YORK®	ASHRAE 90.1 GUIDELINES FOR SOLUTION AIR HANDLING UNITS	
APPLICATION GUIDE	New Release	Form 102.20-AG2 (303)

YORK PROVIDES THE AIR-HANDLING SOLUTION TO ASHRAE 90.1 CONCERNS.

As fossil fuel resources decline and the cost of energy increases, energy standards such as ASHRAE 90.1 will be more strictly enforced. Fortunately, YORK International is committed to providing the Solution to the energy concerns of engineers and building owners.

The purpose of this Application Guide is to show that a design engineer who specifies a Solution air-handling unit is going to get equipment and support dedicated to meeting the requirements of ASHRAE 90.1.

WHAT IS ASHRAE 90.1?

ASHRAE 90.1-2001 provides architects and engineers with guidelines for the design of energy efficient buildings, with the exception of low-rise residential buildings.

The standard covers all aspects of a building from the building envelope, to the HVAC system, service water heating, power distribution systems, electric motors and lighting. The building is treated as a whole, and while most requirements are mandatory, some trade-offs are allowed provided they do not result in increased annual energy consumption. In addition to new buildings, the standard applies to newly constructed sections of existing buildings, as well as new systems and equipment for existing buildings.

Equipment and building systems that use energy primarily for industrial or commercial manufacturing processes are exempt from the requirements of the standard. Historically significant buildings, such as those listed in “The National Register of Historic Places,” and the equipment in such buildings, are also exempt from the requirements of ASHRAE 90.1.

Mechanical equipment that meets the requirements of ASHRAE 90.1 is to carry a permanent label applied by the equipment manufacturer stating such compliance. This requirement is intended to facilitate the building official’s inspection of the building and determination that it complies with 90.1.

WHAT IS INVOLVED IN COMPLIANCE?

There are three ways for a building HVAC system and its equipment to comply with ASHRAE-90.1:

1. The Simplified Approach.
2. The Mandatory Provisions + Prescriptive Path Requirements.
3. The Mandatory Provisions + Prescriptive Path Requirements + the Energy Cost Budget Method.

This document will focus on the first two approaches.

THE SIMPLIFIED APPROACH

The Simplified Approach is intended to reduce the amount of work required to show that a small building with a simple HVAC system complies with ASHRAE 90.1.

The YORK International eco^2 rooftop units can be used on buildings that comply using the Simplified Approach because they are tested and rated in accordance with ARI Standard 360 - “Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment” as required by the standard. Solution units are tested and rated in accordance with ARI 430 – “Central Station Air-Handling Units.”

YORK’s Millennium, Sunline, and Predator lines of rooftop units may also comply with the Simplified Approach. These units are lower in capacity than the eco^2 line. Combined, these four lines of unitary rooftop air-conditioners cover a capacity range of 6.5 to 100 tons and are the units to choose for Simplified Approach projects.

MANDATORY PROVISIONS

The Mandatory Provisions are a set of five requirements that every HVAC system must meet in order to comply with ASHRAE 90.1.

Mechanical Equipment Efficiency

This requirement does not apply to Solution air-handling units because they are not tested/rated in accordance with ARI 210/240 or ARI 340/360. However, the minimum efficiency requirements of Table 6.2.1A would still apply to any condensing unit that is coupled with a Solution AHU. Likewise the minimum efficiency requirements of Table 6.2.1E would apply to any fuel-fired duct furnaces and/or unit heaters used in the units.

Both the YORK YCAL/YCUL condensing units (using R-22) and the gas furnaces used in the units will meet or exceed these minimum requirements.

Gas-fired furnaces with input ratings of at least 225,000 Btu/h require an intermittent ignition or interrupted device (IID) as well as power venting or a flue damper. If the combustion air is drawn from the conditioned space a vent damper can be used in lieu of a flue damper. Also, furnaces of this size are required to have jacket losses of less than 0.75% of the input rating unless the furnaces are located within the conditioned space. Solution gas furnaces will meet these requirements.

Load Calculations

Heating and cooling load calculations must be performed prior to the sizing or selection of equipment. This requirement is intended to prevent the oversizing or undersizing of equipment that may result from the use of outdated rules of thumb. The responsibility for these calculations lies with the design engineer.

Controls

ASHRAE 90.1 requires the use of controls and control strategies that optimize building energy usage. Upfront coordination with the YORK International BAS group can ensure compliance with any and all of the control requirements. Additionally, the following Factory Packaged Controls (FPC) options will meet controls requirements of ASHRAE 90.1:

Zone Thermostatic Controls – Individual zone temperature sensors can be shipped loose with the units. These sensors are available in either single or dual set point models. The dual set point models will include a minimum 5ºF deadband between heating and cooling set points.

Ventilation System Controls – All Solution units are available with damper actuators to satisfy the requirements of this section. The maximum leakage rate of outside air and exhaust air dampers in the Solution product meet the most stringent criteria of this section, and therefore are acceptable for use on any project.

Humidifier Preheat Controls – All steam-jacketed humidifiers offered in the Solution product line will include automatic valves to shut off steam to the preheat jackets when the humidifiers are not in use.

Freeze Protection and Snow/Ice Melting Systems – When freeze protection equipment such as heat tracing, or unit heaters are added to Solution equipment, automatic controls will be included to prevent operation of the equipment at outside air temperatures above 40ºF.

Ventilation Controls for High-Occupancy Areas – The factory-packaged controls, which are available with every Solution unit, include CO_2 sensors for use in demand-controlled ventilation systems.

HVAC System Construction and Insulation

The R-12.5 value of the foam insulation used in the Solution unit panels exceeds the minimum plenum insulation R-values of this section in all cases. The Solution unit construction techniques also meet or exceed the duct sealing requirements of this section as listed in Tables 6.2.4.3A and 6.2.4.3.B.

Solution units do not include factory-installed piping; therefore the piping insulation requirements of this section do not apply. High-end Solution units may include factory-installed piping, in which case any factory installed piping insulation will conform to the requirements of this section of the standard.

Completion Requirements

Drawings and Operation and Maintenance (O&M) Manuals will be provided to the building owner or owner's representative within 90 days after the date of system acceptance as required by the standard. The O&M manuals will include all of the pertinent information as required by the standard.

Field balancing and system commissioning services are available through the YORK International Service Group. When factory-packaged controls are included on a Solution unit, all of the end devices are fully commissioned at the factory and a commissioning report is shipped with the unit. This service not only assures the integrity of the end devices, but also saves valuable time and money in the field, by eliminating the need for field calibration.

PRESCRIPTIVE PATH

The Prescriptive Path consists of a set of nine requirements that are every bit as mandatory as the Mandatory Provisions. Unlike the Mandatory Provisions however, if one or more of the prescriptive requirements cannot be met, the overall job may still comply with ASHRAE 90.1. In this case energy-saving trade-offs must be made with other aspects of the building or building systems. Such trade-offs create a great deal of additional work for the building designer, therefore the Solution product is designed to be a fully compliant line of air-handling units.

Not all of the Prescriptive Path requirements apply to air-handling units and only those that do apply are discussed below.

Economizers

Economizers use outside air in lieu of mechanical cooling to condition a space when conditions are favorable. This “free cooling” can save a great deal of energy when applied correctly making economizers an important part of ASHRAE 90.1.

The Solution line offers several different air economizer configurations to match any job. Each of these economizers will meet or exceed the design and functionality requirements of the standard.

Solution economizers are able to provide up to 100% outside air and are able to accurately measure and control the amount of outside air using the AMS-60 airflow-monitoring damper. The low leakage dampers required in some climates will be standard on *all* Solution units. Properly sized and located exhaust/relief air openings are incorporated into the Solution design to prevent overpressurizing the building and reentrainment of exhaust air into ventilation air intakes.

End devices available through the FPC offering and control options available from YORK BAS allow the economizer to operate in conjunction with mechanical cooling when necessary and prevent economizer operation when it would increase the building heating load.

The standard prohibits the use of a mixed air temperature sensor as the only means of controlling the economizer; rather the economizer control must be integrated with the mechanical cooling control loop. Mixed air limit control is allowed for systems controlled by space temperature such as single zone systems. A supply air temperature sensor can be used to control the economizer in conjunction with the mechanical cooling and is available on Solution units.

Economizers are also required to have high limit shutoff controls. These high limits may be based on temperature or enthalpy depending on the climate. Solution is capable of providing an acceptable high limit in all cases. The YORK AMS-60 airflow measuring station adds another level of energy efficiency by allowing precise measurement and control of the outside air volume during periods of minimum outside air operation.

Simultaneous Heating and Cooling

A great deal of energy is required to simultaneously heat and cool the same airstream, reheat air that has been mechanically cooled, or recool air that has been heated. The design of the system and the zone thermostatic controls must prevent these processes unless:

1. The airflow rate is reduced according to limits set by the standard prior to reheating, recooling or mixing, or
2. Special design considerations or code requirements preclude the use of VAV systems, or
3. At least 75% of the energy for heating the air prior to mixing, or reheating the air after cooling is site recovered.

The types of simultaneous heating and cooling systems that should be avoided include constant volume reheat systems (such as those made by manufacturers of constant volume, underfloor air systems), constant volume dual duct and multizone systems, and perimeter induction systems.

Simultaneous heating and cooling, mixing, reheating and recooling for the purpose of dehumidification is also prohibited unless:

1. The system is small and/or capable of first unloading to 50% capacity, or
2. The system serves a space where specific humidity levels are required to meet process needs (e.g. museums, surgical suites, refrigerated warehouses and ice rinks), or

3. At least 75% of the energy for heating the air prior to mixing, or reheating the air after cooling is site recovered, or
4. The system has a desiccant dehumidifier and 75% of the heat added by the dehumidifier is removed by a heat exchanger.

Air System Design and Control

Fans are the primary consumers of energy in air-handling units, therefore it is important to limit fan power consumption as much as possible. ASHRAE 90.1 puts strict limits on fan power consumption; limits which are often difficult to meet. However, two of the keys to meeting the fan power limitations are to minimize the system static pressure and to use the most efficient fans possible.

Some design engineers include the pressure losses through the unit's supply and return air openings in the external static pressure loss calculation; the same is true of the added pressure loss associated with loaded filters. It is important to ensure those air pressure losses are not included in both the internal and external static pressure losses.

Other factors that contribute to high static pressure losses are excessive coil face velocities, and poorly designed, undersized ductwork. Coil and filter face velocities should be limited to 500 fpm to reduce air pressure drops and the number of duct elbows and transitions should be minimized.

Housed centrifugal fans with airfoil blades, which are typically more efficient than unhoused plenum fans or housed fans with forward curved blades, should be considered when the fan power limitation becomes an issue.

ASHRAE 90.1 defines fan system power as, "The sum of the nameplate horsepower of the motors of all fans that are required to operate at design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source or exhaust it to the outdoors." Return fan motors must be included in the calculation because they run continuously. Exhaust fans that run during design conditions must also be included, however a credit is applied to exhaust fan power because they do not run continuously like return fans. Exhaust fans that do not run during design conditions need not be included in the calculation at all.

Exhaust fans are typically used for building pressure control. Return fans become necessary when the supply fan alone cannot handle the additional static pressure loss of the return duct. It is highly beneficial to use exhaust fans in lieu of return fans whenever possible.

It is also beneficial to use variable air volume systems whenever possible because the fan power limitations for these systems is higher than the limitations for constant volume systems. This is due to the fact that variable volume systems (such as FlexSys UFAD) are more energy efficient.

When a VAV system is used, fans with 30 horsepower and larger motors must meet one of the following criteria:

(a) The fan must have a variable-speed drive, or

(b) The fan must be a vane-axial fan with variable pitch blades, or

(c) Some other control or device must be used to reduce the fan motor demand to 30% of design at 50% of design airflow when the static pressure set point equals 1/3 of the total design static pressure.

Variable speed drives are available on all fans throughout the Solution air-handling line. Vane-axial fans with variable pitch blades are available on high-end Solution air-handlers.

Energy Recovery

Air-handling units with an airflow capacity of 5000 cfm or more and a high percentage (70%) of minimum outside air are required to have an exhaust air energy recovery system with a minimum effectiveness of 50%. The energy recovery system must also be equipped with a bypass to allow any air economizer to work properly.

Except for make-up air units for laboratories or AHUs for surgical suites, not many air-handling systems require a minimum outside air rate of 70% or greater. Therefore, the need for exhaust air energy recovery as written in the standard will be fairly uncommon.

Hot Gas Bypass

Hot gas bypass is a very effective method of controlling the capacity of DX systems at low load conditions. Unfortunately, it is not a very efficient method, therefore ASHRAE 90.1 limits the use of hot gas bypass to systems that include continuous capacity modulation or multiple steps of unloading. The standard further limits the amount of hot gas bypass that can be used to 50% of the total cooling capacity for systems 20 tons and smaller, and 25% of the total capacity for systems over 20 tons. Solution split system DX units will adhere to these limitations when utilizing hot gas bypass.

Electric Motors

Electric motors must comply with the minimum nominal efficiency requirements of the Energy Policy Act of 1992 as listed in Table 10.2. The efficiency requirements apply to Design A and Design B, ODP and TEFC motors in 3600, 1800 and 1200 rpm models. All of the motors used in the Solution line meet or exceed these minimum efficiency requirements.

SO, WHAT DOES ALL THIS MEAN?

It means that ASHRAE 90.1 is a complex standard and ensuring compliance requires coordination throughout all phases of a project. It also means that while it may sometimes be a struggle to meet all of its requirements, it is not a standard to be feared, but rather to be embraced because **YORK International is committed to providing the air-handling Solution to ASHRAE 90.1 concerns**.

REFERENCES

Tables reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE).

TABLE6.2.1A
Electrically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[b]	Test Procedure[a]
Air Conditioners, Air Cooled	<65,000 Btu/h[c]	All	Split System	10.0 SEER	ARI 210/240
			Single Package	9.7 SEER	
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.3 EER	
		All other	Split System and Single Package	10.1 EER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER	ARI 340/360
		All other	Split System and Single Package	9.5 EER	
	≥240,000 Btu/h and <760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.7 IPLV	
		All other	Split System and Single Package	9.3 EER 9.5 IPLV	
	≥760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.2 EER 9.4 IPLV	
		All other	Split System and Single Package	9.0 EER 9.2 IPLV	
Air Conditioners, Water and Evaporatively Cooled	<65,000 Btu/h	All	Split System and Single Package	12.1 EER	ARI 210/240
	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER	
		All other	Split System and Single Package	11.3 EER	
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER	ARI 340/360
		All other	Split System and Single Package	10.8 EER	
	≥240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 10.3 IPLV	
		All other	Split System and Single Package	10.8 EER 10.1 IPLV	
Condensing Units, Air Cooled	≥135,000 Btu/h	–		10.1 EER 11.2 IPLV	ARI 365
Condensing Units, Water or Evaporatively Cooled	≥135,000 Btu/h	–		13.1 EER 13.1 IPLV	

[a] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[b] IPLVs are only applicable to equipment with capacity modulation.
[c] Single-phase, air-cooled air-conditioners < 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.2.1E
Warm Air Furnaces and Combination Warm Air Furnaces/Air-Conditioning Units, Warm Air Duct Furnaces and Unit Heaters

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Warm Air Furnace, Gas-Fired	<225,000 Btu/h		78% AFUE or 80% E_t[d]	DOE 10 CFR Part 430 or ANSI Z21.47
	≥225,000 Btu/h	Maximum Capacity[d]	80% E_c[c]	ANSI Z21.47
Warm Air Furnace, Oil-Fired	<225,000 Btu/h		78% AFUE or 80% E_t[d]	DOE 10 CFR Part 430 or UL 727
	≥225,000 Btu/h	Maximum Capacity[e]	81% E_t[f]	UL 727
Warm Air Duct Furnaces, Gas-Fired	All Capacities	Maximum Capacity[e]	80% E_c[g]	ANSI Z83.9
Warm Air Unit Heaters, Gas-Fired	All Capacities	Maximum Capacity[e]	80% E_c[g]	ANSI Z83.8
Warm Air Unit Heaters, Oil-Fired	All Capacities	Maximum Capacity[e]	80% E_c[g]	UL 731

a E_t = thermal efficiency. See test procedure for detailed discussion.
b Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
c E_c = combustion efficiency. Units must also include an IID, have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
d Combination units not covered by NAECA (3-phase power or cooling capacity greater than or equal to 65,00 Btu/h) may comply with either rating.
e Minimum and maximum ratings as provided for and allowed by the unit's controls.
f E_t = thermal efficiency. Units must also include an IID, have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
g E_c = combustion efficiency (100% less flue losses). See test procedure for detailed discussion.

TABLE 6.2.3.3.4
Maximum Damper Leakage

Climate	Maximum Damper Leakage at 1.0 in w.g.cfm per ft^2 of damper area	
	Motorized	Non-motorized
HDD65>7200 or CDD50>7200	4	Not allowed
HDD65<2701 and CDD50<3601	20	20[a]
All others	10	20[a]

Notes:
a Dampers smaller than 24 in. in either dimension may have leakage of 40 cfm/ft^2.

TABLE 6.2.4.1.3
Minimum Pipe Insulation Thickness[a]

Fluid Design Operating Temp. Range (°F)	Insulation Conductivity		Nominal Pipe or Tube Size (in.)				
	Conductivity Btu·in./(h·ft²·°F)	Mean Rating Temp. °F	<1	1 to <1-1/2	1-1/2 to <4	4 to <8	≥8
Heating Systems (Steam, Steam Condensate, and Hot Water)[b c]							
>350	0.32-0.34	250	2.5	3.0	3.0	4.0	4.0
251-350	0.29-0.32	200	1.5	2.5	3.0	3.0	3.0
201-250	0.27-0.30	150	1.5	1.5	2.0	2.0	2.0
141-200	0.25-0.29	125	1.0	1.0	1.0	1.5	1.5
105-140	0.22-0.28	100	0.5	0.5	1.0	1.0	1.0
Domestic and Service Hot Water Systems							
105+	0.22-0.28	100	0.5	0.5	1.0	1.0	1.0
Cooling Systems (Chilled Water, Brine, and Refrigerant)[d]							
40-60	0.22-0.28	100	0.5	0.5	1.0	1.0	1.0
<40	0.22-0.28	100	0.5	1.0	1.0	1.0	1.5

a For insulation outside the stated conductivity range, the minimum thickness (T) shall be determined as follows:

$$T = r\{(1 + t/r)^{K/k} - 1\}$$

where T = minimum insulation thickness (in.), r = actual outside radius of pipe (in.), t = insulation thickness listed in this table for applicable fluid temperature and pipe size, K = conductivity of alternate material at mean rating temperature indicated for the applicable fluid temperature (Btu·in.[h·ft²·°F]); and k = the upper value of the conductivity range listed in this table for the applicable fluid temperature.

b These thicknesses are based on energy efficiency considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.

c Piping insulation is not required between the control valve and coil on run-outs when the control valve is located within 4 ft of the coil and the pipe size is 1 in. or less.

d These thicknesses are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.

TABLE 6.2.4.2A
Minimum Duct Insulation R-Value,[a] Cooling and Heating Only Supply Ducts and Return Ducts

Climate Zone			Duct Location						
Envelope Criteria Table	HDD65	CDD50	Exterior	Ventilated Attic	Unvented Attic with Backloaded Ceiling	Unvented Attic with Roof Insulation	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
Heating Ducts Only									
B-1 to B-7	0-1800	all	none	none	none	none	none	none	none
B-8 to B-12	1801-3600	all	R-3.5	none	none	none	none	none	none
B-13 to B-15	3601-5400	all	R-3.5	none	none	none	none	none	none
B-16 to B-18	5401-7200	all	R-6	R-3.5	none	none	none	none	R-3.5
B-19 to B-20	7201-9000	all	R-6	R-6	R-3.5	none	none	none	R-3.5
B-21 to B-22	9001-10800	all	R-8	R-6	R-6	none	R-3.5	none	R-3.5
B-23	10801-12600	all	R-8	R-6	R-6	none	R-6	none	R-6
B-24	12601-16200	all	R-8	R-8	R-6	none	R-6	none	R-6
B-25	16201-19800	all	R-10	R-8	R-8	none	R-6	none	R-6
B-26	19801+	all	R-10	R-10	R-8	none	R-8	none	R-6
Cooling Only Ducts									
B-15, 18, 20, 22 to 26	all	0-1800	R-1.9	R-1.9	R-1.9	R-1.9	R-1.9	none	none
B-12, 14, 17, 19, 21	all	1801-3600	R-3.5	R-1.9	R-3.5	R-1.9	R-1.9	none	none
B-7, 9, 11, 13, 16	all	3601-5400	R-3.5	R-3.5	R-6	R-1.9	R-1.9	none	none
B-4, 6, 8, 10	all	5401-7200	R-6	R-6	R-6	R-3.5	R-1.9	none	none
B-3, B-5	all	7201-9000	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
B-2	all	9001-10800	R-6	R-6	R-8	R-3.5	R-3.5	none	R-3.5
B-1	all	10801+	R-8	R-8	R-8	R-3.5	R-3.5	none	R-3.5
Return Ducts									
B-1 to B-26	all climates		R-3.5	R-3.5	R-3.5	none	none	none	none

[a] Insulation R-values, measured in (h·ft²·°F)/Btu, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of 6.2.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F at the installed thickness.
[b] Includes crawl spaces, both ventilated and nonventilated.
[c] Includes return air plenums with or without exposed roofs above.

TABLE 6.2.4.2B
Minimum Duct Insulation R-Value,[a] Combined Heating and Cooling Ducts

Climate Zone			Duct Location						
Envelope Criteria Table	HDD65	CDD50	Exterior	Ventilated Attic	Unvented Attic w/ Backloaded Ceiling	Unvented Attic w/ Roof Insulation[a]	Uncon-ditioned Space[b]	Indirectly Condi-tioned Space[c]	Buried
B-1	0-900	10801+	R-8	R-6	R-8	R-3.5	R-3.5	none	R-3.5
B-2	0-900	9001-10800	R-6	R-6	R-8	R-3.5	R-3.5	none	R-3.5
B-3	0-900	7201-9000	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
B-4	0-900	0-7200	R-6	R-3.5	R-6	R-3.5	R-1.9	none	R-3.5
B-5	901-1800	7201+	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
B-6	901-1800	5401-7200	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
B-7	901-1800	0-5400	R-3.5	R-3.5	R-6	R-1.9	R-1.9	none	R-1.9
B-8	1801-2700	5401+	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
B-9	1801-2700	0-5400	R-6	R-3.5	R-6	R-1.9	R-1.9	none	R-1.9
B-10	2701-3600	5401+	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
B-11	2701-3600	3601-5400	R-6	R-6	R-6	R-3.5	R-3.5	none	R-1.9
B-12	2701-3600	0-3600	R-3.5	R-3.5	R-3.5	R-1.9	R-1.9	none	R-1.9
B-13	3601-5400	3601+	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
B-14	3601-5400	1801-3600	R-6	R-3.5	R-6	R-1.9	R-3.5	none	R-1.9
B-15	3601-5400	0-1800	R-3.5	R-3.5	R-3.5	R-1.9	R-1.9	none	R-1.9
B-16	5401-7200	3601+	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
B-17	5401-7200	1801-3600	R-6	R-6	R-6	R-1.9	R-3.5	none	R-3.5
B-18	5401-7200	0-1800	R-6	R-3.5	R-3.5	R-1.9	R-3.5	none	R-3.5
B-19	7201-9000	1801+	R-8	R-6	R-6	R-1.9	R-3.5	none	R-3.5
B-20	7201-9000	0-1800	R-6	R-6	R-6	R-1.9	R-3.5	none	R-3.5
B-21	9001-10800	1801+	R-8	R-6	R-6	R-1.9	R-6	none	R-3.5
B-22	9001-10800	0-1800	R-8	R-6	R-6	R-1.9	R-3.5	none	R-3.5
B-23	10801-12600	all	R-8	R-6	R-6	R-1.9	R-6	none	R-6
B-24	12601-16200	all	R-8	R-8	R-8	R-1.9	R-6	none	R-6
B-25	16201-19800	all	R-10	R-8	R-8	R-3.5	R-6	none	R-6
B-26	19801+	all	R-10	R-10	R-8	R-3.5	R-8	R-3.5	R-6

a Insulation R-values, measured in $(h \cdot ft^2 \cdot {}^\circ F)/Btu$, are for the insulation as installed and do not include film resistance. The required minimum thicknesses do not consider water vapor transmission and possible surface condensation. Where exterior walls are used as plenum walls, wall insulation shall be as required by the most restrictive condition of 6.2.4.2 or Section 5. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F at the installed thickness.

b Includes crawl spaces, both ventilated and non-ventilated.

c Includes return air plenums with or without exposed roofs above.

TABLE 6.2.4.3A
Minimum Duct Seal Level[a]

Duct Location	Duct Type			
	Supply		Exhaust	Return
	≤2 in. w.c.[b]	>2 in. w.c.[b]		
Outdoors	A	A	C	A
Unconditioned Spaces	B	A	C	B
Conditioned Spaces[c]	C	B	B	C

a See Table 6.2.4.3B definition of Seal Level.
b Duct design static pressure classification.
c Includes indirectly conditioned spaces such as return air plenums.

TABLE 6.2.4.3B
Duct Seal Levels

Seal Level	Sealing Requirements[a]
A	All transverse joints, longitudinal seams, and duct wall penetrations. Pressure-sensitive tape shall not be used as the primary sealant.
B	All transverse joints and longitudinal seams. Pressure-sensitive tape shall not be used as the primary sealant.
C	Transverse joints only.

a Longitudinal seams are joints oriented in the direction of airflow. Transverse joints are connections of two duct sections oriented perpendicular to airflow. Duct wall penetrations are openings made by any screw fastener, pipe, rod, or wire. Spiral lock seams in round and flat oval duct need not be sealed. All other connections are considered transverse joints, including but not limited to spin-ins, taps and other branch connections, access door frames and jambs, duct connections to equipment, etc.

TABLE 6.3.1
Minimum System Size for Which an Economizer is Required

No. of Hours Between 8 a.m. and 4 p.m. with $55°F < T_{db} < 69°F$	1% Cooling Design Wet-Bulb Temperature		
	$T_{wb} < 69°F$	$69°F \leq T_{wb} \leq 73°F$	$T_{wb} > 73°F$
	Minimum System Size (Btu/h)	Minimum System Size (Btu/h)	Minimum System Size (Btu/h)
0-199	N.R.[a]	N.R.	N.R.
200-399	135,000	N.R.	N.R.
400-599	135,000	N.R.	N.R.
600-799	65,000	135,000	N.R.
800-999	65,000	135,000	135,000
1000-1199	65,000	65,000	135,000
>1199	65,000	65,000	65,000

a N.R. means that there is no system size for which an economizer is a requirement in this climate.

TABLE 6.3.1.1.3A
High-Limit Shutoff Control Options for Air Economizers

Climate	Allowed Control Types	Prohibited Control Types
Dry $T_{wb} < 69°F$ or ($T_{wb} < 75°F$ and $T_{db} \geq 100°F$[a]	Fixed Dry Bulb Differential Dry Bulb Electronic Enthalpy[b] Differential Enthalpy	Fixed Enthalpy
Intermediate $69°F \leq T_{wb} \leq 73°F$ $T_{db} < 100°F$	Fixed Dry Bulb Differential Dry Bulb Fixed Enthalpy Electronic Enthalpy[b] Differential Enthalpy	
Humid $T_{wb} > 73°F$	Fixed Dry Bulb Fixed Enthalpy Electronic Enthalpy[b] Differential Enthalpy	Differential Dry Bulb

a T_{wb} is the 1% *cooling design* wet-bulb temperature. T_{db} is the 1% *cooling design* dry-bulb temperature.
b Electronic enthalpy controllers are devices that use a combination of humidity and dry-bulb temperature in their switching algorithm.

TABLE 6.3.1.1.3B
High-Limit Shutoff Control Settings for Air Economizers

Device Type	Climate	Required High Limit (Economizer Off When):	
		Equation	Description
Fixed Dry Bulb	Dry Intermediate Humid	$T_{OA} > 75°F$ $T_{OA} > 70°F$ $T_{OA} > 65°F$	Outside air temperature exceeds 75°F Outside air temperature exceeds 70°F Outside air temperature exceeds 65°F
Differential Dry Bulb	All	$T_{OA} > T_{RA}$	Outside air temperature exceeds return air temperature
Fixed Enthalpy	All	$h_{OA} > 28$ Btu/lb[a]	Outside air enthalpy exceeds 28 Btu/lb of dry air[a]
Electronic Enthalpy	All	$(T_{OA}, RH_{OA}) > A$	Outside air temperature/RH exceeds the "A" set point curve[b]
Differential Enthalpy	All	$h_{OA} > h_{RA}$	Outside air enthalpy exceeds return air enthalpy

[a] At altitudes substantially different than sea level, the Fixed Enthalpy limit value shall be set to the enthalpy value at 75°F and 50% relative humidity. As an example, at approximately 6000 ft elevation the fixed enthalpy limit is approximately 30.7 Btu/lb.

[b] Set point "A" corresponds to a curve on the psychometric chart that goes through a point at approximately 75°F and 40% relative humidity and is nearly parallel to dry-bulb lines at low humidity levels and nearly parallel to enthalpy lines at high humidity levels.

TABLE 6.3.3.1
Fan Power Limitation

Supply Air Volume	Allowable Nameplate Motor Power	
	Constant Volume	Variable Volume
<20,000 cfm	1.2 hp/1000 cfm	1.7 hp/1000 cfm
≥20,000 cfm	1.1 hp/1000 cfm	1.5 hp/1000 cfm

Allowable Fan System Power = [Table 6.3.3.1 Fan Power Limitation × (Temperature Ratio) + Pressure Credit + Relief Fan Credit]

TABLE 6.3.9
Hot Gas Bypass Limitation

Rated Capacity	Maximum Hot Gas Bypass Capacity (% of Total Capacity)
≤240,000 Btu/h	50%
>240,000 Btu/h	25%

TABLE 10.2
Minimum Nominal Efficiency for General Purpose *Design A* and *Design B* Motors[a]

	Minimum Nominal Full-Load Efficiency (%)					
	Open Motors			Enclosed Motors		
Number of Poles ==>	2	4	6	2	4	6
Synchronous Speed (RPM) ==>	3600	1800	1200	3600	1800	1200
Motor Horsepower						
1	-	82.5	80.0	75.5	82.5	80.0
1.5	82.5	84.0	84.0	82.5	84.0	85.5
2	84.0	84.0	85.5	84.0	84.0	86.5
3	84.0	86.5	86.5	85.5	87.5	87.5
5	85.5	87.5	87.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5	89.5	89.5
10	88.5	89.5	90.2	89.5	89.5	89.5
15	89.5	91.0	90.2	90.2	91.0	90.2
20	90.2	91.0	91.0	90.2	91.0	90.2
25	91.0	91.7	91.7	91.0	92.4	91.7
30	91.0	92.4	92.4	91.0	92.4	91.7
40	91.7	93.0	93.0	91.7	93.0	93.0
50	92.4	93.0	93.0	92.4	93.0	93.0
60	93.0	93.6	93.6	93.0	93.6	93.6
75	93.0	94.1	93.6	93.0	94.1	93.6
100	93.0	94.1	94.1	93.6	94.5	94.1
125	93.6	94.5	94.1	94.5	94.5	94.1
150	93.6	95.0	94.5	94.5	95.0	95.0
200	94.5	95.0	94.5	95.0	95.0	95.0

[a] Nominal efficiencies shall be established in accordance with NEMA Standard MG1.

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