000 Btuh.
   b. Annual heating degree days are less than 1,200.
   c. When the system will be operated less than 30 hours per week.
   d. Systems serving single-family or multi-family residential buildings.

G. Mechanical Ventilation:

1. Supply and exhaust systems shall be provided with a readily accessible means to shut off or reduce the ventilation air when the building is unoccupied.

H. Transport Energy:

1. All air systems, air and water systems, and water systems shall have a transport factor 5.5 or greater. Transport factors are the space sensible heat expressed in Btu/Hr. divided by the sum of the supply fan(s), return fan(s), terminal fan(s), and pump(s) input energy expressed in Btu/Hr.

I. Piping Insulation. Insulation is required on:

1. Heating Systems (Hot Water, Steam, Steam Condensate): 120°F. and Higher.
2. Cooling Systems (Chilled Water, Brine, and Refrigerant): 55°F. and Lower.
3. Domestic and Service Hot Water Systems: 100°F. and Higher.
4. Insulation not required on systems where Fluid Temperature is between 55°F. and 120°F.
5. Required Insulation Thickness depends on Fluid Temperature, Insulation Type, and Pipe Size.
6. Insulation Thickness is given in the following table:

PIPING SYSTEM	FLUID TEMP. °F.	INSULATION THICKNESS FOR PIPE SIZES - INCHES (1,3)					
		RUNOUTS UP TO 2" (2)	1" & SMALLER	1-1/4" - 2"	2-1/2" - 4"	5" & 6"	8" & LARGER
HEATING SYSTEMS - STEAM AND HOT WATER							
HIGH PRESSURE/ TEMPERATURE	306-450	1.5	2.5	2.5	3.0	3.5	3.5
MEDIUM PRESSURE/ TEMPERATURE	251-305	1.5	2.0	2.5	2.5	3.0	3.0
LOW PRESSURE/ TEMPERATURE	201-250	1.0	1.5	1.5	2.0	2.0	2.0
LOW TEMPERATURE	120-200	0.5	1.0	1.0	1.5	1.5	1.5
STEAM CONDENSATE	ANY	1.0	1.0	1.5	2.0	2.0	2.0
COOLING SYSTEMS							
CHILLED WATER	40-55	0.5	0.5	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

Notes:

1. **Insulation thicknesses based on insulation having a thermal resistivity in the range of 4.0 to 4.6 Ft^2 Hr. °F./Btu. In.**
2. **Runouts to individual terminal units not exceeding 12 feet.**
3. **For piping exposed to ambient temperatures, increase insulation thickness by 0.5″.**

J. Air Handling System Insulation. Insulation is required on all ducts, plenums, and enclosures:

1. Insulation is required when the Temperature Difference between Air Temperature and Space Temperature is Greater than 25°F.
2. Exceptions:

a. Where the temperature difference is 14°F or less.
b. Within HVAC equipment.
c. Exhaust air ducts.

3. Insulation Thickness is given in the following table:

TEMPERATURE DIFFERENCE °F	R-VALUE SQ.FT. HR. °F./BTU
25	1.7
27	1.8
54	3.6
81	5.4
108	7.2
136	9.1
162	11.0

K. Duct Construction:

1. *SMACNA Heating and Air Conditioning Systems Installation Standards,* 3rd Ed., February 1977.
2. *SMACNA Low Pressure Duct Construction Standards,* 5th Ed., 1976.
3. *SMACNA High Pressure Duct Construction Standards,* 3rd Ed., 1975.
4. *SMACNA Fibrous Glass Duct Construction Standards,* 4th Ed., 1975.
5. High pressure and medium pressure ducts shall be leak tested in accordance with SMACNA Standard.

L. Balancing:

1. System design shall provide a means for balancing both air and water systems.

M. HVAC Equipment:

1. Minimum Equipment Efficiencies.
2. Equipment Rating shall be Certified by Nationally Recognized Standards.

16.03 *ASHRAE Standard 90A-a-1987, Energy Conservation in New Building Design*

A. HVAC Systems Design:

1. Heating and Cooling Load Calculation Procedures. *ASHRAE Handbook 1981 Fundamentals* or similar computational procedure.
2. Indoor Design Conditions: *ANSI\ASHRAE Standard 55-1981 Thermal Environmental Conditions for Human Occupancy*.
   a. Satisfy 80% or More of the Occupants.
   b. Heating (Winter):
      1) *ASHRAE Standard 90A-a-1987:* 72°F. Dry Bulb Recommended; 30% RH Maximum.

2) *ASHRAE Standard 55:* 68°F.–74°F. Dry Bulb (DB) at 60% RH; 69°F.–76°F. DB at 36°F Dew Point (DP).
3) Most Commonly Used Design Condition: 72°F DB.

c. Cooling (Summer):
1) *ASHRAE Standard 90A-a-1987:* 78°F. Dry Bulb Recommended.
2) *ASHRAE Standard 55:* 73°F.–79°F. DB at 60% RH; 74°F.–81°F. DB at 36°F DP.
3) Most Commonly Used Design Condition: 75°F/50% R.H.

3. Outdoor Design Conditions: *ASHRAE Handbook 1981 Fundamentals* or from local climate data:
a. Heating (Winter): 97.5% Values, Minimum.
b. Cooling (Summer): 2.5% Values, Maximum.

B. Duct Construction:

1. *SMACNA Heating and Air Conditioning Systems Installation Standards,* 3rd Ed., February 1977.
2. *SMACNA Low Pressure Duct Construction Standards,* 5th Ed., 1976.
3. *SMACNA High Pressure Duct Construction Standards,* 3rd Ed., 1975.
4. *SMACNA Fibrous Glass Duct Construction Standards,* 5th Ed., 1979.

16.04 *ASHRAE Standard 90.1-1989, Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings*

A. Purpose:

1. To set minimum requirements for the energy efficient design of new buildings so that they may be constructed, operated, and maintained in a manner that minimizes the use of energy without constraining the building function or the comfort or productivity of the occupants.
2. To provide criteria for energy efficient design and methods for determining compliance with these criteria.
3. To provide sound guidance for energy efficient design.
4. It is estimated that as much as 40% of the energy used to heat, cool, and illuminate buildings and to provide hot water could be saved through the effective application of existing technology without reducing building performance or human comfort.

B. Scope:

1. Building Envelope
2. Distribution of Energy
3. Systems and Equipment:
a. Auxiliaries
b. Heating
c. Ventilating
d. Air-Conditioning
e. Service Water Heating
f. Lighting
4. Energy Management

C. Application:

1. To all new Buildings or Portions of Buildings that provide Facilities or Shelter for Human Occupancy and use Energy Primarily to provide Human Comfort.

2. Does not apply to: Areas of Buildings used for Manufacturing, Commercial or Industrial Processing.

D. NEMA Design B; Single Speed; 1200, 1800, or 3600 RPM; Open Drip Proof (ODP) or Totally Enclosed Fan Cooled (TEFC) Motors 1 Hp and Larger that operate more than 500 hours per year must meet the following minimum nominal efficiencies:

Horsepower	Minimum Nominal Efficiency
1 - 4	78.5
5 - 9	84.0
10 - 19	85.5
20 - 49	88.5
50 - 99	90.2
100 - 124	91.7
125 or Greater	92.4

Note: Above table is based on *ASHRAE Standard 90.1* prior to adoption of Addendum 90.1c by ASHRAE Board of Directors.

E. NEMA Design A and B; Open Drip Proof (ODP) or Totally Enclosed Fan Cooled (TEFC) Motors 1 Hp and Larger that operate more than 1000 hours per year must meet the following minimum nominal efficiencies; Minimum Acceptable Nominal Full-Load Motor Efficiency for Single Speed Polyphase Squirrel-Cage Induction Motors having Synchronous Speed of 3600, 1800, 1200, and 900 RPM:

Full Load Efficiencies–Open Motors

HP	2-POLE		4-POLE		6-POLE		8-POLE	
	NOMINAL EFF.	MINIMUM EFF.	NOMINAL EFF.	MINIMUM EFF.	NOMINAL EFF.	MINIMUM EFF.	NOMINAL EFF.	MINIMUM EFF.
1.0	---	---	82.5	81.5	80.0	78.5	74.0	72.0
1.5	82.5	81.5	84.0	82.5	84.0	82.5	75.5	74.0
2.0	84.0	82.5	84.0	82.5	85.5	84.0	85.5	84.0
3.0	84.0	82.5	86.5	85.5	86.5	85.5	86.5	85.5
5.0	85.5	84.0	87.5	86.5	87.5	86.5	87.5	86.0
7.5	87.5	86.5	88.5	87.5	88.5	87.5	88.5	87.5
10.0	88.5	87.5	89.5	88.5	90.2	89.5	89.5	88.5
15.0	89.5	88.5	91.0	90.2	90.2	89.5	89.5	88.5
20.0	90.2	89.5	91.0	90.2	91.0	90.2	90.2	89.5
25.0	91.0	90.2	91.7	91.0	91.7	91.0	90.2	89.5
30.0	91.0	90.2	92.4	91.7	92.4	91.7	91.0	90.2
40.0	91.7	91.0	93.0	92.4	93.0	92.4	91.0	90.2
50.0	92.4	91.7	93.0	92.4	93.0	92.4	91.7	91.0
60.0	93.0	92.4	93.6	93.0	93.6	93.0	92.4	91.7
75.0	93.0	92.4	94.1	93.6	93.6	93.0	93.6	93.0
100.0	93.0	92.4	94.1	93.6	94.1	93.6	93.6	93.0
125.0	93.6	93.0	94.5	94.1	94.1	93.6	93.6	93.0
150.0	93.6	93.0	95.0	94.5	94.5	94.1	93.6	93.0
200.0	94.5	94.1	95.0	94.5	94.5	94.1	93.6	93.0

Full Load Efficiencies–Enclosed Motors

HP	2-POLE		4-POLE		6-POLE		8-POLE	
	NOMINAL EFF.	MINIMUM EFF.	NOMINAL EFF.	MINIMUM EFF.	NOMINAL EFF.	MINIMUM EFF.	NOMINAL EFF.	MINIMUM EFF.
1.0	75.5	74.0	82.5	81.5	80.0	78.5	74.0	72.0
1.5	82.5	81.5	84.0	82.5	85.5	84.0	77.0	75.5
2.0	84.0	82.5	84.0	82.5	86.5	85.5	82.5	81.5
3.0	85.5	84.0	87.5	86.5	87.5	86.5	84.0	82.5
5.0	87.5	86.5	87.5	86.5	87.5	86.5	85.5	84.0
7.5	88.5	87.5	89.5	88.5	89.5	88.5	85.5	84.0
10.0	89.5	88.5	89.5	88.5	89.5	88.5	88.5	87.5
15.0	90.2	89.5	91.0	90.2	90.2	89.5	88.5	87.5
20.0	90.2	89.5	91.0	90.2	90.2	89.5	89.5	88.5
25.0	91.0	90.2	92.4	91.7	91.7	91.0	89.5	88.5
30.0	91.0	90.2	92.4	91.7	91.7	91.0	91.0	90.2
40.0	91.7	91.0	93.0	92.4	93.0	92.4	91.0	90.2
50.0	92.4	91.7	93.0	92.4	93.0	92.4	91.7	91.0
60.0	93.0	92.4	93.6	93.0	93.6	93.0	91.7	91.0
75.0	93.0	92.4	94.1	93.6	93.6	93.0	93.0	92.4
100.0	93.6	93.0	94.5	94.1	94.1	93.6	93.0	92.4
125.0	94.5	94.1	94.5	94.1	94.1	93.6	93.6	93.0
150.0	94.5	94.1	95.0	94.5	95.0	94.5	93.6	93.0
200.0	95.0	94.5	95.0	94.5	95.0	94.5	94.1	93.6

Note: **Above tables are based on *ASHRAE Standard 90.1, Addendum 90.1c.***

F. HVAC Systems Design:

1. Heating and Cooling Load Calculation Procedures. *ASHRAE Handbook 1985 Fundamentals* or similar computational procedure:
   a. Building envelope loads based on building envelope criteria of *ASHRAE Standard 90.1.*
   b. Lighting loads based on actual lighting level or power budgets consistent with lighting requirements of *ASHRAE Standard 90.1.*
   c. Other Loads, People and Equipment:
      1) Actual information based on intended use.
      2) Manufacturer's data.
      3) Technical Publications such as ASHRAE.
      4) Other sources.
      5) Designer's experience.
   d. Safety Factor: 10% Maximum
   e. Pick-Up Loads:
      1) Heating: 30% Maximum system capacity allowance for morning warm-up cycles.
      2) Cooling: 10% Maximum system capacity allowance for morning cool-down cycles.

f. Areas requiring special process temperature requirements, humidity requirements, or both shall be served by separate HVAC systems.

2. Indoor Design Conditions: *ANSI\ASHRAE Standard 55-1981 Thermal Environmental Conditions for Human Occupancy* or Chapter 8, *ASHRAE Handbook 1985 Fundamentals:*
   a. Satisfy 80% or More of the Occupants.
   b. Heating (Winter):
      1) *ASHRAE Standard 55:* 68°F.–74°F. Dry Bulb (DB) at 60% RH; 69°F.–76°F. DB at 36°F Dew Point (DP).
      2) Most Commonly Used Design Condition: 72°F DB.
   c. Cooling (Summer):
      1) *ASHRAE Standard 55:* 73°F.–79°F. DB at 60% RH; 74°F.–81°F. DB at 36°F DP.
      2) Most Commonly Used Design Condition: 75°F/50% R.H.
3. Outdoor Design Conditions: *ASHRAE Handbook 1985 Fundamentals* or from National Climatic Center or similar recognized data source:
   a. Heating (Winter): 99% Values, Minimum.
   b. Cooling (Summer): 2.5% Values, Maximum.
4. Ventilation:
   a. Lowest volume necessary to maintain adequate indoor air quality.
   b. Meet *ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality.*
   c. Air required for exhaust makeup for source control of contaminants.

G. Controls

1. System Control. At least 1 temperature control device.
2. Zone Control. Individual thermostatic controls within each zone.
3. Off-Hours Controls:
   a. Automatic controls capable of setback temperatures or equipment shutdown.
   b. Automatic or reduced outdoor air volume during unoccupied periods.
4. Humidity Control:
   a. Humidistat is required for winter humidification, 30% maximum winter humidity level for comfort purposes.
   b. If a humidistat is used for summer dehumidification, 60% minimum summer humidity level is required for comfort purposes.
5. Economizer controls are required:
   a. Air Side Economizers: Dry-Bulb Temperature or Enthalpy.
   b. Water Side Economizers: Direct Evaporation, Indirect Evaporation, or Both.
   c. Exceptions:
      1) Fans with a capacity of less than 3,000 CFM or total cooling capacity of less than 90,000 Btuh.
      2) Systems serving residential spaces or hotel or motel rooms.
6. Controls shall prevent:
   a. Reheating.
   b. Recooling.
   c. Simultaneous mixing of hot and cold air.
   d. Other simultaneous heating and cooling systems.
   e. Exceptions:
      1) VAV systems that reduce air flow to minimum before reheating, recooling or mixing take place.
      2) Zones where pressure relationships or cross-contamination requirements are impractical—Hospitals, Laboratories.
      3) Heat recovery is used for reheating.
      4) Zones with peak supply air of 300 CFM or less.

7. Temperature Reset Controls:
   a. Air Systems: Systems supplying heated or cooled air to multiple zones shall include controls that automatically reset supply air temperatures by respective building loads or outside air temperature.
      1) Exceptions:
         a) VAV Systems.
         b) Where resetting supply air temperatures can be shown to increase energy usage.
   b. Hydronic Systems: Systems supplying heated and/or chilled water shall include controls that automatically reset supply water temperatures by respective building loads or outside air temperature.
      1) Exceptions:
         a) Variable Flow Pumping Systems.
         b) Where resetting supply water temperatures can be shown to increase energy usage.
         c) Systems with less than 600,000 Btuh design capacity.

H. Piping Insulation. Insulation is required on:

1. Heating Systems (Hot Water, Steam, Steam Condensate): 105°F. and Higher.
2. Cooling Systems (Chilled Water, Brine, and Refrigerant): 55°F. and Lower.
3. Domestic and Service Hot Water Systems: 105°F. and Higher.
4. Insulation not required on systems where Fluid Temperature is between 55°F. and 105°F.
5. Required Insulation Thickness depends on Fluid Temperature, Insulation Type, and Pipe Size.
6. Insulation Thickness is given in the following table:

FLUID DESIGN OPERATING TEMP. RANGE °F.	INSULATION CONDUCTIVITY		NOMINAL PIPE DIAMETER - INCHES (3)					
	RANGE (1)	MRT (2)	RUNOUTS UP TO 2" (3)	1" AND LESS	1-1/4" - 2"	2-1/2" - 4"	5" & 6"	8" & LARGER
HEATING SYSTEMS - STEAM, STEAM CONDENSATE, AND HOT WATER								
ABOVE 350	0.32-0.34	250	1.5	2.5	2.5	3.0	3.5	3.5
251-350	0.29-0.31	200	1.5	2.0	2.5	2.5	3.5	3.5
201-250	0.27-0.30	150	1.0	1.5	1.5	2.0	2.0	3.5
141-200	0.25-0.29	125	0.5	1.5	1.5	1.5	1.5	1.5
105-140	0.24-0.28	100	0.5	1.0	1.0	1.0	1.5	1.5
DOMESTIC AND SERVICE HOT WATER SYSTEMS								
105 & GREATER	0.24-0.28	100	0.5	1.0	1.0	1.5	1.5	1.5
COOLING SYSTEMS - CHILLED WATER, BRINE, AND REFRIGERANT								
40-55	0.23-0.27	75	0.5	0.5	0.75	1.0	1.0	1.0
BELOW 40	0.23-0.27	75	1.0	1.0	1.5	1.5	1.5	1.5

Notes:

1. Conductivity Range (Btu. In./Hr. Ft^2 °F.)
2. MRT = Mean Rating Temperature (°F.)
3. Runouts to individual terminal units not exceeding 12 feet.
4. For piping exposed to ambient temperatures, increase insulation thickness by 0.5″.

I. Air Handling System Insulation. Insulation is required on:

1. Exterior Building Systems: Insulation Thickness is Based on CDD65 or HDD65, whichever results in greater insulation thickness and insulation type.
2. Inside Building Systems: Insulation is required when the temperature difference between air temperature and space temperature is greater than 15°F. Insulation thickness is based on temperature difference and insulation type.
3. Insulation Thickness is given in the following table:

DUCT LOCATION	COOLING (3)		
	ANNUAL COOLING DEGREE DAYS BASE 65 °F.	INSULATION R-VALUE	INSULATION THICKNESS (2)
EXTERIOR OF BUILDING:	BELOW 500 500 TO 1150 1151 TO 2000 ABOVE 2000	3.3 5.0 6.5 8.0	0.75 1.5 1.5 2.0
INSIDE BUILDING OR IN UNCONDITIONED SPACES (1): $\Delta T \leq 15$ $15 < \Delta T \leq 40$ $\Delta T > 40$	 --- --- ---	 NONE REQ'D 3.3 5.0	 --- 0.75 1.5

DUCT LOCATION	COOLING (3)		
	ANNUAL COOLING DEGREE DAYS BASE 65 °F.	INSULATION R-VALUE	INSULATION THICKNESS (2)
EXTERIOR OF BUILDING:	BELOW 500 500 TO 1150 1151 TO 2000 ABOVE 2000	3.3 5.0 6.5 8.0	0.75 1.5 1.5 2.0
INSIDE BUILDING OR IN UNCONDITIONED SPACES (1): $\Delta T \leq 15$ $15 < \Delta T \leq 40$ $\Delta T > 40$	 --- --- ---	 NONE REQ'D 3.3 5.0	 --- 0.75 1.5

Notes:

1. **ΔT (Temperature difference) is the difference between space design temperature and the design air temperature in the duct.**
2. **Minimum insulation thickness required. Internally insulated (lined) ducts usually use 1″ thickness. Externally insulated ducts usually use 1½″ or 2″ thickness.**
3. **Table based on *ASHRAE Standard 90.1-1989.***

J. Duct Construction:

1. *SMACNA HVAC Duct Construction Standards—Metal and Flexible, 1985.*
2. *SMACNA Fibrous Glass Duct Construction Standard, 1979.*
3. *SMACNA HVAC Duct Leakage Test Manual, 1985.*
4. If duct system is to operate in excess of 3 in. wc., ductwork shall be leak tested and be in conformance with *SMACNA HVAC Duct Leakage Test Manual, 1985.*

K. Operation and Maintenance Information:

1. O&M Manual shall be provided to Building Owner.
2. Manual to include:
   a. Required Routine Maintenance
   b. HVAC Control Information: Including schematics, diagrams, control descriptions, and maintenance and calibration information.

L. Testing, Adjusting, and Balancing shall be conducted in accordance with AABC or NEBB Standards or equivalent procedures (ASHRAE, SMACNA):

1. Air System Balancing: Accomplished first to minimize Throttling Losses and then Fan Speed.
   a. Damper throttling may be used for air systems under the following conditions:
      1) Fan motors of 1 Hp or less.
      2) If throttling results in no Greater than ⅓ Hp Fan Horsepower draw above that required if fan speed were adjusted.
2. Hydronic System Balancing: Accomplished first to minimize Throttling Losses and then Pump Impeller shall be trimmed or Pump Speed shall be adjusted.
   a. Valve throttling may be used for hydronic systems under the following conditions:
      1) Pumps with motors of 10 Hp or less.
      2) If throttling results in no greater than 3 Hp Pump horsepower draw above that required if the impeller were trimmed.
3. HVAC Control Systems shall be tested to assure that control elements are calibrated, adjusted, and in proper working order.

M. System Sizing: Systems and equipment shall be sized to provide no more than the space and system loads calculated in accordance with *ASHRAE Standard 90.1:*

1. Exceptions:
   a. Standard equipment sizing limitations.
   b. If oversizing does not increase energy usage.
   c. Stand-by equipment with automatic change-over control only when primary equipment is not operating.
   d. Multiple units of the same equipment (Chillers, Boilers, etc.) may be specified to operate concurrently only if optimization controls are provided.

N. Fan System Design Criteria: Supply Air, Return Air and Exhaust Fans:

1. Constant Volume Systems: 0.8 W/CFM of Supply Air.
2. Variable Air Volume (VAV) Systems: 1.25 W/CFM of Supply Air.
3. VAV Systems with Fan Motors 75 Hp and Larger requires controls or devices to demand no more than 50% of design wattage at 50% flow.
4. *ASHRAE Standard 90.1* requires air handling systems to utilize either:
   a. VAV Systems.
   b. Supply Air Temperature Reset Systems.

O. Pumping System Design Criteria:

1. Maximum Piping System Design Friction Rate: 4.0 Ft./100 Ft. of Pipe.
2. Variable Flow: Systems with control valves which modulate or step open and closed to meet load shall be designed for variable flow. System shall be capable of reducing flow to 50% or less using variable-speed-driven pumps, staged pumping, or pumps riding pump performance curves.

3. Exceptions:
   a. Systems where a Minimum Flow greater than 50% of Design Flow is required (Chiller Systems).
   b. Systems which include Supply Water Temperature Reset.
4. *ASHRAE Standard 90.1* requires pumping systems to utilize either:
   a. Variable Flow Pumping Systems.
   b. Supply Water Temperature Reset Systems.

P. HVAC Equipment:

1. Minimum Equipment Efficiencies:
   a. Full Load Efficiencies.
   b. Part Load Efficiencies.
   c. Includes Service Water Heating Equipment.
   d. Includes Field Assembled Equipment: Individual Components to Meet Requirements (Coils, Fans); Sum all Component Energy Usage.
2. Equipment Rating shall be certified by nationally recognized standards.
3. Operation and Maintenance: O&M Information shall be provided with Equipment including Mechanical Prints, Equipment Manuals, Preventive Maintenance Procedures and Schedules, and Names and Addresses of Qualified Service Agencies.

Q. Energy Management:

1. Each Distinct Building Energy Service shall have a Measurement System to accumulate a Record or Indicator Reading of the overall amounts of energy being delivered.
2. All Equipment used for Heating or Cooling and HVAC delivery of greater than 20 KVA or 60,000 Btuh energy input shall be arranged so that inputs and outputs such as Flow, Temperature, and Pressure can be individually measured to determine the equipment energy consumption, the installed performance capabilities and efficiencies, or both. Installation of measurement equipment is not required but proper access is required to permit measurements in the future.
3. Central Monitoring and Control Systems:
   a. Energy Management Systems should be considered in any building exceeding 40,000 Sq. Ft. in Gross Floor Area.
   b. Minimum Energy Management System Capabilities:
      1) Readings and Daily Totals for Electrical Power and Demand.
      2) Readings and Daily Totals for External Energy and Fossil Fuel Use.
      3) Record, Summarize, and Retain Weekly Totals.
      4) Time Schedule HVAC Equipment and Service Water Heating Equipment.
      5) Reset Local Loop Control System for HVAC Equipment.
      6) Monitor and Verify Heating, Cooling, and Energy Delivery Systems.
      7) Time Schedule Lighting Systems.
      8) Provide Readily Accessible Override Controls.
      9) Provide Optimum Start/Stop Control for HVAC Systems.

16.05 Fuel Conversion Factors

A. Electric Baseboard to Hydronic Baseboard:

1. KWH × 1.19 = KWH for Electric Boiler
2. KWH × 0.033 = Gals. for Oil-Fired Boiler
3. KWH × 0.046 = Therms for Gas-Fired Boiler

B. Electric Furnace to Hydronic Baseboard:

1. KWH × 1.0 = KWH for Electric Boiler
2. KWH × 0.028 = Gals. for Oil-Fired Boiler
3. KWH × 0.038 = Therms for Gas-Fired Boiler

C. Ceiling Cable to Hydronic Baseboard:

1. KWH × 1.06 = KWH for Electric Boiler
2. KWH × 0.03 = Gals. for Oil-Fired Boiler
3. KWH × 0.041 = Therms for Gas-Fired Boiler

D. Heat Pump to Hydronic Baseboard:

1. KWH × 1.88 = KWH for Electric Boiler
2. KWH × 0.052 = Gals. for Oil-Fired Boiler
3. KWH × 0.073 = Therms for Gas-Fired Boiler

E. Electric Baseboard to Warm Air Furnace:

1. KWH × 1.19 = KWH for Electric Furnace
2. KWH × 0.039 = Gals. for Oil-Fired Furnace
3. KWH × 0.054 = Therms for Gas-Fired Furnace

F. Electric Furnace to Fuel-Fired Furnace:

1. KWH × 0.032 = Gals. for Oil-Fired Furnace
2. KWH × 0.045 = Therms for Gas-Fired Furnace

G. Ceiling Cable to Warm Air Furnace:

1. KWH × 1.06 = KWH for Electric Furnace
2. KWH × 0.034 = Gals. for Oil-Fired Furnace
3. KWH × 0.048 = Therms for Gas-Fired Furnace

H. Heat Pump to Warm Air Furnace:

1. KWH × 1.88 = KWH for Electric Furnace
2. KWH × 0.061 = Gals. for Oil-Fired Furnace
3. KWH × 0.085 = Therms for Gas-Fired Furnace

I. Warm Air Systems to Hydronic Baseboard System:

1. Gals. Oil for W.A. × 0.857 = Gals. for Hydronics
2. Therms Gas for W.A. × 0.857 = Therms for Hydronics
3. Gals. Oil for W.A. × 1.2 = Therms for Hydronics
4. Therms Gas for W.A. × 0.612 = Gals. for Hydronics